



Assessment of the Marine Transportation System (MTS) Challenges

Summary Report

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Preface

This report concludes and summarizes a series of six Task Reports prepared by the Volpe Center for the Maritime Transportation System (MTS) Assessment, initiated in July 2006 under a reimbursable agreement (RA) with the United States Army Corps of Engineers (USACE). The purpose of the RA was to provide support to the Committee on MTS (CMTS) and its Needs Assessment Integrated Action Team (IAT) for conducting an Assessment of the MTS Challenges. The report has been prepared by Dr. Bahar Barami, the Volpe Center project manager, and revised to reflect the comments and inputs received from the project sponsors and members of the MTS Needs Assessment IAT, including the comments received from LCDR Ellis Moose, USCG, CG-54121, and Matthew Chambers, Bureau of Transportation Statistics (BTS), USDOT. Nathan Grace, MacroSys, LLC., provided editorial assistance and Rod Cook, Chief, Intermodal Infrastructure Security and Operations Division, Volpe Center, provided peer review and quality control input.

As the 7th Task Report, this report provides a summary of the previous six tasks that consisted of over 470 pages of data analysis and review of academic, industry, and government studies of the MTS operations. The six task reports, plus a report prepared for the Office of Naval Research (ONR) on short sea shipping, a total of 555 pages, are transmitted as appendices to this Summary Report, as follows:

- Appendix A - Task 1. MTS Infrastructure Challenges
- Appendix B - Task 2. MTS Economics and Productivity Challenges
- Appendix C – Task 3. MTS Environmental Challenges
- Appendix D - Task 4. MTS Safety
- Appendix E - Task 5. MTS and National Security
- Appendix F - Task 6. MTS Institutional Challenges
- Appendix G – Assessment of Short-Sea Shipping Options for Domestic Applications

MTS Assessment

Scope of Analysis

The U.S. marine infrastructure network encompasses the navigable inland waterways, harbor channels, ports, terminals and intermodal connectors, coastal sea-lanes and associated maritime domain, locks, dams and levee systems, and vessels and equipment. This vast system of waterways and assets supports a broad array of commercial cargo and passenger transportation, military navigation and force projection, and non-transportation uses of the waterways for recreational boating, commercial fishing, aqua-culture, and oceanic research.

This report conducts an assessment of the MTS functions and condition, threats to its continued operations, and vulnerabilities that make the threats more likely to materialize, within a risk and resiliency analysis framework developed for this assessment. Within this framework, the study also evaluates the inherent elements within the system which mitigate the consequences of the MTS risk factors, and identifies technology deployment and policy solutions that would enhance MTS sustainability and resiliency.

Overarching Concepts

At the core of the MTS assessment is the concept of a “system of systems,” a term used to emphasize system complexities and operational interdependencies at work in a critical infrastructure system such as maritime transportation. A system is characterized as a complex composite of parts, units, and subsystems that together perform the required functions and operations that help maintain the integrity and boundaries of the operational entity. As any other complex system, the components of the MTS are interconnected subsystems characterized by open boundaries and information feedback loops that create chain-effects and a complex path of causality often not based on simple one-way cause-and-effect relationships.

The U.S. MTS is a system characterized by an immense functional diversity and complexity. As a global gateway in support of commercial transportation of goods and passengers, military force projection, and recreational and non-transportation commercial uses, the MTS is a critical linchpin in the nation’s economy and national defense. For military operations, the projection of power for our island nation depends to a large extent on sealift deployment. The force projection as well as crisis response and recovery capabilities that underpin U.S. national security objectives increasingly depend on the domestic and commercial MTS plans and operations. This is especially the case because of the closure of so many overseas bases over the past two decades, resulting in a force projection capability that is primarily continental U.S. (CONUS)-based.¹ The U.S. MTS is also characterized by its geographic diversity, with a complex network of maritime operations that interfaces with the shoreside waterway infrastructure and land-side intermodal connections to operate in the context of the global and domestic commercial supply chain functions and military operations.

¹ USDOT, *An Assessment of the U.S. Marine Transportation System: A Report to Congress*, September 1999.

Risk Analysis Framework

Risk analysis is commonly based on methodologies that calculate risk as the product of the conditional probability of an adverse event occurring during a defined time period, and the attendant consequences. The potential threats include an array of disruptions of the MTS operations arising from intentional threats such as acts of terrorism or labor strikes, disruptions caused by natural disasters or unintended navigational incidents, spills and collisions, or disruptions arising from the aging infrastructure or delayed maintenance and inadequate capacity. Conventional *risk analysis* involves a three-part process:

- *Risk Assessment*: Estimating system threats, vulnerabilities, and consequences of adverse events;
- *Risk Management*: Identifying preventive and mitigating options; and
- *Risk Communication*. Communicating the decisions for implementation of the mitigating measures.

The standard *risk assessment* approach defines the MTS infrastructure risks as the relationship between the prevailing threats posed by the domestic and international maritime activities, the likelihood that these threats will be realized and lead to operational disruptions, and the severity of consequences: ²

$$R = pT \times C$$

Where:

R= *Risk* of disruption or failure in any of the MTS; p = Probability of threat realization; T = *Threat*; C = *Consequences* of resulting damages.

Risk models further break down the threat (T) as a product of *exposure* to sources of threat, and the present *vulnerabilities*:

$$T = E \times V$$

Where:

E = Probability that the *exposure* of the MTS subsystem to external and internal threats will increase the risks involved in an adverse event or disruption;

V = Probability that the *vulnerabilities* inherent in the MTS facilities, waterways, terminals, cargo or vessels, and the absence of safeguards to prevent disruption or mitigate systemic failures, will lead to a disruption.

This report spans the scope of the first two components of risk analysis: it conducts a *risk assessment* for the MTS by identifying the scenarios and use-conditions and then asking:

- *What can go wrong?*
- *What is the likelihood that it would go wrong?*
- *What are the consequences?*

² Adapted from Yacov Y. Haimes, *Risk Modeling, Assessment, and Management*, Wiley Series in Systems Engineering, 1998; and Yacov Y. Haimes, "Roadmap for Modeling Risks of Terrorism to the Homeland," *Journal of Infrastructure Systems*, June 2002.

The report also conducts a *risk management* evaluation of the MTS by asking: *What can be done to mitigate the consequences?* It identifies the countermeasures and preventive solutions, analyzes the potential tradeoffs, and calculates the anticipated impacts of the solutions on future operations and events, asking:

- *What can be done to mitigate the consequences?*

Finally, the MTS Assessment report asks:

- *What elements of the system contribute to its resiliency and sustainability?* as addressed within the “Resiliency Analysis Framework” developed below.

These concepts have served as guiding principles for the MTS assessment conducted in this report. While not designed as a formal “risk-benefit analysis,” “risk and reliability assessment,” or “condition assessment,” the study conducts a high-level baseline assessment of the MTS risk and resiliency by relying on readily available studies and impact estimates.

Resiliency Analysis Framework

Resiliency originates in system attributes and safeguards that reduce the probability of a single-point failure. The principles of “resiliency engineering” involve adaptive problem-solving focused on maximizing system strengths, alleviating system weaknesses, and deploying effective countermeasures to mitigate the impacts of incidents. *Sustainability*, a concept often used in reference to a strategic perspective focused on an efficient, long-term resource-use, is often used interchangeably with resiliency, conveying the overarching goal of “*meeting the needs of the present without compromising the needs of the future.*”³ Within this framework of sustainability and resiliency, analysis of the existing and future MTS resiliency is conducted based on four principle concepts in resiliency engineering: system’s *adaptiveness to disruption*, *fault-tolerance*, *built-in redundancies*, and *buffers* that mitigate the consequences, reduce the severity of the events, and expedite recovery:⁴

- a. A resilient MTS infrastructure is *adaptive* and flexible. It has access to information and operational intelligence that monitor the facility boundary conditions and guard against potential threats, allowing the system to adapt to changing conditions and respond to incidents with agility. Access to real-time data and monitoring systems provides maritime domain awareness (MDA) and enables deployment of effective technology solutions and decision support systems (DSS).
- b. A resilient MTS infrastructure has components and attributes that make it more *fault-tolerant* and robust. These attributes lower system threats (i.e., the totality of the events that “can go wrong”) and reduce its vulnerabilities (i.e., the probability

³ Definition of sustainability is derived from the widely accepted definition proposed by the World Commission on Environment and Development.

⁴ Discussion of resiliency in this section is loosely based on Erik Hollnagel, David D. Woods, Nancy Leveson, editors, *Resilience Engineering: Concepts and Precepts*, Ashgate, 2006.

that if something does go wrong the damages are minimal and the system can recover rapidly). These include design-based capabilities that make the infrastructure robust, and enable it to absorb attacks and resume normal operations shortly after a disruption.

- c. A resilient MTS infrastructure has *built-in redundancies* that help reduce vulnerability to single-point failures. Such systems have built-in layers of safeguards and parallel functionalities that enable the system to adapt to malfunction in one subsystem by shifting to backup capacity to sustain operations.
- d. A resilient MTS infrastructure has mitigative operational conditions that work as *buffers* to help reduce the severity of the consequences in the event of a disruption. These buffers will enable a more effective response, so that the affected components rapidly recover a stable state and continue operations after major disruptions.

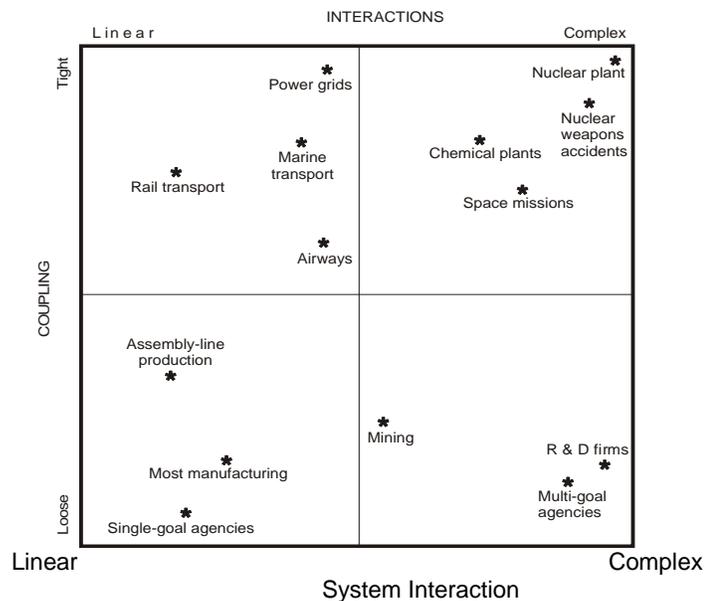
In the context of a systems' approach to the assessment of MTS risks and resiliency, it is evident that MTS shares some of the attributes of a high-risk system. However, MTS has many inherent risk-mitigation elements that make it resilient and sustainable. High risk complex systems that are most prone to systemic accidents are systems characterized by their high degrees of “*interactiveness*” and “*tight coupling*,” with little built-in flexibility. High-interaction systems tend to be complex, rather than linear, with complexity measured by attributes such as close spacing of equipment; multiple common-mode connections of components; limited isolation of failed components; specialized personnel with limited awareness of interdependencies; limited substitution of supplies; and unintended feedback loops.⁵ Systems with a high degree of interactiveness are prone to malfunction because the interactions can lead to departure from standard operating processes. A system with tight coupling has no slack or buffer between two items; what happens in one system directly affects the other. In general, tightly-coupled systems have more time-dependent processes, delays in processing are not possible, and their sequences are invariant, with only one way to reach the production goals: B must follow A, because that is the only way to make the product: (e.g., a nuclear plant cannot produce electricity by shifting to oil or coal as a fuel, but a more flexible power-production plant can shift from oil to coal); and resources cannot be substituted. In addition, they have little slack, thus quantities must be precise. Tight-coupling and high degrees of interactiveness can aggravate the effects of the initial malfunction with cascading effects that can delay rapid recovery from an accident.

Some MTS components such as locks and dams are linear: if a unit fails the impacts on the upstream and downstream systems can be known and controlled. Many other components of the MTS, however, can be highly interactive and tightly-coupled, with non-linear outcomes of an accident. For instance, if a large tanker, containership, or passenger cruise ship is involved in a collision, interactions among the parts can happen in unexpected sequences and the outcomes of an accident can be catastrophic. In a typical large self-propelled ocean vessel, the concepts of non-linearity and tight-coupling become critical to safe navigation decisions when the interactions with other vessel traffic in the vicinity need

⁵ Discussions on complex system attributes are based on Charles Perrow, *Normal Accidents: Living with High-Risk Technologies*, Princeton University Press, 1999.

to be synchronized with the flow of information from myriad sources – radar and satellite systems, voice and radio communications, and charts displaying changes in the weather or tide levels. As a ship enters a crowded channel, it encounters not only the weather changes, but also bank effects (the suction created as it passes close to the underwater bank of a channel), tides and current flows, wrecks and rocks, bridges, tows and other ships, a crowded radio channel, and navigation lights mixed in with the lights of port and harbor facilities and communications towers.⁶ The risks confronting marine navigation compared to other operating systems with various degrees of complexity can be illustrated by positioning them within one of the four quadrants developed from the juxtaposition of tight coupling and interactiveness (where the coupling ranges from loose to tight, displayed on the X axis), and the degree of interactiveness (ranging from linear to complex, as displayed on the Y axis.) Figure 1 shows the relative risk position of the “marine transport system” in comparison with other systems with varying degrees of interaction among parts and component coupling. For instance, the position of the MTS in quadrant 1 (signifying tight-coupling with linear interactions) in Figure 1 is in contradistinction with the placement of a nuclear plant in quadrant 2 (signifying tight-coupling with complex interactions.)

Figure 1 - Marine Transportation Risks: System Interaction and Tight Coupling



Adapted from: Charles Perrow, *Normal Accidents, Living with High Risk Technologies*, Princeton University Press, 1999.

Within the twofold framework of risk and resiliency analysis, this report conducts an assessment of the MTS infrastructure and operations, identifies the attributes of the present and future MTS that could mitigate the tight-coupling attributes of a complex MTS and enhance its resiliency by providing adaptive responses and redundancies that would lessen

⁶ Princeton University’s Charles Perrow, in an attempt to define simple and complex systems, explains the complexity of a system as a function of the probability of occurrence of what he refers to as “normal accidents;” defining an accident as “a failure in a subsystem, or the system as a whole, that damages more than one unit, and in doing so disrupts the ongoing or future output of the system.”

the potential catastrophic outcomes. This analysis is done in the context of the strategic priorities of the 2008 *MTS National Strategy* and the *Draft Implementation Plan* issued in March 2009.

National MTS Strategic Priorities

Five overriding priorities drive the MTS strategic goals, as outlined in the *MTS National Strategy*:

- a. Supporting continuity of operations and sustained international commerce by ensuring adequate capacity;
- b. Ensuring national security and vessel/passenger safety;
- c. Contributing to environmental stewardship;
- d. Ensuring adequate financing mechanisms, training and data, and institutional structures in support of MTS operations;
- e. Ensuring system resiliency and operational reliability.

Continuity of Operations: Facilitating Trade and Ensuring Adequate Capacity

The MTS consists of 25,000 miles of navigable inland and intracoastal waterways, including 12,000 miles of commercially- active inland waterway navigable channels (with depths of 9 feet or more) and 2,342 miles of Great Lakes and St. Lawrence Seaway.⁷ The navigable waterway system has a total of 9,584 commercially active “facilities” on the Atlantic, Gulf, and Pacific coasts, the Great Lakes, and inland waterways (6,500 ocean and Gulf facilities, 2,300 inland river facilities, and 750 Great Lakes facilities.)⁸ These consist of 5,066 deepwater facilities (defined variably as facilities between 12- and 15 feet of water depth), and 4,518 shallow-water facilities.⁹ By usage, the harbor channels consist of 5,279 cargo facilities, 3,319 passenger/service facilities, and some 986 “unused” facilities.¹⁰ A system of canals, locks and dams, aids to navigation (AtoN), ports and terminals, and intermodal connectors supports navigation of marine vessels and operations of the MTS facilities.

Ensuring continuity of operations for the commercial and military functions that depend on the MTS would require provision of adequate capacity for navigation and transportation services. Meeting this priority would require sustained efforts to ensure availability of alternate waterways and reduce the probability of casualties resulting from system failure or asset malfunction. Critical assets deemed essential to continuity of operations include facilities that have high degree of interdependence with other critical segments, have high replacement costs or downtimes associated with their disruption, or are vulnerable to attacks with potentially severe economic, safety or environmental impacts.

⁷ FHWA, USDOT, Office of Freight Management and Operations, Freight Facts and Figures, 2007,

⁸ USACE, *Transportation Facts*, 2007.

⁹ While USACE defines deep water as 15 feet, other sources use the 12-foot criterion.

¹⁰ USACE, *The U.S. Waterway System – Transportation Facts*”, Navigation Data Center, December 2007; <http://www.iwr.usace.army.mil/NDC/factcard/fc07/factcard.pdf>

National Security and Navigation Safety

The MTS priority for ensuring national security and navigation safety would require support for measures that would reduce the probability that the potential safety and security threats would materialize. These safety and security priorities would run the gamut from strategies for improving vessel safety and operating safeguards to enforcement of regulations promoting waterway safety.

Environmental Stewardship

MTS priorities with respect to environmental stewardship include finding the ways in which the marine ecosystem and transportation co-exist so that emissions, spills, and invasive species are minimized, and the integrity of sensitive natural marine habitats and watersheds are protected.

Adequate Funding and Institutional Structure

MTS priorities with respect to the Federal role include steps to ensure adequate funding, mariner training, data availability, and institutional structures guiding the domestic and international operations.

System Resiliency and Reliability

The National Strategy emphasizes the MTS priorities for promoting system resiliency and reliability by reducing the risk of disruption from waterway closure, and planning for orderly recovery from natural and man-made incidents.

Economic Importance of MTS for U.S. Global Competitiveness

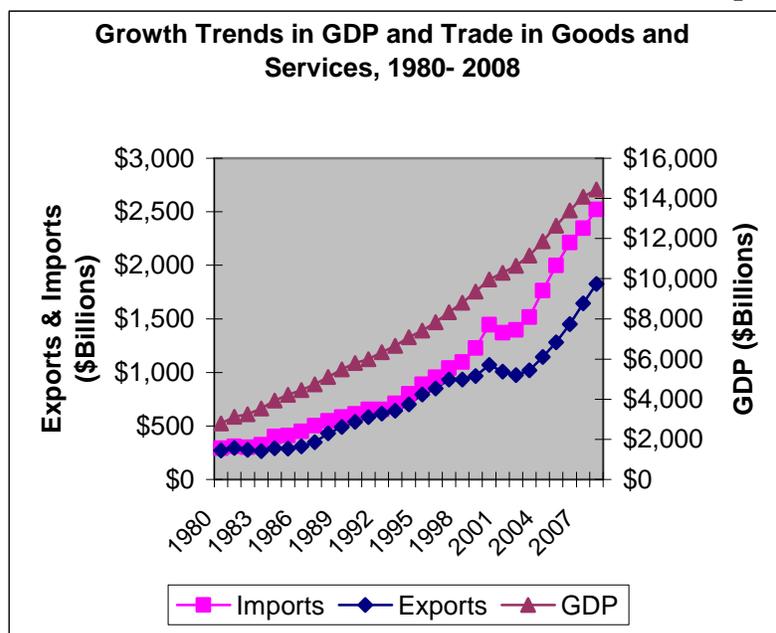
The scope of MTS functions as the global gateway for the nation is broad and expansive. As a global gateway, the U.S. MTS represents the critical linchpin in the operations of commercial cargo and passenger transportation, national defense and mobilization, and many non-transportation commercial maritime operations such as aqua-culture, fishing, ship-building, and oceanic research.

At the core of the MTS functions as the global gateway are the critical economic functions that ensure competitiveness of the nation's commercial production and distribution sectors. The extent to which the nation's competitiveness requirements are met is contingent on the efficient operations of the vessels, terminals, and the waterways for shipment of the exports and imports, and efficient functioning of the supply chains that manage the logistics of production and distribution for the global network of merchandise trade.

GDP and Global Maritime Trade

MTS has been a leading force in the growth of U.S. commerce and GDP. The value of the MTS-dependent U.S. international export and import trade has continually grown in the past decades in tandem with GDP, and at times at a more rapid pace. The total value of export and import goods (not including services) in 2008 was \$3.4 trillion (\$2.1 trillion in imported goods, and \$1.3 trillion in exported goods). When the values of service exports and imports are added, the total value of U.S. trade in 2008 was \$4.3 trillion, as reflected in Figure 2.

Figure 2 - U.S. International Trade in Goods and Services Compared to GDP



Source: Volpe generated chart based on 2008 data from Bureau of Economic Analysis, <http://www.bea.gov>

By weight, about 80 percent of the total U.S. goods exports and imports moves by water. By value, however, the MTS-dependent merchandise claims a smaller share. It has been estimated that 63 percent of the value of non-contiguous U.S. waterborne foreign trade originates in waterborne trade, while only about 10 percent of the contiguous U.S. trade with Canada and Mexico moves via waterborne transport. In all, half of the value of all U.S. foreign trade originates in waterborne transportation, accounting for some \$1.7 trillion in trade value, equivalent to 12 percent of the \$14.4 trillion GDP in 2008.¹¹

The global economic downturn of the past two years has led to declining volumes of cargo shipments for domestic as well as international commerce. Official statistics on the magnitude of the impact on MTS operations are not available at this point. The potential implications of the traffic slowdown for port capacity needs are addressed in the sections that follow.

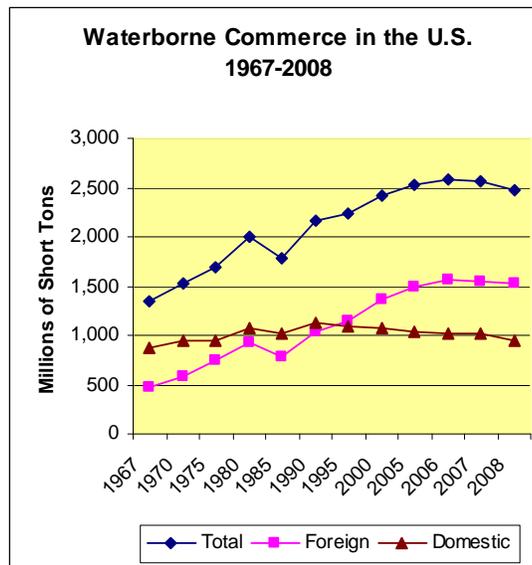
Foreign and Domestic U.S. Waterborne Trade

The U.S. MTS supports the inbound- and outbound-flows of 2.6 billion tons of commercial cargo shipped in domestic and international commerce, a volume that has grown twofold since 1967. Figure 3 shows the trends in the growth of domestic and foreign waterborne commerce, the near doubling of the tonnage shipped in the past four decades, and the reversal of the composition of the nation's domestic- and foreign-waterborne trade since 1993, when the foreign waterborne shipments began to exceed domestic shipments. Today, the U.S. maritime trade is driven by growth in foreign trade. In 2008, 62 percent of the U.S. MTS shipments (1.5 billion tons) were for transporting foreign-trade merchandise, and the remaining 38 percent (1 billion tons) for domestic trade. In 1967, foreign trade accounted for only 35 percent of the tonnage carried in U.S. waterborne trade (Figure 3.) Galvanizing the growth of foreign trade shipments has been the rise in U.S. imports. Today, imports (inbound freight) account for 73 percent of the U.S. foreign waterborne commerce; while exports (outbound freight) account for the remaining 27 percent (not shown in the chart).

The composition of the cargo shipped in the U.S. waterborne trade is dominated by bulk commodities and crude products. This is in clear contrast to the trend in the world trade where containerized cargo dominates the mode of shipment. Predominance of bulk commodities in U.S. waterborne trade is true for both foreign and domestic trade, but more so for the latter. In the foreign waterborne U.S. trade, 72 percent of the shipments consist of bulk commodities and crude/primary products (petroleum, chemicals, coal, ores/crude products). In the domestic waterborne U.S. trade, 85 percent of the shipments consist of bulk and crude/primary commodities.

¹¹ U.S. International Trade in Goods and Services: Exports, Imports, and Balances, *Bureau of Economic Analysis*, last updated October 9, 2009.

Figure 3 – Trends in Domestic and Foreign Waterborne Traffic



Source: IWR, USACE, Waterborne Commerce of the United States, Calendar Year 2008, Part 5 *National Summaries* (based on preliminary 2008 data.)

The growth in world seaborne merchandise trade, on the contrary, has been driven by the escalating growth in containerized trade. Containerized cargo accounts for nearly half of the shipments traded worldwide by water. Today’s world seaborne merchandise trade transports 7.2 billion tons of cargo annually, more than double the volume of 3 billion tons in 1975. Containerized cargo accounts for 3.1 billion tons of freight (44 percent of total world seaborne shipments), followed by shipments of oil and petroleum products (accounting for 2.3 billion tons, or 32 percent of the world merchandise trade), and coal and ores (accounting for the third largest commodity group, with 1.5 billion tons, or 20 percent of the world traded cargo.)

Global Supply Chains and the MTS

The growing dependence of U.S. consumers and industrial producers on outsourcing and low-price imports has been facilitated by the logistics strategies that have streamlined the management of channels of commerce for today’s shippers. Today’s logistics paradigms, with the help of advanced information technology (IT) systems, have enabled supply chain managers to lower logistics costs for shippers, retailers, and vessel operators through strategies such as “value chain management,” “pull-based inventory control,” “just-in-time (JIT) delivery,” “cross-docking” and “inventory deferral.” As vessel operators and cargo carriers compete for their market share by offering lower shipping rates per container or vessel-call, they adopt the same supply chain strategies that shippers and retailers use. These strategies have profound implications for how the estimated \$1.7 trillion worth of the U.S. MTS-dependent cargo are transported. The impacts are threefold:

- Global marine shipping has enabled vessel carriers to increase their vessel size and improve their cargo-handling techniques by taking advantage of *economies of scale*. These cost savings have lowered per-unit shipping costs and increased the number of units shipped for each vessel port-call. Increasingly larger vessels (bulk vessels or containerships) deployed in the international tradelanes have generated sizable cost savings as they have reduced per unit shipping costs: compared to a 4,500 twenty-foot equivalent unit (TEU) vessel, an 8,000 TEU vessel in the Asia-U.S. West Coast trade route reduces vessel costs by \$99 per TEU; a 10,000 vessel produces additional saving of \$51 per TEU.
- MTS logistics strategies have generated significant *economies of scope* for U.S. importers and vessel operators by expanding their market reach and lowering trading costs. This is done by liner companies helping exporters and importers to lower costs through trans-shipment strategies: i.e., reducing the number of port calls on each shipping lane but reaching out to more trading markets by container “land-bridging.” The strategy allows carriers to expand their market reach by making selective port calls at large urban ports and then transshipping the cargo to other locations (e.g., moving the marine container by rail from the Pacific Coast ports to the Atlantic Coast markets, or by “mini-land- bridge” service by trucking a container from Los Angeles to Houston as a substitute for all-water Panama Canal transit.)
- Shippers and retailers reduce their inventory carrying costs when vessel operators facilitate value-added services such as *cross docking*, *transloading* into domestic containers, and *inventory deferral* at inland distribution centers to reduce inventory carrying costs. *Cross docking* consists of unloading materials from an incoming vessel and placing them in a staging area where inbound materials are sorted, consolidated and stored until the outbound load is ready for shipment. By processing the import cargo arriving at a regional distribution center (DC) instead of the retailer’s docking yard or warehouse, cross docking reduces the retailer’s inventory-carrying costs significantly. Similarly, container *transloading* is an effective cost-saving strategy that is done by stripping and “de-vanning” the contents of 20-, 40-, or 45-foot marine import containers and re-stuffing them into 48’ or 53’ domestic containers at regional DC. *Inventory deferral* is a related strategy for reducing retailers’ inventory carrying costs by postponing the release of the imported goods in transload centers until the retailer is ready. Increasingly, major retailers are receiving shipments of waterborne cargo at their distribution hubs with an unspecified destination. Inventory deferral enables the retailer to maintain the same level of sales with an estimated 20 percent less inventory. This is a significant financial saving that reduces not only inventory carrying costs, but also the potential product obsolescence. The distribution hubs help the retailers defer the deployment decision for goods arriving from Asia to the U.S. retail destinations for up to 45 days. Delaying the deployment of cargo until the consignee is ready to receive the shipment in the U.S. saves the shippers’ inventory-carrying costs by reducing the time interval for distribution to the retail point-of-sale from an average of 23 days to 6 days.

Challenges and Constraints

The *MTS National Strategy* has identified five overriding challenges facing the attainment of its strategic priorities:

- a. Inadequate infrastructure capacity and deteriorating asset condition;
- b. Increased frequency of disruption and incidents;
- c. Growing exposure to high-consequence safety and security risks;
- d. Growing vulnerability to spills and environmental incidents;
- e. Growing budgetary and funding constraints and training/data access gaps;

What follows are the findings from over 400 pages of six MTS Assessment Task Reports that evaluated these challenges in the context of a risk and vulnerability framework. These six Task Reports are distributed as technical appendices to this Summary Report.

Risks of Inadequate Infrastructure Capacity and Deteriorating Asset Condition

MTS integrity and continuity of operations are potentially threatened by vulnerabilities arising from lack of adequate capacity and asset maintenance. The consequences of these vulnerabilities are safety risks arising from deteriorating asset condition and the economic costs of the loss of international competitiveness. Marine infrastructure capacity is measured as the point of equilibrium at which the physical supply of the MTS assets intersects with the demand schedules of the facility-users. On the supply side, determining a facility's capacity are factors such as the channel or harbor depth and configuration relative to the size of the vessels calling at the ports, the condition and size of the lock and dam system, the condition and carrying capacity of the intermodal connections, and the landside terminal and berth capacity. On the demand side, factors such as the volume of vessel traffic, frequency of port calls, competing land uses, and the pattern of concentration of traffic among marine ports determine the balance of available and needed capacity.

The MTS infrastructure capacity challenges can be measured as the gap at the intersection of the demand and supply curves. These gaps are manifested through four key capacity challenges: inadequate channel depth, inadequate lock and dam maintenance, congestion at the top 10 ports, and overloaded or deficient intermodal connectors and bridges. The recent economic downturn has somewhat reduced the capacity shortfalls and the urgency of taking steps to mitigate the effects of congestion. However, the inevitable future surges in domestic and international demand for exported and imported goods will likely renew the capacity challenges.

Growing Gap in Meeting Channel Capacity Needs

A key capacity challenge of the U.S. navigable waterways is the gap between the available depth of the Federally-maintained channels and the draft requirements of the increasingly larger vessels using the waterways. In the past two decades, the depth requirement of new vessels has grown from about 39 feet to over 45 feet. Only a handful of ports (e.g., Los

Angeles/Long Beach) currently have the required channel depth to serve these ever-larger modern cargo vessels. Because of this capacity gap, containerships serving U.S. ports are increasingly experiencing “constrained calls” – defined as cases in which a vessel’s design draft plus a safety clearance exceeds channel depth restrictions. The National Dredging Needs Study (NDNS) of U.S. Ports and Harbors, conducted by the USACE in 2000 and updated in 2003, identified the magnitude and timing of harbor improvements needed to accommodate future vessel sizes and vessel calls. The study found that without the planned channel improvement projects, the total number of constrained calls by 2020 would be about 25 percent of the total vessel calls. The NDNS predicted that completion of the planned projects nationwide by 2020 would reduce constrained calls by half.¹²

Channel capacity constraints translate to unavailability of some harbor facilities on a full-time basis, with the attendant economic losses and delays. A key segment of some of the most highly-used Federal navigation channels – referred to as the center channel or half-width of the channels – is available only 35 percent of the time. Vessels navigating these channels have to wait for the water level to rise and provide adequate channel depth. This condition is counter to the USACE five-year plan that seeks to achieve 95 percent half-channel availability for these projects.¹³ Three factors contribute to the widening capacity gap: 1) growing vessel size, 2) growing number of port calls, and 3) the escalating capital costs of port development:

- The size of the vessels serving the U.S. maritime trade has been growing steadily, particularly for containerships. Between 2003 and 2008, the average deadweight (DWT) size of vessels calling at U.S. ports has grown by 6% to 52,535, while the average DWT size of containerships has grown by 14% to 49,200. Most of the increase in the post-Panamax vessels, i.e., those with capacity of 4,000 twenty-foot-equivalent unit (TEU) or more. Average TEU capacity of containerships has grown from 666 TEU in 1991 to 4,200 TEU today, while new vessels on order range in size from 10,000 TEU to 14,000 TEU. The number of post-Panamax vessels calling at U.S. ports has more than doubled from 4,000 to about 9,000 port calls, between 2002 and 2007.¹⁴
- The frequency of port calls has also grown, with the largest increments from post-Panamax vessels of over 4,000 TEU. Between 2003 and 2008, tanker port calls grew by 13% to 21,00 calls per year; all containership port calls grew by 8% to 18,735 calls per year; while port calls by containerships of over 5,000 TEU grew by 278% from 1,110 calls to 4,300 calls. Container capacity of some of the largest containerships currently calling at the U.S ports is about 9,000-10,000 TEU, with vessel drafts of up to 46 feet. Future forecasts are for 12,000 TEU ships with vessel drafts of 49 feet, and even larger vessels of 14,000 TEU-capacity with drafts of 50 feet planned for entry in

¹² USACE, “National Dredging Needs Study of U.S. Ports and Harbors, Update 2000,” May 2003; pp. 183-185. Note that these forecasts are dated and new forecasts will be used when available.

¹³ Draft CMTS Report to the President, dated November 14, 2007.

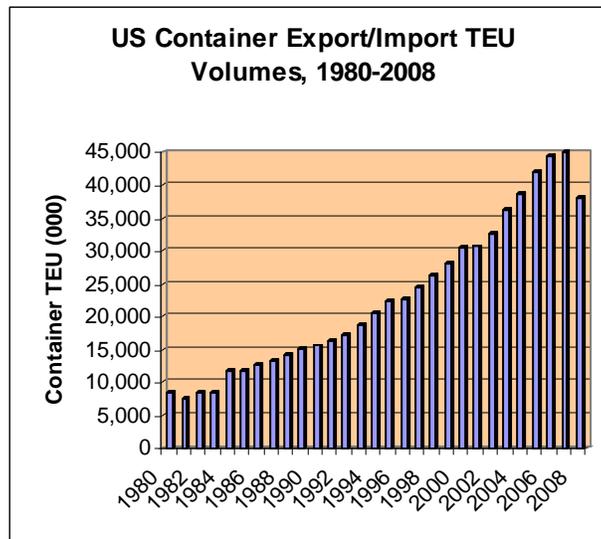
¹⁴ The current Panama Canal has a limit of 965 feet (length), 106 feet (beam) and 39.5 (draft). This nominally limits a ship to less than 4,000 TEUs. With the completion of the third set of locks in 2014, the Canal will be able to handle ships carrying up to 13,000 TEUs.

the U.S. market. As older vessels calling at U.S. ports are retired, the size of the newer vessels replacing them has grown, as they are replaced by larger post-Panamax vessels.

In general, the size of the vessels calling at U.S. ports has been above the world average for port calls, a reality that has contributed to the growing MTS capacity gap. The average size of containerships calling at U.S. ports is estimated to be 17 percent larger than the size of vessels calling at ports elsewhere in the world. In its 2006 *Annual Report to Congress*, MARAD attributed the reason for this above-average size of the vessels calling at U.S. ports to the scarcity of small U.S. feeder vessels and short sea shipping (SSS) services. The size of a feeder ship is between 2,000-3,000 TEU, instead of the 6,000-plus TEU vessels routinely calling on coastal ports. The Report notes that in Europe and Asia, smaller feeder vessel and SSS services handle most of the intra-European and intra-Asian trade.¹⁵

Reflecting the growing containership TEU volumes is Figure 4, showing the trend in containerized trade volumes between 1980 and 2008. This Figure depicts the growth in container volume from 1980-2007, followed by a 16 percent decline in 2008. Before this recent downturn, container shipments had been growing steadily by over 430 percent (from 8.4 million TEU in 1980 to 45 million TEU in 2007, with the exception of a slight decline in 2001 and a period of slowdown between 1981 and 1983.) The 16 percent decline in the 2008 traffic relative to 2007 (from 45,000 TEU to 38,000 TEU) is reflective of several divergent trends in the nation’s top-10 container ports, including the major losses experienced by the West Coast container ports, compensated in part by gains in traffic on the East Coast container ports (trends in top-10 port container port traffic are described below.)

Figure 4 – Growth Trends in U.S. Export/Import Container TEU, 1980-2008



Source: American Association of Port Authorities (AAPA), North American Container Ports, 2008

¹⁵ Maritime Administration, *Annual Report to Congress*, Fiscal Year 2006.

- Finally, compounding the growing capacity gap in the MTS has been the high capital investment costs of port improvement and channel deepening. Modernizing the landside- and harbor-side port facilities to accommodate the growth in the size of today's containerships requires significant levels of capital investment – not only for dredging the channels and deepening the berths, but also paying for larger cranes and improved container storage and marshalling yards. These high costs account to a large extent for the growing concentration of international port calls at a handful of parts. The fact that only a few ports have been able to make these investments has reinforced the trends in concentration of container traffic at the top five or ten ports.¹⁶ The ripple effect of the growing concentration at the nation's mega ports has been to further aggravate the MTS waterway capacity challenges by adding to land-side congestion and traffic bottlenecks, as noted later in this report.

Deteriorating Conditions of the Nation's Locks, Dams and Levees

The USACE is responsible for maintaining 275 lock chambers at 230 sites on the 12,000 miles of inland and intracoastal waterways. About 171 of these lock sites are located in designated fuel-taxed waterways. The USACE is also responsible for inspection and maintenance of the Federal levee system, annually inspecting some 2,000-levee units. The viability of the MTS inland waterway system is jeopardized because of the deteriorating condition of the equipment and infrastructure due to delayed maintenance. Safety risks and disruptions in navigation caused by unscheduled lock downtimes and waterway shutdowns are some of the consequences of these deteriorating conditions. Inadequate funding for asset maintenance, coupled with the aging infrastructure and inadequate lock size for accommodating modern vessels, have been the key causes of the deteriorating condition of the inland waterways.

Aging locks, levees and dams pose critical challenges for the viability of MTS infrastructure. The design life of an average lock is 50 years. Currently, over half of the lock chambers in the U.S. waterway system are over fifty years old and exceed their design lives. Many of the locks in need of maintenance and repair have not received the needed funding. Only 196 of the commercially active lock sites and 240 lock chambers currently receive funding.¹⁷ Lack of maintenance has led to frequent instances of unscheduled closures of the inland lock and dam system, the associated disruption in navigation, and the potential for loss of life and property damage caused by dam failures. Lock downtimes, and the associated consequences of delays and economic costs, have been on the rise in recent year.¹⁸ Undersized locks represent another area of vulnerability that disrupts navigation and leads to delays, as they require breaking up tows at each lock and reassembling them once through the lock. Lock queues and bottlenecks resulting from traffic buildup during lock downtimes add to operating costs and transit times.¹⁹ Navigation

¹⁶ BTS, *America's Container Ports: Delivering the Goods*, March 2007

http://www.bts.gov/publications/americas_container_ports/html/port_concentration.html

¹⁷ The USACE US Waterway System – *Transportation Facts*, 2007 has reported that the USACE owns or operates 257 lock chambers at 212 sites.

¹⁸ BTS, <http://www.bts.gov> and <http://www.greatlakes-seaway.com>

¹⁹ USACE, New Release, "U.S. Army Corps of Engineers Provides Locations of Unacceptably Maintained Levees," February 1, 2007.

delays from lock unavailability or lock closures have grown from approximately 30,000 hours in 1992 to 110,000 hours in 2005, with nearly half of the closures due to unscheduled lock downtimes. The time cost of lock queues and bottlenecks have been estimated at over 550,000 hours annually, costing the users \$385 million in added operating costs.

Safety risks from inadequate dam and levee maintenance are also significant. In the wake of the Hurricane Katrina and the failure of the dam and levee systems, the Urban Land Institute published a report, warning that some 3,500 unsafe dams in the U.S. were without adequate funding for their repairs.²⁰ There are also reportedly some 121 units of the 2,000 Federally-maintained levee units inspected by the USACE that are in unacceptable condition.²¹ The Urban Land Institute report concluded that though the price tag for tax payers for infrastructure maintenance has been considered too high, the cost has proven to be only a fraction of the \$110 billion in federal aid that was committed in the hurricane's wake. The report estimated that a total investment of \$30 billion was needed to bring all 79,000 dams nationwide into safety compliance, noting that the Federal government provides less than \$10 million annually to the States for such programs.

Congestion at the Nation's Top 10 Marine Ports

Port congestion, driven in part by the escalating volume of trade traffic, the growing size of vessels and frequency of port calls, and in part by concentration of vessel-calls at a few ports, has emerged as a major obstacle in the ability of the MTS to meet the needs of international commerce. Concentration of traffic at the top 5 to 10 container ports has grown, as well as the associated problems of congestion and service gaps. However, the recent economic recession has slowed down the rate of concentration at the top 10 container ports. In 2008, the top five container ports accounted for 57 percent of containership capacity; the nation's top 10 container ports accounted for 78 percent of containership capacity; the nation's top 30 container ports accounted for 98.9 percent of all containership capacity.²²

Concentration rates at the U.S. bulk ports have not been as high as those in container ports. In 2007, the latest year for which tonnage data for waterborne trade (domestic and foreign) were available, the top 5 ports by tonnage volume (Ports of South Louisiana, Houston, New York/New Jersey, Long Beach, and Beaumont, Texas) accounted for only 29 percent of all cargo tonnage moved; top 10 ports (which include the top 5 in addition to Corpus Christi, Huntington/Tristate, New Orleans, Los Angeles, and Mobile) accounted for 43 percent of the total tonnage moved; while top 30 ports accounted for 73 percent of tonnage, reflecting a more balanced distribution of the nation's bulk cargo among the 130 ports with volumes more than 1 million tons per year (together carrying a total of 2.7 billion tons of cargo in 2007.)²³

²⁰ Urban Land Institute, *Infrastructure 2007: A Global Perspective*, 2007. <http://www.uli.org/AM/>

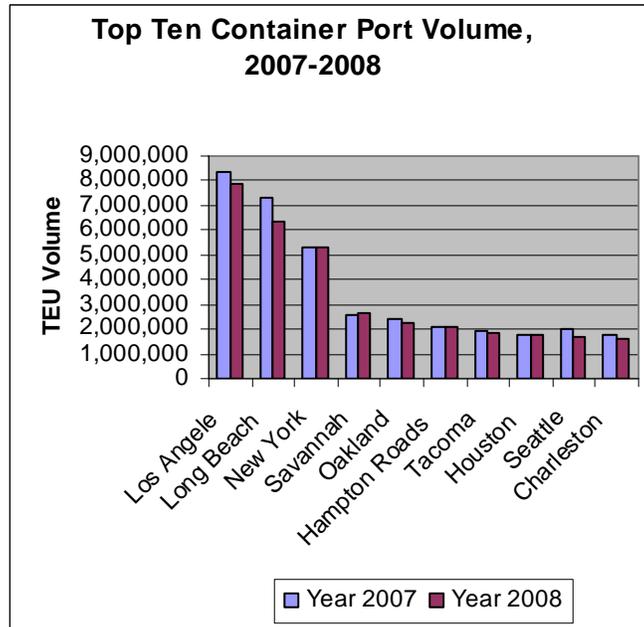
²¹ USACE, New Release, "U.S. Army Corps of Engineers Provides Locations of Unacceptably Maintained Levees," February 1, 2007.

²² American Association of Port Authorities (AAPA), *North American Port Container Traffic*, 2009.

²³ AAPA, Total Export and Import Tonnage for 2007.

Figure 5 compares container TEU volumes for 2007-2008 at the top ten container ports, showing declines ranging from -3 percent (for Port of Tacoma) and -6 percent (for Ports of Los Angeles and Oakland) to a high of -13 percent (for Ports of Long Beach and Seattle). The Atlantic ports showed smaller declines at ports of NY/NJ, Hampton Roads and Charleston, while port of Savannah showed a slight gain. The Gulf port of Houston also showed a moderate gain (Figure 5).

Figure 5 – Top Ten U.S. Container Port Traffic, 2007-2008



Source: Volpe generated chart based on data from AAPA, North American Port Container Traffic, 2008.

The growing concentration at the top 10 container ports is leading to a rapid loss of the MTS excess capacity at the nation’s international container ports, a loss that can potentially be highly disruptive. Loss of excess capacity can further expose the ports to threats of disruption, narrowing the port’s operational margin of error, and reducing the ports’ ability to resume normal operations. By one estimate, terminal excess capacity at the U.S. marine terminals will disappear by 2011, the date on which the planned TEU capacity growth will have reached the expected user demand levels, making the utilization rate 100 percent.²⁴ A U.S. Chamber of Commerce study of 16 key ports in the U.S. concluded that by 2010, 75 percent of the ports studied would have significant capacity problems, and that most of the container capacity would be used up. The study cited the forecasts suggesting that over the next 20 years container volume will double and nearly all non-bulk cargo will be containerized, emphasizing the adverse consequences of inadequate intermodal access to U.S. ports:

²⁴ Drewery Shipping Consultants data, reported in John Vickerman, “Global Ports & Containerization Development: Choke Points and Opportunities,” presented at the Fourth Annual Grain & Oilseed Transportation Conference, Memphis, Tennessee, March 26, 2007.

“...the U.S. port and intermodal freight system is now being operated in many areas at the limits of its maximum capacity. Should any component of the system break down, more than one fourth of the economy will be crippled. [The report recommended] dedicating more resources for the critical and often neglected ‘last-miles’ connecting the National Highway System to intermodal freight facilities, particularly our ports.”²⁵

With the current economic recession, it is likely that the full loss of the existing excess capacity will be delayed for the time being. There is, however, an emerging consensus that productivity improvements will no longer prove a viable solution at ports since berth space is scarce and that any operational improvement will need to be reconciled with organized labor.

Overloaded or Structurally Deficient Bridges and Intermodal Connectors

Capacity challenges at the MTS connectors due to deficient or overloaded intermodal connectors, structurally defective bridges, and bottlenecks caused by inadequate capacity at port access links pose a key threat to the viability of MTS terminal operations. Intermodal connectors are often considered the “weakest link” in the MTS network, creating significant vulnerabilities. Highlighting the need to step up construction of needed intermodal access facilities is a report by the American Association of State Highway and Transportation Officials (AASHTO) projecting that the volume of trade flows along the nation’s freight corridors, military supply movement routes, and intermodal connectors will grow from 40 million to 110 million by 2020.²⁶ The AASHTO report is consistent with the estimates of the National Highway System (NHS) *2000 Connector Report to Congress* finding that connectors to marine port facilities to have twice the percentage of mileage with pavement deficiencies when compared to other facilities. Included in the NHS intermodal access links are connectors to 253 ocean and river ports and to 59 ferry terminals.²⁷ Based on this NHS connector study, a National Cooperative Highway Research Program (NCHRP) assessment of 660 terminals and 1,222 miles of connectors found that the condition of 12 percent of the total connector pavement mileage was poor or very poor. By terminal type, 15 percent of the intermodal connectors at ocean/river port terminals were deemed poor or very poor. Three broad MTS-related infrastructure connectors and corridors were found to be key contributors to congestion. The NCHRP recommended that these facilities be funded by freight-related user fees from outside the Highway Trust Fund, as part of 25-year initiative called Critical Commerce Corridors, to enable States to add capacity to freight gateways and upgrade highway bottlenecks by completing 14,000 miles of Trade Corridors, 400 lane miles of intermodal “last mile” connectors, and 1,000 miles of Fort-to-Port Routes.²⁸

²⁵ U.S. Chamber of Commerce, *Trade and Transportation: A Study of North American Port and Intermodal Systems*, 2003.

²⁶ American Association of State Highway and Transportation Officials (AASHTO), “A New Vision for the 21st Century,” July 2007.

²⁷ Federal Highway Administration, “NHS Intermodal Freight Connectors A Report to Congress”, December 2001

²⁸ NCHRP, National Cooperative Highway Research Program (NCHRP), *Future Options for the National System of Interstate and Defense Highways*, NCHRP Project 20-24 (52), May 2007.

Lack of adequate rail capacity also contributes to MTS intermodal access vulnerability. A recent CBO study stressed the importance of rail access, capacity, and on-dock throughput for the performance of the nation's container ports. The study documented that in the late 2004, the capacity constraints experienced by the railroads serving major container ports led to a major slowdown in distribution of imports at the nation's ports.²⁹ The USCG has also reported obstructive marine rail bridges as posing significant safety risks.³⁰

Congested MTS access links impose significant economic costs from traffic delays. Interchanges at the nation's major ports and intermodal terminals are the largest contributors to highway bottlenecks and delays. A study conducted for FHWA has found that bottlenecks and recurring congestion at major intermodal terminal interchanges account for 40 percent of the total delays on the nation's highways. On these interchanges, the volume of traffic routinely exceeds the capacity of the roadway, resulting in stop-and-go traffic flow and long backups. Among interchanges with the largest number of delay hours were freeway interchanges at urban freight corridors (such as highway access to the Ports of LA/LB or NY/NJ), reporting an estimated 124 million hours of delay in 2004.³¹

Structurally deficient bridges also represent significant MTS vulnerability and safety risks. In 2007, there were 600,000 bridges in the U.S. According to the National Bridge Inventory (NBI), a database maintained by the FHWA Office of Bridge Technology, 72,264 (12 percent) of these bridges were "structurally deficient," and another 81,257 (14 percent) were "functionally obsolete."³² Underscoring the economic consequences of inadequate funding for MTS maintenance operations is a recent report by the TRB, National Academy of Science (NAS), on challenges of infrastructure financing. The report identifies inadequate maritime funding mechanisms for system maintenance as an alarming trend, warning:

"Lack of system preservation and rehabilitation produces a downward spiral...The price of short-term savings from deferred maintenance, however, is proportionately greater rehabilitation cost later...Raising the visibility and developing support for system preservation is critical to the 21st century transportation system."³³

Economic Risks of Disruption in Operations

The MTS is vulnerable to disruption because of the intrinsic properties of its infrastructure and functions. These systemic vulnerabilities arise from the waterways' vast size, its visibility, its open and unprotected access, its broad exposure to adverse weather and navigation hazards, its under-maintained infrastructure facilities, and the growing reliance

²⁹ CBO, Freight Railroad Transportation: Long-Term Issues, January 2006.

<http://www.cbo.gov/ftpdocs/70xx/doc7021/01-17-rail.pdf>

³⁰ USCG *Proceedings*, Dr. Kamal Elnahal, "Bridges are the Critical Links in Shaping Tomorrow's Waterways", Office of Bridge Administration, Summer 2007.

³¹ Cambridge Systematics, "An Initial Assessment of Freight Bottlenecks on Highways: A White Paper", October, 2005.

³² FHWA, National Bridge Inventory, <http://www.fhwa.dot.gov/bridge/>

³³ TRB, *Critical Issues in Transportation*, National Academy of Sciences (NAS), 2005.

on imports and its attendant imbalance in container traffic. These vulnerabilities raise the probability of operational disruption resulting from shipper/carrier uncertainty about service reliability, and increase the subsequent losses of trade revenues.

Economic Losses from Port Closure

Costs of port closure, whether due to natural disasters, labor strikes, capacity-related problems or terrorist threats, have proven sizable in recent years, partly because the losses ripple down the regional economy or lead to permanent shift of traffic to new shipping lanes. A study conducted for the Department of Labor in 2002 estimated that a 7-day shutdown of container traffic through the ports of Los Angeles and Long Beach (LA/LB) would generate losses to the economy of roughly \$75 million per day. A Congressional Budget Office (CBO) estimate of the economic costs of port disruptions – modeled after the disruptions in the aftermath of the 2002 West Coast labor disputes, based on two scenarios for a one-week shutdown and a 3-year shutdown at the LA/LB ports – estimated the one-week shutdown to lead to losses between \$65 million to \$150 million per day, with an estimated loss of \$450 million for an average week of shutdown. The 3-year shutdown scenario was estimated to lead to greater losses amounting to between 0.35 to 0.55 percent of the Gross Domestic Product (GDP), equivalent to a loss of \$45 billion to over \$70 billion per year. The CBO study assumed that in the aftermath of the closure, the backlog of ships waiting to enter ports would be resolved by strategies such as carriers shifting port-calls to alternative ports, reconfigured supply chains, and the possibility that producers would turn to domestic sources of supply and consumers would consume a different mix of goods.³⁴ The CBO study attempted to correct for the previous high-end estimates of \$1.96 billion per day in losses from the 10-day 2002 shutdown of the Southern California container ports.³⁵

Consequences of the Growing Reliance on Imports

The economic consequences of the nation's growing reliance on imports have been twofold: the declining per-ton value of waterborne exports and imports, and the rising macroeconomic costs of trade deficits. Both of these trends have potential long-term implications for the revenues available for MTS infrastructure improvements.

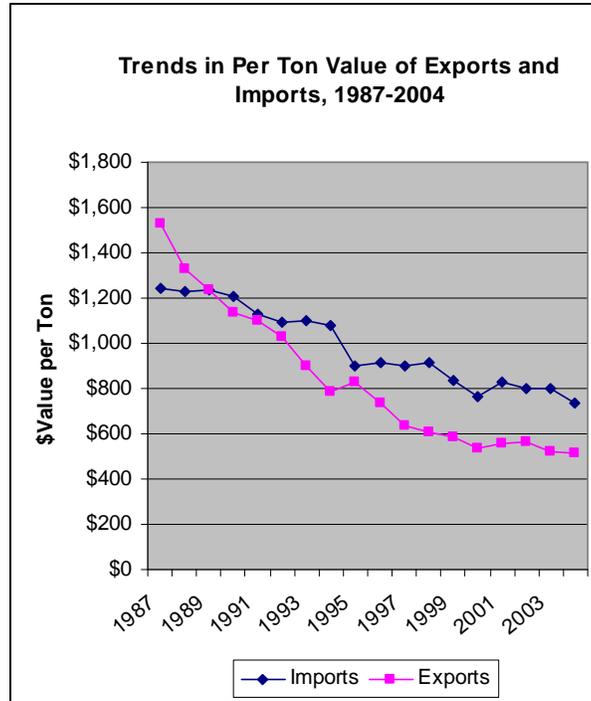
Per-ton value of the U.S. exports and imports has declined in the past decades, while the total value of merchandise trade has risen. The plummeting per-unit values are attributed to at least two factors. First, the value of waterborne import cargo has declined because the global outsourcing trend has lowered production costs. Second, there has been a change in the composition of the U.S. exports: increasingly, the U.S. exports of high-value manufactured products are replaced with lower value commodity exports. Today, waste paper and scrap metal are the leading U.S. export products. Because the revenues gained by many MTS services supporting the container trade are based on the value of the shipped

³⁴ Congressional Budget Office (CBO), *The Economic Costs of Disruptions in Container Shipments*, March 29, 2006. http://www.cbo.gov/ftpdoct/71xx/doc7106/03_29_container_shipments.pdf

³⁵ The estimated losses of \$1.96 billion per day were based on Martin Associates, *An Assessment of the Impact of West Coast Container Operations and the Potential Impacts of an Interruption of Port Operations*, 2000, October 2001.

cargo, this decline has significant ripple effects on the revenues of the public and private port facilities and their ability to fund port improvement projects (Figure 6.)

Figure 6 – Trends in Declining per Ton Value of the U.S. Exports and Imports



Source: Volpe chart based on calculation of the average values per ton, using data from BEA, U.S. International Trade in Goods and Services, 1960-2004 for value of Goods Exports and Imports; and tonnage data from IWR, Waterborne Commerce of the United States, Calendar Year 2006, Table 1-6;³⁶

The nation’s ever increasing reliance on imports has also led to a widening gap in the balance of payments. In 1975, the balance of trade was positive, with 12 billion more in U.S. exports than imports; by 2006 the steadily rising trade deficit had resulted in a record trade deficit of \$760 billion. As a result of the economic recession of the past two years, this trade gap had shrunk to \$726 billion by 2008. Figure 7 illustrates the trend in the gap between exports and imports, 1960-2008.

³⁶ Note that average values in Figure 18 are based on the Volpe Center calculations of the 2006 trade values obtained from Bureau of Economic Analysis and the tonnage data obtained from the U.S. Army Corps of Engineers Waterborne Commerce of the United States. Per-ton values may not be consistent with other sources of average-value calculation.

Figure 7 – Balance of International Trade in Goods and Services, 1960-2008

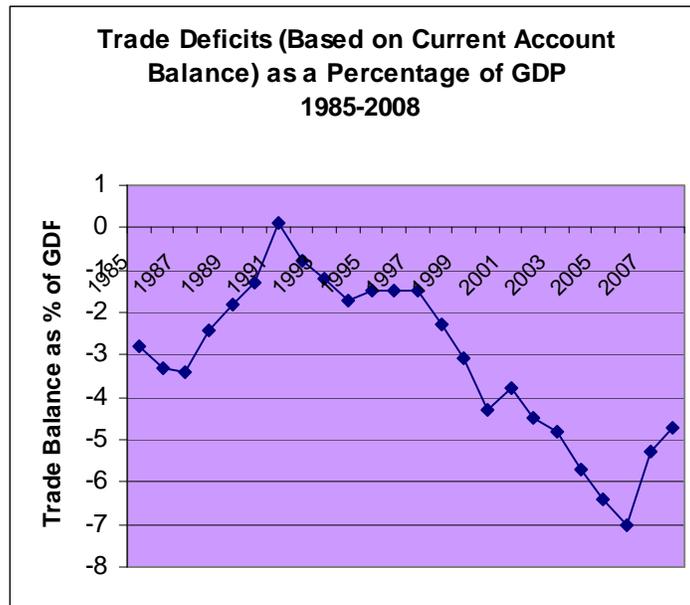


Source: Volpe produced chart based on BEA data reported in the *U.S. International Trade in Goods and Services*, last updated October 9, 2009

The negative U.S. trade deficit resulting from a 2008 balance of \$2.6 trillion in imported goods and services and \$1.8 trillion in exported goods and services has placed a downward pressure on the exchange rate and a drop in the value of the U.S. dollar. The Congressional Research Service (CRS) has cautioned that when the rate of trade deficit exceeds the International Monetary Fund (IMF) benchmark of -5.0 percent, the trend would “warrant caution.” This is because foreign investors would stop buying dollar-denominated assets in order to offset their holdings of the U.S. currency, thus hastening the drop in the value of the dollar. The U.S. trade deficit as a percent of GDP rose to its highest point in the 2005-2006 period, with the deficit rate reaching to close to -7.0 percent of GDP. In the past two years, however, with the severe economic recession and decline in consumer demand for imports, the deficit rate has begun to decline. In 2008 the Current Account Balance as a percentage of GDP was -4.72 percent, showing a declining deficit relative to the 2007 deficit level of -5.30³⁷ (Figure 8.)

³⁷ http://www.economywatch.com/economic-statistics/United-States/Current_Account_Balance_Percentage_GDP/

Figure 8 - Trade Deficits as a Percentage of GDP, 1985-2008



Source: Volpe generated chart based on CRS, Issue Brief for Congress, “U.S. International Trade: Data and Forecasts”, 2008

Economic Consequences of Container Transloading

Growing rates of container transloading – i.e., the practice of transferring the contents of 20-foot, 40-foot, and 45-foot marine containers into 48-foot and 53-foot domestic containers to be shipped by rail or truck – have created significant challenges in terms of MTS infrastructure congestion, capacity bottlenecks, and excessive operating costs for repositioning the empty import containers. Recent studies have shown that as much as 40 percent of the containerized goods that arrive in Los Angeles and Long Beach are transloaded to domestic containers before being shipped by truck or rail to retailers, manufacturers and warehouses out of state.³⁸ As noted previously, container transloading is a primary tool for retailers’ inventory deferral strategies, a practice that has worsened the imbalance between the number of containers in inbound and outbound trade.

Because transloading reduces the number of “intact” containers handled at major international ports, conventional congestion mitigation solutions such on-dock rail, Agile Port, and the Alameda Corridor project have proven ineffective. Transloading of intact containers into domestic boxes has not only worsened congestion at the major import ports, but has also contributed to the declining revenues at many of the nation’s international ports. The imbalance between imports and exports has created a massive number of empty containers which are non-revenue moves for carriers and terminals. Under normal circumstances, the cost of repositioning an empty container is considered a manageable operational cost and a normal component of container shipment operations. However, current conditions of export-import imbalance have led to alarming costs and traffic

³⁸ Robert C. Leachman, Port and Modal Elasticity Study, September 8, 2005.

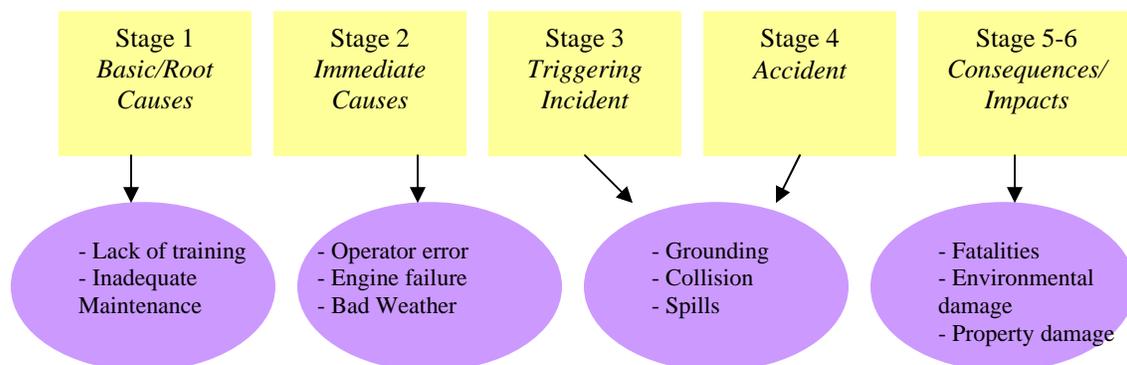
disruptions. Over 1 million empty import containers are transported in Southern California each year. Very few of these containers find backhaul loads in exports; virtually all of them are trucked empty back to the marine terminal. In addition to the problems arising from truck congestion and environmental pollution, and revenue pressures for ports and local governments, the abundance of empty container repositioning has also worsened terminal congestion because empty containers have longer dwell times. Because of the high cost of repositioning empty containers as non-revenue moves to Asian origins, many marine terminals are faced with a buildup of empty containers with longer average dwell times, a storage problem that is worsened because many local ordinances prohibit terminal operators from stacking empty container higher in order to save storage space.

Safety and Security Risks Arising from Growing Exposure to High-Consequence Events

Vessel Safety Risks

Vessel accidents often occur not as a consequence of a single failure, but as part of a causal chain of events, errors and hazards encountered during the voyage. The risk assessment process links the *root causes* (factors such as inadequate staffing, training or supervision, and poor preventive equipment maintenance or inspection of critical systems) of an accident to *immediate causes* (factors such as human error/incompetence, mechanical and equipment failure, and hazardous situations that may or many not lead to an accident). These causes coalesce when a *triggering incident* (e.g., undesirable events related to system failure or lapses in operational controls such as loss of propulsion, steering failure, electrical power failure, navigation chart error, or human error) that may be detected or corrected in time to prevent accidents. These factors may or may not lead to *accidents* – i.e., occurrences such as spills, collisions or grounding that cause damage to vessels or personnel, the *consequences* of which may be fatalities, property losses, or environmental damage with broader economic or system-wide *impacts*. Figure 9 illustrates the causal chain of accidents and the sequence of events preceding an accident involved in a marine incident.

Figure 9 – Causal Chain of Accidents



In the context of the safety profile of the U.S. transportation system as a whole, the waterborne mode has far fewer accidents and casualties than the highway mode, but more than the aviation, rail, and transit modes. With about 10,400 accidents, 800 fatalities, and 5,200 injuries per year, commercial vessels and recreational boats account for about 2 percent of all transportation fatalities and 0.2 percent of all accidents and injuries in the U.S. In comparison, highway vehicles (with about 6 million accidents, 42,000 fatalities, and 2.6 million injuries) account for 99.5 percent of all transportation accidents, 95 percent of all fatalities, and 98.8 percent of all injuries. Commercial vessels in general, and freight ships, tankers and offshore service vessels (OSV) in particular, have shown a steadily declining trend in accident and casualties (i.e., combined fatalities and injuries). Recreational boats (claiming by far the largest share of marine accidents and casualties), passenger and fishing vessels, and tug/barge/towing equipment have shown rising or fluctuating rates of accident and casualty.

- Tanker vessels have shown low and steadily-declining casualty levels in the past years. Most of the recent tanker incidents have involved oil spills. The primary causes of roughly 300 worldwide tanker accidents were mechanical failure related to hull damage or engine-failure, collision, grounding and fire. Fatalities and injuries resulting from tanker accidents have been rare and fewer than 2 to 3 per year.
- Freighters (container and drybulk vessels) fatalities and injuries have generally declined in the past three decades, but have shown fluctuating spikes. Before 1990, accidents involving these vessels resulted in more than 10 fatalities and injuries on average per year. In the past two decades the average casualties have declined to 1 fatality and 4 injuries per year. Though consistent transit data have not been available for normalizing these accident rates, the spikes may be attributed to rising carrying capacity of vessels and traffic volumes.
- Towing vessels and barges have been among marine vessels with fluctuating accident rates. The average casualty rates have declined from over 30 towing vessel fatalities and injuries per year before 1990 to fewer than 20 for most of the past few years in combined fatalities and injuries.
- Offshore service vessels and Mobile Offshore Drilling Units, often at high risk of collisions because of exposure to hazards associated with deep sea navigation, have shown steadily declining casualty figures, with the average rates in the past few years declining to fewer than 10 casualties per year in combined annual fatalities and injuries.
- Commercial fishing vessels have exhibited rising and above-average accident and casualty rates. While the fishing vessel fatalities have declined from an average of 61 deaths per year to 17 between 1970 and 2006, the injuries have increased from an annual average of 24 injuries to 30. Both trends – declining fatality rates and rising injury rates – are indicative of the improved efficacy of the USCG Search and Rescue (SAR) operations: while the performance of the SAR operations has improved and fewer occupants of fishing vessels are perishing in the waterways, the number of injuries has not declined as rapidly; the growing exposure to hazards of fishing vessels

- Commercial passenger vessel fatalities have also increased from an average of 3 deaths between 1970 and 1999, to an average of 8 deaths between 2000 and 2006. Injuries from passenger vessel accidents have grown at an even faster rate, from 24 in the 1970-1990 period to an average of 80 in the past two decades, possibly for the same reason as in commercial fishing accidents: the success of SAR operations has reduced the number of fatalities, with the concomitant result that injuries have risen because of the rising exposure and traffic.
- Recreational boats have had the highest number of accidents and casualties. A total of 5,191 boating accidents were reported in the USCG Boating Accident Report (BAR) in 2007. These accidents resulted in 685 deaths, 3,673 injuries, and property damages amounting to \$53 million.³⁹ In absolute terms, there have been 70 fewer fatalities between 1996 and 2007, and 663 fewer injuries. The average number of accidents has also declined from a high of over 8,000 in 1996. These figures cannot be normalized reliably by the change in the estimated 13 million registered recreational boats, partly because there are millions more unregistered boats in the U.S. representing high navigational risks, most of which small boats of less than 20 feet in length.

National Security Risks

Ports are vulnerable to security threats and terrorist attacks, the consequences of which can be highly disruptive and potentially catastrophic. The international maritime domain can be characterized as one of the least governed regions left on earth. Ports are open and accessible urban facilities interwoven with a complex transportation network close to crowded metropolitan areas, an accessibility that makes ports vulnerable to a variety of threat to the vessels and cargo containers.

Marine security threats arise from the exposure to an array of risks that include:

- Vulnerability of the U.S. maritime assets in the *open seas* to threats arising from hostile nation states, non-state terrorist entities, criminals and sea pirates;
- Vulnerability of the U.S. *ports and terminals* to terrorist attacks and the closure of ports and waterways;
- Threats arising from the use of marine *cargo and vessels* when used as a conduit for hostile attacks;
- Threats arising from the hostile activities of the marine *staff and workers* operating the vessels and terminals.

Two landmark pieces of legislation enacted by Congress have had significant implications for the MTS security: the Maritime Transportation and Security Act (MTSA) and the

³⁹ The USCG statistics are based on the Boating Accident Report (BAR), required to be filed by any operator or owner of a recreational boat involved in an accident in which a person: dies, disappears (presumed dead); or is injured (requiring medial treatment beyond first aid); or there are damages of \$2000 or more; or a complete loss of a vessel.

Security and Accountability for Every Port (SAFE Port) Act. The MTSA, enacted in November 2002, amends the Merchant Marine Act of 1936 and includes the following key features:

- To address port and terminal facility vulnerabilities, the MTSA has established requirements for conducting port, facility, and vessel vulnerability assessments, and for preparation of a National Maritime Transportation Security Plan, a port wide security plan, called an Area Maritime Security Plan (AMSP), and security plans for waterfront facilities and commercial vessels,
- To address open-sea vulnerabilities to hostile threats, the MTSA has required installation and operation of Automatic Identification Systems (AIS) aboard certain commercial vessels;
- To address threats from vessels and cargo, the MTSA has required the establishment of a program to better secure international intermodal transportation systems by conducting cargo screening, tracking, physical security, and compliance monitoring;
- To address threats from activities of the workers, the MTSA has required the issuance and use of Transportation Worker Identification Credential (TWIC) cards for personnel whose responsibilities require them to access secure spaces aboard ships.

The Safe Port Act of 2006 made a number of adjustments to existing MTSA programs and created additional programs and initiatives. The Act:

- Codified the Container Security Initiative (CSI) and the Customs-Trade Partnership Against Terrorism (C-TPAT);
- Established the Domestic Nuclear Detection Office (DNDO) with responsibility for conducting research, development, testing and evaluation of radiation detection equipment;
- Established Interagency Operation Centers where agencies organize to meet the security needs of the port area at selected ports;
- Set an implementation schedule and fee restrictions for TWIC;
- Required that all containers entering high-volume U.S. ports be scanned for radiation sources by December 31, 2007;
- Required that additional data be made available to CBP for the Automated Targeting System (ATS) for targeting cargo containers for inspection;
- Required that Area Maritime Security Plans include a salvage response plan to ensure efficient and quick reestablishment of flow of commerce following a maritime transportation security incident; and
- Required periodic reassessments of the effectiveness of anti-terrorism measures in foreign ports.

Environmental Risks Arising from Vessel Emissions, Oil Spills, and Ballast Water

MTS environmental risks primarily originate from four sources: engine and equipment emissions, oil spills, contaminated dredged materials, and the invasive species transported in the vessels' ballast water.⁴⁰

- Exhaust emissions from marine vessel propulsion engines and port equipment for handling cargo represent a key MTS environmental risk. Among major sources of the nation's mobile source emissions are the *Category 3* marine engines – very large marine engines above 30 liters per cylinder capacity most commonly used to propel international containerships, tankers, bulk carriers and cruise ships – that use exclusively “residual fuel oil,” a low-grade fuel with a high degree of viscosity and high levels of sulfur oxide (SO_x) content, nitrogen oxide (NO_x) and particulate matter (PM). Over 60 percent of the estimated 8.5 billion gallons of fuel used by marine vessels operating in the U.S. coastal and inland waterways is residual fuel oil, a major contributor to SO_x, NO_x emissions and PM. Another 24 percent of the marine vessels, mostly smaller vessels or auxiliary equipment, use distillate diesel; and the remaining 16 percent, mostly recreational boats, use gasoline. Marine vessels are the second largest source of domestic freight engine emissions.⁴¹ A recent study released by the International Maritime Organization (IMO) underscored the growing contribution of marine vessels to global air pollution and rising GHG emission: emissions from international maritime transport grew by 43 percent, compared to CO₂ emissions from aviation that grew by 34 percent between 1990 and 2004.
 - Emissions from marine cargo transportation are caused not only by the engines used to power vessels but also the engines used in the land-based equipment for moving marine cargo at ports, commonly referred to as *cargo handling equipment* (CHE), i.e., yard tractors, top- and side-loaders, forklifts, and cranes. Large volumes of containers handled at the nation's largest ports requiring extensive land-side activity container handling and repositioning are responsible for the high CHE emission levels at these ports. In the San Pedro Bay ports (that include the Ports of Long Beach and Long Beach), for example, CHE emissions account for 20 percent of the ports' emissions which also rise at idling speeds.
 - The practice of “hoteling,” i.e., operating vessel engine and equipment at idling speed, is a major factor in high levels of emission at marine ports. Hoteling is a common practice used to run the main propulsion plant while the ship is at rest to provide power for the needs of the shipboard electrical

⁴⁰ There are other environmental risks which are less of an issue, including shipboard generated garbage, sewage and human waste, chemical discharge of hotel equipment such as washers, food preparation equipment, and photo developer on cruise ships, as pointed out by LCDR Ellis Moose, USCG, CG-54121, in a November 2009 report review.

⁴¹ Reported in FHWA, *Assessing the Effects of Freight Movement on Air Quality at the National and Regional Level, Final*, Report, April 2005, based on the EPA National Emission Inventory data.

and other auxiliary systems.⁴² NOx emissions per ton of fuel are nearly twice as high for low-speed diesel engines. One study of the NOx emissions from hoteling by ocean-going vessels has shown that NOx emissions were highest at the Port of Houston, accounting on average for half of the ports' emissions, followed by the Ports of LA/LB where hoteling accounted for roughly 30 percent of the vessel emissions. The Environmental Protection Agency (EPA) has predicted that by 2030, the nation's marine emissions will grow significantly if no action is taken to regulate engine emissions and fuel quality.⁴³ The contribution of ship emissions is most significant in U.S. ports and coastal areas that are subject to heavy maritime traffic. Currently more than 40 U.S. ports are located in non-attainment areas for ozone or fine particulates or both. However, the problem is not limited to port areas and varies according to the wind and weather patterns that determine how much of the vessel emissions reach land and pollute the non-port inland regions.

- Oil spills and discharge of bulk chemicals and hazardous materials represent another environmental risk of marine transportation. The USCG data show a dramatic decline in overall spill volumes since 1990, reflecting the impacts of the new regulatory requirements of the Oil Pollution Act (OPA) of 1990, the new International Convention on the Prevention of Pollution from Ships (MARPOL) oil carriage regulations, and the emerging culture of safety among the operators and state/local port authorities. Oil spill events involving more than 1,000 gallons between 1973 and 2004 followed a general downward trend. The USCG has reported that over 80 percent of the spills occurring between 1973 and 2004 were less than 100 gallons.⁴⁴
- Risks arising from the disposal of contaminated dredged materials also represent a challenge, given that dredging projects are most often located in busy ports and waterways that have been home to industrial production facilities and are therefore likely to have contaminated sediments. The USACE is responsible for the proper management, placement or disposal of all dredged materials, and is required to find alternatives that meet the substantive and procedural requirements of the National Environmental Policy Act (NEPA), the Clean Water Act (CWA), and the Marine Protection, Research, and Sanctuaries Act (MPRSA). These requirements address both clean and contaminated dredged materials, and evaluate the available alternatives for their disposal and beneficial use. Treatment of contaminated sediments can be expensive, estimated at up to \$50 per cubic yard. However, not all

⁴² LCDR Ellis Moose, CG-54121, in a November 2009 report review has noted that slow speed diesel engines cannot be used for hoteling, since their engines turn the prop when they run. Instead, most ocean-going ships hotel using shipboard auxiliary diesel generators instead of running main propulsion plants to hotel.

⁴³ The USCG has noted that the pending U.S. accession to MARPOL Annex VI could potentially impact the baseline status of vessel emissions (comments on the Draft Report by Commander Paul M. Stocklin, August 21, 2008.)

⁴⁴ LCDR Ellis Moose, CG-54121 has pointed out that these spill figures do not account for intentional illegal discharge of oily waste by bypassing oily water separators, a practice that. This occasionally occurs in the coastal zone. He has pointed out that the USDOJ environmental crimes task force, with the support of the USCG has made strides in curtailing this illegal practice by stepping up enforcement.

dredged materials are contaminated and many beneficial uses of dredged materials are available.

- Release of ballast water by marine vessels that could pollute the water and introduce invasive species (or aquatic nuisance species, or ANS) also represents environmental challenges. The rapid rate of international trade and the growing sizes of commercial marine vessels have accelerated the transport of ANS, as they ride in the ships' ballast tanks and also attach themselves as external appendages. Ocean-going ships carry water in ballast tanks for the purpose of balancing the vessel's load. A typical modern bulk carrier or tank ship can carry as much as 200,000 metric tons of ballast water, most of which is discharged in the departure port as the ship takes on its cargo. The total amount of ballast water discharged in U.S. waters each year is about 8 million metric tons. An example of the environmental damage from ballast water is the invasion of the zebra mussel in the Great Lakes, estimated to have cost approximately \$5 billion in damages to water pipes and boat hulls. While it might appear that the U.S. would be the recipient of much of the ballast water discharged in the world, the data indicate that the U.S. is a net exporter of ballast water. This is because so many ships, particularly large tankers and containerships, return overseas with full ballast tanks for balancing the weight after discharging their cargo within the U.S. waters.

Risks Arising from Growing Budgetary and Institutional Constraints

The institutional constraints on the MTS operations arise from the overarching statutory and legislative forces that determine:

- a. How MTS operations and infrastructure improvements are funded;
- b. How the existing regulatory guidelines governing MTS operations shape the nature and boundaries of domestic and international operations (vessels, routes, ports, crewing, ownership, etc.);
- c. How mariners, crew members, enforcement agencies, and other users of the marine resources are trained, and what quality of data and decision-support systems they have access to in order to achieve maritime domain awareness (MDA);
- d. How MTS agencies work together, or fail to work together, to ensure continuity of operations and system resiliency in response to emergencies.

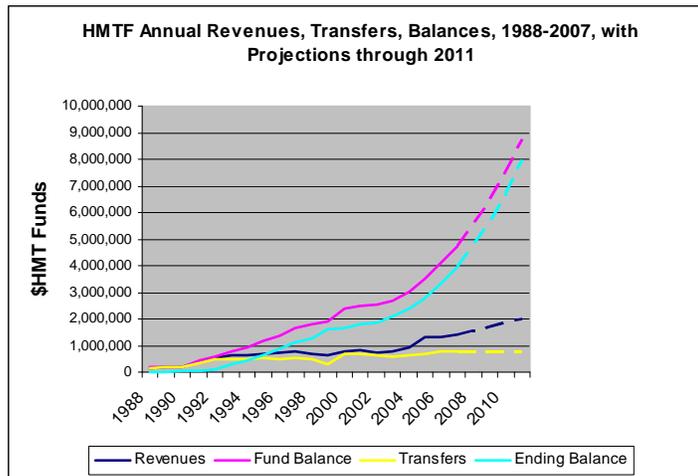
The constellation of these institutional forces influences how well the MTS functions are performed given the constraints imposed by the expressed priorities for national security, vessel safety and environmental stewardship, and the capabilities made available by access to enabling technologies for decision support, maritime domain awareness (MDA) and data sharing.

Funding shortfalls remain paramount among the MTS institutional challenges. Congress enacted the Harbor Maintenance Tax (HMT) in the 1986 Water Resources Development Act (WRDA) as a general 0.125 percent *ad valorem* tax levied on the value of all

waterborne cargo loaded or unloaded at a port. The tax is paid by the shipper or the product importer. Exports have been exempted from paying the tax. Cargo entering at ports in Alaska, Hawaii, and Puerto Rico is also exempt from the fee. For domestic shipments, the fee is levied at only one port – either the port of departure or the port of entry, but not both. The HMT is intended to pay for harbor dredging. The proceeds of the HMT go into the Harbor Maintenance Trust Fund (HMTF) and are used to reimburse the cost of maintenance dredging for federal channels, cover the costs of the St. Lawrence Seaway Development Corporation, and reimburse the Customs and Border Protection (CBP) for the costs of fee collection.

Figure 10 shows the uses and balances of the HMTF between 1988 and 2007, with projected review through 2011. In 2007, with a total of \$4.7 billion in fund balance and annual revenue of \$1.4 billion, the fund authorized expenditure of \$779 million to pay for Corps of Engineers waterway projects and \$19 million for the St. Lawrence Seaway and CBP expenses. The remaining HMTF balance of \$3.9 billion was left unused (or used to reduce the budget deficit.) Though the HMTF collections far exceed funds appropriated for harbor maintenance, many federally-managed waterway channels are under-maintained, with a significant backlog of improvement projects. A 2008 Government Accountability Office (GAO) report has underscored that the sizable HMTF surplus is inconsistent with principles of equity as well as efficiency, warning that the “misalignment between fee collection and expenditures has undermined the credibility of the HMTF.”⁴⁵ By 2011, according to the USACE *Annual Report to Congress*, the surplus will reach \$8 billion, as shown in Figure 10.⁴⁶

Figure 10 - Harbor Maintenance Trust Fund Annual Revenues, Expenditures, and Balances, 1988-2007, with Projections through 2011



Source: Volpe generated chart based on IWR, *Annual Report to Congress on the Status of the Harbor Maintenance Trust Fund for Fiscal Years 2005 and 2006*.

⁴⁵ Government Accountability Office, *Federal User Fees: Substantive Reviews Needed to Align Port-related Fees with the Programs they Support*, GAO-08-321, February 2008.

⁴⁶ GAO, February 2008, p 26.

The 1986 WRDA also authorized a fuel tax collected as part of the Inland Waterways Trust Fund (IWTF). The tax consists of a 20-cent per gallon tax levied on diesel fuel purchased by tugs and towboats operating in the inland waterways. The IWTF funds are intended for paying for half the cost of lock and dam maintenance. The other half of the cost is paid for from general revenues, to account for non-transportation benefits, including the uses of the waterways for national defense, water supply, flood control and recreation. According to the IWR officials, for the Fiscal Year 2008, IWTF had a balance of \$130.8 million. For FY09, and the preliminary balance was \$147.4 million (of which \$47.2 million has already been designated as "transfer authority" funds for the USACE – i.e., the funds are already spoken for to cover outstanding liabilities – leaving only \$100.2 million for new obligations.) The recent recession has reduced the annual revenues from the tug-barge fuel tax collection, from a normal annual collection of \$85-90 million in revenues, to less than \$80 million this current year.⁴⁷ The existing funds are not adequate for covering the maintenance costs of all the inland waterway lock sites. Only 195 lock sites out of the existing 230 sites have received maintenance funding from the IWTF.

⁴⁷ E-mail correspondence from David Grier, IWR, October 16, 2009.

Reducing the Impacts of Disruption: Building Resiliency into the MTS

Enhancing the resiliency of the MTS within the context of complex and tightly-coupled infrastructure and operating systems would require solutions that would make the assets robust, fault tolerant and smart. As one leading expert has put it, “A resilient society is one that will not fall apart in the face of adversity..... preparing for the worst makes the worst less likely to happen.”⁴⁸ The MTS *National Strategy* has described the elements for enhancing MTS resiliency as:

“Protecting MTS efficiency and resiliency requires providing ports and infrastructure with layers of operational capability, increasing target hardiness and improving the quality and capacity of the intermodal connectors that complete internal movement of the passengers and goods.” [The Strategy recommends] decreasing the physical vulnerability of these assets through new design criteria or improvements in order to mitigate the consequences of an attack or event affecting communications and critical systems, it may be possible to achieve an overall reduction in risk to the MTS.”⁴⁹

The resiliency framework developed in this study has identified the elements of a robust marine transportation system based on the principles of system adaptiveness, fault-tolerance, redundancy, and mitigative buffers that reduce severity of consequences. Together, these solutions represent the array of tools in the nation’s arsenal of *layered defense*, consisting of *detection, prevention, protection, interdiction, and response and recovery*. This assessment concludes with recommending a resiliency strategy that promotes:

- MTS *adaptiveness*, by implementing solutions that use advanced information and communications technologies and real-time intelligence and navigation data to enhance maritime domain awareness (MDA) in support of risk prevention, detection, and preparedness.
- MTS *fault-tolerance*, by implementing programs geared to adequate upgrade and maintenance of the waterways, terminals, and locks/dams/and levee systems;
- MTS *built-in redundancies*, by better utilizing the vast inland waterway infrastructure and unused terminals and promoting solutions such as expanded operations for Short-Sea Shipping (or America’s Marine Highway programs); and
- *Mitigating response and recovery* solutions that reduce the severity of events and help the system to rapidly return to normal conditions.

⁴⁸ Stephen Flynn, *The Edge of Disaster: Rebuilding A Resilient Nation*, Random House, 2007.

⁴⁹ *National Strategy for the Marine Transportation System: A Framework for Action*, July 2008.

Making MTS more Adaptive to Disruption

MTS resiliency is intrinsically linked with the system's *Maritime Domain Awareness* (MDA) achieved by manipulating the information that flows through the nation's network of critical infrastructure. The National Infrastructure Protection Plan (NIPP), developed by the Homeland Security Directive 7 (HSPD-7) as a comprehensive risk management framework to define critical infrastructure protection roles and responsibilities for the Department of Homeland Security (DHS), has identified 18 critical infrastructure and key resource (CIKR) sectors that share components and interfaces with many other critical infrastructures, most notably the nation's information technology (IT) and communications systems, dams, energy sources, intermodal highway and rail links and bridges, and emergency response (ER) services. Because of this high degree of interdependence between the MTS and other CIKRs, information sharing and interagency collaboration are critical to successful deployment of countermeasures that enhance the MTS resiliency and adaptiveness to disruption. The following examples illustrate the technology solutions that act as preventive safeguards that enable MTS operations to use information and advanced technologies to enhance MTS resilience and adaptiveness to disruption:

- Strategies to enhance the nation's MDA are at the core of the 2005 *National Strategy for Maritime Security* (NSMS). Underscoring the overarching importance of MDA for maritime safety, security, and economic viability is the NSMS characterization of MDA as the "effective understanding of anything associated with the global maritime domain that could impact the security, safety, economy or environment of the U.S."⁵⁰ The nation's MDA capability enables the USCG and other maritime decision makers to determine the appropriate response to maritime safety and security threats through collection, fusion, analysis, and dissemination of threat and vulnerability information. The strategy allows data on cargo vessels to be fused and analyzed to provide intelligence and situational awareness and reveal anomalies and behavior patterns.
- Successful applications of information and intelligence technologies for ensuring MTS safety and security have involved deployment of electronic information systems such as Automatic Identification System (AIS), Electronic Chart Display Information System (ECDIS), and real-time tides and water-level data, and preventive cargo security programs such as Non-Intrusive Inspection (NII) and Secure Border Initiative (SBI). These solutions enhance MTS resiliency by helping safety and security officers to detect and control threats and vulnerabilities before they are realized.
- The MTS National Strategy has proposed strategies for promoting real-time navigation information through systems such as Physical Oceanographic Real Time Systems (PORTS), e-navigation, under keel clearance, High Frequency Radar (HFR), air gap technology, Real-Time Current Velocity systems at locks, and systems associated with development of the Integrated Ocean Observing System (IOOS). The strategy has proposed coordinating

⁵⁰ *National Infrastructure Protection Plan*, 2006.

Federal navigation programs to reduce duplication and standardize data elements and configurations.

Examples of successful deployment of adaptive technology solutions include:

- The SmartLock system, used for improving the performance of the nation's locks and dams and reducing operating costs, is a navigation, networking and communication system that establishes links between the tow and the lock and gives the pilot of the tow greater knowledge as to the position of the tow relative to the lock. Developed by the Carnegie Mellon University based on the same principles used for the air traffic control system, the SmartLock prototype system allows towing vessel operators to speed the locking process during periods of low-visibility and adverse weather conditions, thus improving the safety and efficiency of the lock system.⁵¹
- The LoadMax system, a technology that has proven effective in facilitating domestic cargo movements on the inland waterways, is a water-level forecasting tool that helps river pilots and captains to determine optimal departure times and vessel speeds to take advantage of tides and high water levels to allow the vessels to be loaded to the maximum draft capacity.
- The Virtual Container Yard, a truck scheduling and dispatching system designed to relieve port area congestion and the handling of empty-containers, allows truckers to locate empty cargo containers close to the site where they have an export pickup rather than make an unnecessary trip to a port terminal where empties are typically stored. The system addresses the problem of empty containers resulting from trade imbalance by alleviating the need for truckers to return an empty container to the port. The system is based on the underlying notion of a computerized "clearinghouse" or "bulletin board" for information on the status and availability of containers at marine terminals. The functions performed include: posting of container status information, communication between parties, equipment exchange, supply chain decisions about container transloading and decision on the need for value-added functions on the contents of the container.⁵² Virtual Container Yard has its precedent in the port wide truck appointment system developed several years ago at the Port Authority New York/New Jersey as part of a successful initiative to deploy the Internet Portal FIRST to improve trucking efficiency and turn times.

⁵¹ Ron DeParma, New Technology could Help Boats Navigate Thick Fog, Pittsburgh Tribune-Review, October 5, 2005

⁵² The Tioga Group, Empty Ocean Container Logistics Study, May 8, 2002.

Making MTS More Fault-Tolerant by Promoting Robust Design-Based Capabilities

Fault-tolerance and robustness of the MTS infrastructure can be enhanced by promoting design and maintenance strategies that harden the physical infrastructure through a layered system of safeguards and provide adequate funding for facility maintenance. As a component of the MTS *layered defense-in-depth*, these capabilities help promote solutions that have protective as well as preventive benefits, as they harden the infrastructure and prevent cascading effects of deteriorating structures.

Support a Dedicated Use of the HMTF for Modernizing the Waterway System

Currently the HMTF shows a surplus of over \$3 billion that is being used for reducing the Federal budget deficits. Promoting a dedicated use of the fund balance for maintenance and dredging of the inland waterways would be a positive step towards improving the MTS structural hardiness and operational efficiency. With the backlog of improvement projects, and a large segment of the Federally-managed waterway channels, locks/dams and levees and bridges subject to delayed maintenance, promoting a more efficient use of the funds would be conducive to greater financial accountability and avoidance of what the National Academy of Sciences (NAS) has called a “downward spiral” precipitated by “lack of system preservation,” as noted above.

Support Design and Construction of a Fleet of Small Self-Propelled Jones Act Feeder Vessels

The higher cost of deploying U.S.-built self-propelled vessels has been an obstacle to the development of an efficient domestic container feeding service. Current regulatory requirements for the construction and use of Jones Act fleets have created an excessive reliance on barge-tow and articulated tug-barge (ATB) vessels for domestic shipping and prevented the expansion of a fleet of medium-speed small ships that could effectively compete in the domestic freight markets.⁵³ The Jones Act fleet is predominantly tugs and barges, partly because of their lower construction cost and partly because they do not require the crew sizes mandated for self-propelled ships. Increasing the fleet of higher-speed self-propelled vessels and reconsidering USCG manning requirements would be important steps towards closing the gap in the inventory of self-propelled feeder vessels.

To reduce excessive reliance on the barge-tow and ATB vessels and expand the fleet of medium-speed small ships will require an optimal average speed that would enable these ships to effectively compete in the freight markets. Industry analysts have maintained that the speed of such ships would not need to be as fast as 25 or 30 knots per hour, as some high-speed ship designs have suggested. A speed range of 18- to 20-knots would be adequate for competing.⁵⁴ A self-propelled ship with the speed of 15 knots would be

⁵³ IHS Global Insight, Inc., *An Evaluation of Maritime Policy in Meeting the Commercial and Security Needs of the United States*, prepared for the USDOT, MARAD, January 7, 2009.

⁵⁴ Lombardo, Gary A., Robert F. Mulligan, and Change Q. Guan, U.S. *Short Sea Shipping: Prospects and Opportunities*, U.S. Merchant Marine Academy, prepared for Short Sea Shipping Cooperative (SCOOP), November 1, 2004.

adequate for meeting the speed requirements for moving a domestic cargo container on short-haul lanes. As one industry expert has put it, a medium speed ship moving at 15 knots could deliver the same container 500 miles away in about 1.5 days (less than 34 hours) considering that an average truck that is subject to the HOS rules drives 500 miles per day. The design of these self-propelled vessels could incorporate some of the features of ATBs to capture benefits from lower crewing requirements, while their small size would also enable them to match the crew size advantages of ABTs.⁵⁵ Another study conducted by the Institute for Global Studies concluded that the current inventory of tug-barge vessels represents a class of service vessels too slow to compete effectively for capturing a significant share of existing road and rail traffic. The research team suggested that support for construction of higher speed ships, perhaps in the 20-knot range, would be effective in promoting SSS for a broader range of cargo and would close the existing gap in the small medium-speed vessels with low operating costs.⁵⁶

Making Title XI grants available for construction of self-propelled Jones Act vessels for domestic cargo shipment would be the first step in the process of promoting short sea shipping. Once the early design and performance elements of a prototype medium speed self-propelled vessel are identified, it is likely that the future construction costs will be lower. Market surveys have suggested that there is a large enough market demand for self-propelled vessels to generate economies of scale in their production, significantly reducing future construction costs. As the scale of production for these vessels grows, the need for Title XI grants is likely to decline. Among candidate vessels for serving the feeder markets would be roll-on/roll-off (RoRo) or lift-on/lift-off (LoLo) vessels that could successfully serve truck competitive SSS markets. Cost savings from deployment of RoRo vessels are often significant because they avoid terminal handling costs that could potentially increase the required freight rate by as much as 20 percent. Because they have less need for loading and offloading equipment, RoRo vessels are likely to have faster port turnaround times and attract a larger segment of the higher-price containerized cargo market.⁵⁷

Making MTS more Resilient by Promoting Built-in Redundancy

The vast, underutilized segments of the MTS infrastructure and assets offer opportunities for enhanced resiliency of the critical infrastructure by offering layers of system redundancy for cargo and passenger transportation.

Promote Short Sea Shipping

Reducing the impact of regulatory rigidities as well as market conditions that have stifled the growth of domestic markets for marine transportation would be a positive step towards

⁵⁵ Comments of Mr. John Bobb, USCG, Chief, Oceans & Transportation Branch, Office of Waterways Management, Journal of Commerce Conference on Marine Highways, Jacksonville, Florida, April 1-2, 2009. Mr. Bobb suggested that the best way to meet this need would be to have a competitive grants process for design of a small ship.

⁵⁶ Institute for Global Maritime Studies, *America's Deep Blue Highway: How Coastal Shipping Could Reduce Traffic Congestion, Lower Pollution, and Bolster National Security*, September 2008.

⁵⁷ Lombardo, Gary A., Robert F. Mulligan, and Change Q. Guan, *Short Sea Shipping: Prospects and Opportunities*, U.S. Merchant Marine Academy, prepared for Short Sea Shipping Cooperative (SCOOP), November 1, 2004.

promoting a more efficient domestic shipping industry. Currently there is no viable feeder port system in the U.S. operating within a well-integrated, interconnected network, partly because of the higher costs of deploying U.S.-built self-propelled vessels for domestic feeding service. The U.S. Marine shipping “feeder” system (defined as the practice of using smaller self-propelled ships for local or coastal transport to carry bulk cargo or containers to and from ports not scheduled to be called by the ocean vessels serving international trade, and to connect smaller ports to major ocean ports)⁵⁸ needs major overhaul and improvement. Low freight volume is a major obstacle to the growth of domestic shipping because it prevents carriers from achieving scale economies. Once economies of scale are achieved and this obstacle is overcome, domestic cost disadvantages relating to high vessel construction costs could prove relatively insignificant.

Other obstacles that may detract from opportunities to gain market share include lack of access to medium-speed self-propelled vessels (as described above), and the long-ingrained shipper expectation of unreliable service. Overcoming these obstacles, together with strategic alliances with truck and rail carriers, are essential for SSS operations to be successful, as emphasized in a U.S. Merchant Marine Academy study.⁵⁹

Promoting a pricing mechanism that incorporates the full range of external and internal costs of moving a load of cargo would help expand the markets for short sea shipping. The external costs of moving a container by truck about 200 miles on the interstate highway system from Boston to New York, for instance, would generate \$131 per trip in unpaid-for external costs in addition to the \$500 paid for by the shipper. These external costs represent the additional costs of highway congestion, air and noise pollution, accidents, and infrastructure maintenance costs not paid for through fees, tolls, gasoline taxes, excise taxes and heavy truck user fees. To bolster the environmentally friendly features of SSS, pricing policies should be pursued to take advantage of fuel efficient marine propulsion systems with lower emissions. One approach to closing the cost differential between the highway and SSS operations would be through a rebate or subsidy program. Marine operators may be compensated with a rebate equivalent to the lower external costs of moving cargo by water. Large volume-thresholds for water shipments and higher diesel prices would also reduce the cost differential between road and water for moving a container. Diesel prices above \$3 or \$4 per gallon, for instance, tend to shift the balance in favor of the more efficient tug-barge operations. The Virginia Port Authority manager of the James River Norfolk-Richmond Feeder Barge Service, for instance, found that moving a container on the Norfolk to Richmond lane is cheaper by truck when oil prices are low. The program at first proved viable when diesel prices were at \$4 per gallon, but after oil prices began to drop the barge service was no longer viable. However, reaching adequate volume commitments that would allow short sea carriers to achieve economies of scale would reduce the need for a subsidy and enable the East Coast marine operators to run a

⁵⁸ P&O Nedlloyd 2005, quoted in Yonge, 2007

⁵⁹ Lombardo, Gary A., Robert F. Mulligan, and Change Q. Guan, *Short Sea Shipping: Prospects and Opportunities*, U.S. Merchant Marine Academy, prepared for Short Sea Shipping Cooperative (SCOOP), November 1, 2004.

potentially profitable and sustainable feeder service to smaller ports between New York, Savannah, and Jacksonville.⁶⁰

As part of its strategy to expand capacity, the MTS National Strategy has proposed the expansion of short sea shipping through the establishment of a pilot program to designate Marine Highway Corridors to use the waterways to relieve congestion on roadways. Lessons-learned from the European Union (EU) would also offer some valuable lessons. EU's Marco Polo Freight Transport Program, for instance, is a publicly funded initiative undertaken "to shift or avoid" a substantial part of the expected increase in international freight traffic from roads to coastal short-sea shipping, rail, and inland waterway transport. The program, first launched in 2003, is currently embarking on its second funding initiative. It provides a subsidy of €2 per 500 ton-kilometers shifted off the road, subject to conditions of viability and sustainability after receiving the five-year grants. Types of programs that qualify applicants to receive the Marco Polo grant funds include actions that cause a modal shift, are catalyst for overcoming structural barriers in the market, or improve cooperative ventures for better use of the transport network.⁶¹

Exempt Domestic Cargo from Double Payment of HMT

The requirement for the shippers to pay the HMT for the domestic leg of a container movement on the coastal or inland waterways has been a major obstacle to expansion of domestic short-sea-shipping. HMT is first applied to containers arriving at the initial U.S. port from overseas, and then again when they arrive at the final destination port by transshipment. This double taxation of short-sea moves restricts the ability of these carriers to expand their services and puts them at a significant disadvantage when competing against trucking carriers. As such, the HMT represents an additional cost to domestic short-sea shippers that is not borne by their over-the-road counterparts.

Maritime industry stakeholders have maintained that HMT may not be the best method of financing waterway improvements and that domestic container shipments should be exempted from the tax payment. Current efforts in support of the exemption include H.R. 3319 to amend the IRS code to exempt domestic intermodal cargo containers from the HMT.⁶² The American Association of Port Authorities (AAPA) has drafted several position papers and supported legislative initiatives in support of the waiver, maintaining that only a small fraction of the HMT collection on domestic shipments comes from the intermodal cargo. In its advocacy for the removal of the HMT, AAPA has argued that domestic cargo accounts for only 4.3 percent of the annual HMT revenues, and that its exemption would have negligible effects on the HMT revenues.⁶³ Other advocates of

⁶⁰ Statement of Russell Held, Virginia Port Authority, at the Journal of Commerce Conference on Marine Highways, Jacksonville, FL, April 1-2, 2009.

⁶¹ Appendix G of this Summary Report provides a detailed study conducted by the Volpe Center on Short Sea Shipping in the U.S., with an analysis of best practices in Europe.

⁶² LCDR Ellis Moose, USCG, has noted that there is some congressional concern that this strategy will trigger international objections under trade laws, and that for this reason Congress is more in favor of tax credits than tax exemptions.

⁶³ The American Association of Port Authorities, The Harbor Maintenance Tax and Congestion Relief (v.9.1.05) http://aapa.cms-plus.com/files/PDFs/HMT_Coastwise_Paper_01Sept05.pdf

exempting domestic cargo containers from the HMT have maintained that the waiver would most likely be revenue-neutral for the region, as any foregone tax revenue would be offset by funds saved in highway construction and repair as truck trailers are removed from the highway.⁶⁴ Another argument in support of removing the HMT for domestic short sea transport is that many segments of the short sea service operate shallow draft vessels that do not require deep channels. Further lending support to the argument in favor of exempting domestic moves of import containers from paying the HMT is a study by the University of New Orleans estimating that shifting domestic movements of containers from highways to waterways would translate to significant benefits in savings in highway infrastructure maintenance costs and external costs of traffic congestion and air pollution, in magnitudes far greater than losses incurred from the HMT waiver.⁶⁵

Support Efficient Utilization of Small Ports and Inland Port Networks

The nation's vast inland waterway system is not integrated with the nation's intermodal freight system. In a 2005 feasibility study prepared by the University of Virginia the study team explored alternative means for augmenting transportation capacity and the Inland Waterways Intermodal Transportation System to alleviate capacity shortfalls and highway congestion. The report noted that the Inland River Container Services are underutilized resources because they are not fully integrated with the intermodal system, thus depriving the nation of the potential benefits of a low-cost and efficient transportation mode.⁶⁶

Best practices involving the construction of inland container handling centers in locations away from congested international ports have proven the strategy to be effective for expanding capacity and reducing congestion by better utilization of the vast network of terminals and deepwater facilities. Efforts for development of Port Inland Distribution Networks (PIDN) for a hub & spoke system of container transfer corridors for rail and barge operations have been underway in several corridors with varying degrees of success. The potential benefits would include greater port throughput, reduced highway truck traffic and terminal dwell times, lower container transfer costs, and reduced emissions. A well integrated network of small ports and PIDN could effectively utilize the vast MTS waterway facilities and the large number of underutilized secondary deep-water terminals and unused terminals. There are approximately 55 ports that handle more than 10 million tons annually and have channel depths over 40 feet. As previously noted, the top 10 ports in the U.S. handle close to 80 percent of the container traffic, while the top 30 ports account for about 99 percent of all container traffic. By pursuing policies and tax incentives that promote the use of smaller terminals in less congested ports or underserved regions and intermodal corridors, and by revamping the infrastructure and operating capabilities of the unused inland facilities, the MTS infrastructure resilience will be significantly improved.

⁶⁴ Reeves & Associates, "Analysis of the Potential Market for Short-Sea Shipping Services over the Ports of Fall River and New Bedford," March 29, 2006.

⁶⁵ University of New Orleans: National Ports and Waterways Institute, *Short-Sea Vessel Service and Harbor Maintenance Tax*, October 2005.

⁶⁶ "Inland Waterways Intermodal Transportation System Design and Feasibility Analysis" prepared by the University of Virginia for MARAD in May 2005.

ACRONYMS

AAPA	American Association of Port Authorities
AASHTO	American Association of State Highway and Transportation Officials
AIS	Automatic Identification System
CI/KR	Critical Infrastructure Key Resource
CMTS	Committee on the Maritime Transportation System
COB	Container on Barge
DHS	Department of Homeland Security
DOE	Department of Energy
DWT	Deadweight
ECDIS	Electronic Chart Display and Information System
EIA	Environmental Impact Analysis
ENC	Electronic Navigation Chart
EPA	Environmental Protection Agency
FHWA	Federal Highway Administration
GDP	Gross Domestic Product
GPS	Global Positioning System
HMT	Harbor Maintenance Tax
HMTF	Harbor Maintenance Trust Fund
IAT	Integrated Action Team
ICMTS	Interagency Committee for the Maritime Transportation System
IRCS	Inland River Container Services
IWR	Institute for Water Resources
IWTF	Inland Waterway Trust Fund
LA/LB	Ports of Los Angeles/Long Beach
MARAD	Maritime Administration
MDA	Maritime Domain Awareness
MTSNAC	MTS National Advisory Council
MTS	Maritime Transportation System

NCHRP	National Cooperative Highway Research Program
NDNS	National Dredging Needs Study
NHS	National Highway System
NIPP	National Infrastructure Protection Plan
NOAA	National Oceanic and Atmospheric Administration
MTSA	Maritime Transportation Security Act of 2002
NRC	National Research Council
PANY/NJ	Port Authority New York/New Jersey
RFID	Radio Frequency Identification
SCOOP	Short Sea Shipping Cooperative Program
SOW	Scope of Work
SSS	Short Sea Shipping
TEU	Twenty Foot Equivalent
TRB	Transportation Research Board
ULCC	Ultra Large Crude Carriers
USACE	United States Army Corps of Engineers
USCG	United States Coast Guard
USDA	United States Department of Agriculture
USDOD	United States Department of Defense
USDOT	United States Department of Transportation
WRDA	Water Resources Development Act

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Appendix A

Assessment of the Marine Transportation System (MTS) Challenges

Task 1: Assessment of Infrastructure Challenges

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Preface

This report is the revised Task 1 deliverable for the Volpe Center Reimbursable Agreement (RA) VH-99 with the United States Army Corpse of Engineers (USACE). The report has been prepared by Dr. Bahar Barami, the Volpe Center project manager, and revised to reflect the comments and inputs received from the project sponsors and members of the Marine Transportation System (MTS) Needs Assessment Integrated Action Team (IAT), including the following comments received from: the IAT Working Group on February 28, 2008; William Aird, on April 23, 2008; Eric Wolfe, on June 4, 2009; Kathleen Bailey, Environmental Protection Agency (EPA), on October 13, 2009; Captain David McFarland, National Oceanic and Atmospheric Administration (NOAA), on October 14, 2009; and Richard Lolich, MARAD on November 20, 2009. The project manager is grateful to the following Volpe colleagues for editorial support and peer-review comments: Mike Dyer, Paul Zebe, Sarah Abdelkader, Dr. Marc Mandler, and Rodney Cook.

Executive Summary

MTS Background

In September 2004, the Congressionally-established U.S. Commission on Ocean Policy, pursuant to its legislative mandate from the Oceans Act of 2000, released its report entitled, “A Ocean Blueprint for the 21st Century”. In December 2004, in response to the recommendations of the Ocean Blueprint, the President’s Ocean Action Plan was issued, directing the elevation of the Interagency Committee for the Marine Transportation System (ICMTS) to a cabinet-level committee chaired by the Department of Transportation (DOT) Secretary. On July 11, 2005, acting upon this recommendation, the Committee on the Marine Transportation System (CMTS) was established as a Federal interagency committee with the mission to improve the U.S. MTS.

The CMTS has endorsed the creation of a number of Integrated Action Teams (IATs), including the National Strategy and Needs Assessment IATs:

✚ The National Strategy IAT released its *National Strategy for the MTS: A Framework for Action*, in July 2008. The National Strategy presented a policy framework for addressing the most pressing challenges to the MTS in five priority areas: capacity, safety and security, environmental stewardship, resilience and reliability, and financing and economics. It identified five principal MTS components: navigable waterways, ports, intermodal connections, vessels, and users (commercial, military, and recreational); and emphasized the vital importance to the nation of the MTS preparedness to perform three key functions: commerce, recreation, and national defense. Among the priority action areas endorsed by the National Strategy are:

- encouraging the expansion of short-sea shipping (SSS);
- sharing best practices and creating incentives for private sector infrastructure investment to improve operations;
- facilitating standardized terminologies, analytical tools, and flow-through models to foster increased productivity; and
- developing performance measures to assess the productivity of the MTS and the risk of potential infrastructure failure.

✚ The Needs Assessment IAT, which this study is prepared for, was formed to conduct an overall assessment of the state of the MTS. At the initial July 2005 CMTS meeting, the members articulated the need for the assessment as a high-priority requirement, recommending that a comprehensive analysis be conducted to assess “current state and the future needs of each Federal and non-Federal component modes of the MTS.” The initial scope of work (SOW), drafted by the Needs Assessment IAT in July 2006, had specified that an assessment of the full scope of the MTS condition be conducted, including an analysis of the system’s operational and infrastructure requirements, identification of the gaps and potential solutions, and a set of recommendations to be presented as part of a Report to Congress. The cost of this assessment was estimated at

Study Scope

This study represents a scaled-down, yet quite extensive, scope of the MTS Needs Assessment. The study is intended to support the CMTS goal of targeting the most critical “actionable” elements of the MTS. The study will conduct a baseline assessment of the current state of the MTS and the associated challenges by preparing six task reports on the MTS infrastructure, economic, environmental, safety, security, and institutional challenges. This is done within a risk assessment and resiliency framework that analyzes the present and projected threats to the continued performance of the infrastructure, identifies system vulnerabilities and consequences of a disruption in the system operations, and characterizes the intrinsic system attributes, built-in fault-tolerance and redundancies that could potentially enhance system resiliency.

This study’s approach to the assessment of infrastructure attributes is based on a standard risk assessment methodology. The study constructed a risk and resiliency assessment framework for each infrastructure component and operations, using available facility condition findings and trend statistics for maritime infrastructure maintenance. The intent has been to construct a high-level risk and reliability analysis framework to be tested as a proof-of-concept for the resiliency framework in this and future task reports, and be used for implementation of the National Strategy goals. The purpose has not been to conduct a formal risk and vulnerability assessment; nor has it been to conduct a condition assessment.

Risk Assessment Framework

This study conducted a high-level baseline assessment of the MTS risk and resiliency status by asking the following three questions: *What can go wrong? What is the likelihood that it would go wrong? What are the consequences?* For answers to these questions, this study identifies the risks facing the MTS infrastructure risks within a framework that establishes relationships between the prevailing threats, the likelihood that these threats will be realized and lead to operational disruptions, and the severity of consequences.

Within this threat assessment framework, the probabilistic occurrence of adverse events is calculated. These events include disruptions related to the aging infrastructure and delayed maintenance, inadequate capacity, unintended incidents, spill, collisions, and natural disasters, and intentional threats, labor strikes, military deployments and acts of terrorism. The framework further breaks down the threats as a product of *exposure* to sources of threat, and the present *vulnerabilities*, i.e., the intrinsic properties of the MTS infrastructure that point to weaknesses that can be exploited and lead to a system failure, including absence of safeguards to prevent disruption or mitigate systemic failures.

Assessment of the potential magnitude of the consequences and impacts, given the likelihood of a high impact event occurring, is based on calculating the probability of loss of life and injuries; the extent of economic losses from a disruption; potential for cascading

chain effects; potential for national security breaches; and the potential for adverse environmental impacts.

The high-level infrastructure risk assessment model created in this study was constructed on the following premises:

- The *objective functions* are to maximize waterway and landside capacity, throughput and efficiency, and minimize operational and maintenance/upkeep costs, and the safety, security, and environmental risks.
- The *state variables* include the MTS characteristics: size, condition, and dimensions; traffic and trade volumes; vessel activities; and available technologies.
- The relevant *constraints* include channel depth, landside physical boundaries, funding limitations, required commercial service levels/performance, availability of land, legacy assets and equipment, and regulatory requirements.
- The relevant *decision variables* include planned facility improvement projects, technology deployment initiatives, and enforcement and implementation of security/safety/environmental programs and regulations.
- Incorporating in the framework the effects of *random variables* such as the frequency and magnitude of marine accidents and spills, weather-related disruptions and climate change issues, natural hazards, labor strikes, military deployments, terrorist actions, equipment reliability, and also *exogenous variables* such as the emergence of new international trading routes and partners, global economic fluctuations, and the existing and anticipated location of consumer markets.¹

Resiliency Assessment Framework

The resiliency of the system is estimated as the presence of system redundancies, infrastructure hardiness and fault tolerance, and available countermeasures that reduce the inherent infrastructure vulnerabilities and mitigate the consequences of a disruption. Potential countermeasures evaluated for enhancing system resiliency could be preventive or mitigative in nature: the *preventive measures* include technological and operational safeguards that lessen the likelihood of the threats being realized and reduce the identified vulnerabilities, these include design-based safeguards, built-in structural redundancies, engineered robustness and target hardening, design elements to enhance fault tolerance, and incident prevention and deterrence components. The *mitigative response strategies* include measures for alleviating the damages and reducing severity of the impacts and

¹ EPA's Kathleen Bailey has noted that the MTS also needs to reduce its carbon footprint, and that there is growing evidence of rise in sea level and more severe and frequent storms; referencing the following EPA document: "Planning for Climate Change Impacts at U.S. Ports," EPA, <http://www.epa.gov/sectors/ports>

consequences. These strategies may be part of the National Strategy for Maritime Security and its eight supporting plans to include the Maritime Infrastructure Recovery Plan.

Harbor Channel Components of the Navigable Waterways

The components of the approximately 25,000 miles of commercially-navigable U.S. waterway channel system include some 6,500 commercially-active coastal and Gulf terminals, 2,300 inland river terminals, and 750 Great Lakes terminals (consisting of a total of 5,066 deepwater, and 4,518 shallow-water terminals.) Only 12,000 miles of the 25,000 have depths of 9 feet or more (to make them commercially competitive with railroads.)² There are about 300 deepwater ports that handle any significant volume of trade, about half of which are “selected” ports that handle traffic volumes of more than 1,000,000 tons of cargo annually. Among “selected” ports are approximately 55 that handle more than 10,000,000 tons annually, and have a channel depth of over 40 feet. The top 30 ports handle approximately 98 percent of all freight.

Vulnerabilities that contribute to the likelihood of a disruption in the navigable waterways include the growing gap between the existing channel depths and draft requirements of the vessels using the waterways. As the size of vessels serving the U.S. ports has grown, the U.S. waterways have not kept up with the dredging needs to maintain the required depth. Most of the new containerships calling at U.S. ports require channel depths of over 45 feet. In the past two decades, the depth requirement for new vessels has grown from 39 feet in 1984, to about 48 feet. Only a handful of ports today have the required channel depth needed to serve these ever larger modern vessels. These ports include Ports of Los Angeles/Long Beach (LA/LB), Seattle and Tacoma, Baltimore, Norfolk, Oakland, and Savannah. Because of inadequate channel size, many of the highly-used U.S. harbor channels today are available only a fraction of the time.

The number of “constrained calls” is also growing, as the number of cases in which a vessel’s design draft plus a safety clearance exceeds channel depth restrictions has increased. The May 2003 National Dredging Needs Study (NDNS) report concluded that without the planned channel improvement projects, the total number of “constrained calls” by 2020 would be about 25 percent of the total vessel calls. The February 2008 National Strategy report states that this estimate still remains valid.

The consequences of a major disruption in the navigable channels – whether caused by the growing number of constrained calls due to inadequate channel depth, a major accident, or unavailability of harbor facilities on a full-time basis – include the economic costs of traffic delays and suboptimal shipping schedules as well as the potential loss of life, injuries, and environmental disasters. In a recent analysis conducted by the CMTS showed that as a result of inadequate funding to maintain the most highly used Federal navigation channels a key segment of these channels (referred to as the center channel or half-width of the channels) is available only 35 percent of the time. The report emphasized the potential threats to navigation safety from “light-loading” or “lightering.”

² Mr. Eric Wolfe has pointed out that though the Federal law defines deep-draft as 9 feet, many deep draft channels that are limited to 7 feet.

The factors that could contribute to the resiliency of the navigable waterways include the large number of deepwater terminals available in all regions of the U.S. Only a handful (roughly 150 terminals) of the approximately 5,000 deepwater (those with depths of 12 feet or greater) MTS facilities handle any noteworthy volume of commercial traffic; given that the top 10 ports handle 90 percent of the container trade volume.³ This vast underutilized deepwater infrastructure can potentially serve as backup resources to enable system operators to respond effectively to disruptions caused by natural or man-made threats or capacity constraint by diverting traffic to less congested facilities. There are also available navigation tools that could increase the resiliency of the navigable waterways, among them technologies such as LoadMax, a water-level forecasting tool developed for the Columbia River ports to maximize cargo lifts on ocean freighters without deepening the channel. The LoadMax tool helps pilots and captains set departure times and vessel speeds to take advantage of tides and fresh water flows, allowing the vessels to be loaded to the maximum depth allowed for a safe vessel transit.

Locks and Dam Components of the Navigable Waterways

Approximately 12,000 miles of the inland and intracoastal waterways are made navigable by roughly 200 commercially-active locks and dams that are maintained by the USACE. More than half of these locks are over 50 years old and have exceeded their design lives. There are also some 2,000 Federal levee units maintained by the USACE.

Threats to the viability of the lock/dam/levee system are unavailability of the lock system, and risks associated with dam and levee failure. System vulnerabilities that place the viability of the MTS waterway system at risk are aging locks with inadequate funding for maintaining them, under-maintained dams and levees, and inadequate lock size for accommodating modern shipping vessels.

Economic consequences of lock queues and bottlenecks caused by undersized locks or lock closure have been significant, as they have raised operating costs and transit times for the users. The time costs of lock queues and bottlenecks have been estimated at \$385 million in added operating costs due to over 550,000 hours of delay annually. Navigation delays from lock unavailability and lock closures have grown between 1992 and 2005, from approximately 30,000 hours in 1992, to 110,000 hours, with nearly half of the closures due to unscheduled lock downtimes.

Consequences of safety risks due to dam and levee failure may also be significant. According to a recent study by the Urban Land Institute, engineers have identified 3,500 unsafe dams in the U.S., and not enough funding has been available for repairing them. For the Federally maintained levee system, the consequences of levee failure due to poor maintenance are also potentially catastrophic. According to a February 2007 USACE report, there are some 121 levee units, out of the 2,000 levee units inspected by the agency that are in “unacceptable” condition. Another potentially adverse consequence of inadequate funding for maintenance is the downward spiral generated by deferred maintenance operations that have the potential to lead to far greater future rehabilitation costs.

³ The US Army corps of engineers has defined deep water at 15 or more feet.

A potentially effective countermeasure for enhancing the resiliency of the lock and dam system is the Carnegie Mellon University SmartLock navigation and communications system that establishes links between the tow and the lock, giving the pilot of the tow greater knowledge as to the position of the tow relative to the lock, and allowing a steady locking speed during periods of low-visibility and adverse conditions. Deployment of advanced technologies such as automatic identification system (AIS), vessel traffic services (VTS), and Electronic Chart and Display Information System (ECDIS) are also among proven measures for improving the operational safety and efficiency of the tow and barge systems used on the navigable waterways.

Ports

The nation's international trade ports are characterized by a growing concentration of container and bulk-product import trade in a few large ports. Of the 150 "selected" deepwater (defined as depths of 9 feet to 15 feet) ports, ten account for the predominant majority of export and import activities and have been growing in their share of trade volumes. Fifteen are commercial strategic ports that may be used for military surge deployments. In 2008, the top 10 U.S. container ports accounted for over 90 percent of the U.S. international containerized trade, up from 78 percent in 1995. The top five container ports (ports of LA/LB, New York, Seattle/ Tacoma, Savannah and Charleston) accounted for 57 percent of containership capacity. The top 10 ports (which in addition include Norfolk, Oakland, Houston, Miami, and Port Everglades) accounted for 78 percent of containership capacity; and the nation's top 25 container ports accounted for 98.9 percent of all containership capacity.

Among the events that can go wrong at the nation's container ports are operational disruptions due to capacity constraints and congestion-related delays. The vulnerabilities at the U.S. container ports that could increase the probability that the potential threats to port operations may be from: a) inability to close the growing gap between vessel draft needs and the ports' existing channel capacity; and b) landside and harbor-side congestion caused by the high concentration of traffic at a handful of ports.⁴

The consequences of the realization of the potential threats to the nation's ports include: a) loss of trade revenues and the attendant costs and operational disruptions arising from shipper/carrier uncertainty about reliability of the service; and b) loss of excess capacity and the attendant narrowing of the operational margin of error for the vessel carrier. A recent Congressional Budget Office (CBO) study estimated the economic costs of port disruptions by examining two impact scenarios: a 1-week shutdown and a 3-year shutdown of operations at the Ports of Los Angeles and Long Beach. The one-week shutdown was estimated to lead to losses between \$65 million and \$150 million per day, with an estimated loss of \$450 million for an average week of shutdown. The 3-year shutdown was estimated to lead to greater losses, estimated to amount between 0.35 percent and 0.55 percent of GDP, equivalent of a loss of \$45-\$70 billion per year.

⁴ Mr. Eric Wolfe, NOAA has commented that threats arising from surface transportation issues, user fees, vehicle emission limits, and cabotage laws are also relevant constraints.

Another consequence of the rising congestion and infrastructure maintenance costs has been the growing uncertainty about the reliability of the nation's large container ports. One outcome of this uncertainty has been the decision of some shippers and carriers to change their cargo distribution channels and practices to limit the impacts of port/terminal capacity problems or waterway closure. These practices have included shipper/carrier efforts to incorporate redundancy (e.g., building multiple cargo transfer facilities and "import distribution centers" and making additional vessel calls) in their supply chains and vessel rotation to ensure shipment reliability.

Loss of excess capacity is yet another adverse consequence of the rapid growth of the U.S. container trade, which can potentially have a cascading effect by further exposing the ports to threats of disruption by narrowing the ports' operational margin of error and flexibility, and reducing their ability to resume normal operations. By one estimate, terminal excess capacity at the U.S. marine terminals will disappear by 2011. This projected loss of container ports' unused capacity represents a looming vulnerability, which will reduce the waterway system resiliency and its ability to return to normal operating conditions after disruptions in shipping operations. Short or no notice military surge deployments can also disrupt normal port, intermodal and shipping operations. In addition, some ports are hampered by periods of environmental constraint such as long periods of reduced visibility from fog, storms, and high winds.

Expanding the MTS container handling capacity through better utilization of the existing deepwater ports that are not part of the top 5-10 container ports would be an effective countermeasure and pivotal to the nation's ability to be resilient in the event of container port capacity shortfalls and service disruptions.

Intermodal Connections

MTS-related intermodal connectors identified in the National Highway System (NHS) include 1,400 connectors to freight terminals, ocean and river ports, rail and pipeline terminals, and passengers and ferry terminals. Also included in the intermodal connectors are the bridges connecting the various land and water components of the MTS infrastructure.

A key threat to the viability of MTS facilities is disruption in operations due to faulty or overloaded connectors. The system vulnerabilities that increase the probability that the threats would be realized are the weaknesses that stem from: a) missing or overloaded port access links; b) structurally deficient bridges; and c) congestion induced by inadequate capacity on key access links. Connectors to marine port facilities have been found to have twice the percentage of mileage with pavement deficiencies compared to other facilities. A National Cooperative Highway Research Program (NCHRP) study found 15 percent of the intermodal connectors at ocean/river port terminals was deemed "poor" or "very poor." Structurally deficient bridges also represent a significant MTS vulnerability. According to the National Bridge Inventory (NBI), in 2007, 72,264 (12 percent) of the nation's 600,000 bridges were "structurally deficient," and another 81,257 (14 percent) were "functionally obsolete." Another aspect of functional obsolescence is the inability of the new larger and taller ships to access port facilities that are masked by bridges too low to accommodate

these new vessels. Inadequate intermodal access capacity, including a rapidly shrinking rail capacity, has been a major contributor to port congestion and operational disruptions. State/local restrictions on truck emissions are also among constraints impacting port operations.

The economic consequences of traffic delays due to congested or missing MTS access links or inadequate link capacity are significant. The costs of inadequate access capacity often come in the form of excessive delays and bottlenecks. Highway interchanges at the nation's major ports and intermodal terminals are the largest contributors to highway bottlenecks and delays, as a recent study on highway freight bottlenecks conducted for FHWA indicated. Among interchanges with the largest number of delay hours were urban freeway interchanges at urban freight corridors (such as highway access to the Ports of LA/LB or NY/NJ), reporting an estimated 124 million hours of delay in 2004. Safety risks and economic costs of obstructive marine rail bridges have also contributed to the potential challenges posed by deficient MTS intermodal connectors.

As mitigation measures, U.S. container ports have begun taking a system-level approach to enhancing intermodal connector throughput. These ports are now looking beyond their jurisdictional boundaries to plan comprehensive system improvements, including countermeasures such as extended gate hours, congestion pricing, trucker appointment systems, off-dock container yards, chassis pools, high-speed rail shuttles, expanded rail connections, automated yard marshalling and inventory control, and automated gates.

Vessels

The vessel- and fleet-related components of the MTS contribute to the performance of the marine infrastructure but also impact its vulnerabilities and capacity challenges. There are about 40,000 privately owned U.S. vessels available for operation in the U.S. for domestic and foreign trade, about 97 percent of which operate in domestic trade on coastal and inland waterways. The remaining 3 percent of the U.S.-owned vessels (1,310) operate in ocean transport for foreign trade or for offshore oil exploration. In total, approximately 6,900 U.S.- and foreign-owned vessels make about 65,000 calls at U.S. ports. The tonnage capacity and under-keel draft requirements of the vessels in international trade calling at the U.S. ports have continued to increase. Container capacity for some of the largest containerships currently calling at the U.S. ports is about 9,000-10,000 twenty-foot-equivalent units (TEU), with vessel drafts of up to 46 feet. Future forecasts are for 12,000 TEU ships with vessel drafts of 49 feet, and even larger vessels of 14,000 TEU-capacity with vessel drafts of 50 feet planned for entry in the U.S. market.

Key threats to the viability of the nation's container ports and bulk terminals are disruptions caused by inability of the ports' berths and harbor channels to accommodate the growing size of ocean-going vessels. The system vulnerabilities that increase the probability that the threats will be realized include: a) the growing gap in the depth requirements of containerships and tankers calling at the U.S. ports, and the available harbor depth to

accommodate them; b) the increasing number of vessel calls; and c) the high investment costs for purchasing container lift or bulk product handling equipment.⁵

The gap between the required vessel draft and available harbor depth in the U.S. has been pointed out in a recent analysis conducted by Maritime Administration (MARAD) in the agency's *2006 Report to Congress*. According to the report, the average size of containerships calling at U.S. ports is 17 percent larger than the size of vessels calling at ports elsewhere in the world. The report explained that one reason for the larger average size of the vessels calling at U.S. ports, and hence the growing gap between the vessel draft needs and the available channel depth, is the scarcity of small U.S. feeder vessels and short sea shipping services. The report points out that in Europe and Asia, smaller feeder vessel and SSS services handle most of the intra-European and intra-Asian trade. The size of a feeder ship is between 2,000-3,000 TEU, instead of the 6,000-plus TEU vessels routinely calling on coastal ports.

The U.S. container ports for the most part have not been able to keep up with the growing harbor/berth depth requirements of the modern containerships. Many of the nation's major dry and wet bulk ports are not currently capable of serving the largest bulk ships either. The high costs of accommodating the rising size and volume of the vessels calling at the U.S. ports have jeopardized the continued operation of many MTS terminal facilities. The costs incurred for expansion of channel and berth depth, improvements to land-side port capacity, and purchase of intermodal lifts and bulk processing equipment constitute limiting factors for the expansion of the MTS infrastructure.

The growing number of port calls at the nation's top load centers, coupled with the growing size of vessels calling at them, further exposes ports to threats of disruption. The sharp increase in the number and size of the vessel calls in the past two decades has contributed to capacity constraints at the landside and waterside and increased the probability of disruption and delay. Between 2001 and 2006, containership calls at U.S. ports increased by 25 percent; calls by ships between 4,000 TEU and 4,999 TEU increased by 86 percent; and calls by ships of over 5,000 TEU increased by 240 percent.

The consequences of system weaknesses caused by the gap between vessel draft and service requirements are the associated costs of congestion, continued underutilization of the vast MTS resources, and the foregone opportunities for expansion of waterborne domestic commercial transportation service.

Promoting the use of smaller feeder vessels and implementation of SSS and the Marine Highway Program initiatives are strategies that have proven effective in reducing the adverse infrastructure-related, environmental and economic consequences of a transportation system dominated by large vessels and a highway-based freight movement system. By serving as a component of the nation's layered critical infrastructure, SSS and the Marine Highway Program can help mitigate infrastructure vulnerabilities to disruptions caused by natural disasters, recurring incidents and traffic bottlenecks, and congestion at

⁵ Mr. Eric Wolfe, NOAA, has also pointed out constraints relating to foreign competition arising from imposition of port user fees which drive traffic to Western Canadian ports.

large commercial ports. The underutilized components of the MTS infrastructure have the potential to enhance the resiliency of the critical infrastructure by offering an effective layer of system redundancy for cargo and passenger transportation.

In conclusion, the Task 1 Report created an analytical framework for a high-level assessment of MTS threats, vulnerabilities, and resiliency. Applying this framework to the assessment of MTS infrastructure risks, the report identified the systemic challenges that arise from the physical characteristics of the MTS infrastructure and the associated safety and operational risks of disruption, and offered a number of potential solutions for promoting system resiliency. Future Tasks 2 through 6 will address the remaining economic, safety, security, environmental, and institutional challenges facing the MTS.

Study Background

The scope of this Task Report was initially defined in a July 2006 Statement of Work (SOW) for a Reimbursable Agreement (RA) with the U.S. Army Corps of Engineering (USACE). The SOW was developed by the Marine Transportation System (MTS) Integrated Action Team (IAT) for the purpose of conducting a system Needs Assessment for the MTS. The first draft of this task report was distributed to the Needs Assessment IAT members on December 17, 2007, followed by the first round of revisions reflected in the March 20, 2008 report. The current report reflects additional revisions to incorporate the comments received by IAT reviewers, as noted in the Preface.

The MTS Initiative

In November 1998, the DOT Secretary appointed a Congressionally-mandated task force to assess the adequacy of the U.S. MTS to operate in a safe, efficient, secure, and environmentally-sound manner. In September 1999, the task force prepared *An Assessment of the U.S. Marine Transportation System: A Report to Congress*,⁶ recommending that the MTS Initiative be a shared responsibility of the public and private sectors, and indicated the need for improved coordination. In response to this recommendation, the Interagency Committee for MTS (ICMTS) was created to improve coordination among 17 Federal agencies involved with the MTS.

In September 2004, the Congressionally-established U.S. Commission on Ocean Policy, pursuant to its legislative mandate from the Oceans Act of 2000, released its report entitled “An Ocean Blueprint for the 21st Century”. In December 2004, in response to the recommendations of the Ocean Blueprint, the President’s Ocean Action Plan was issued, directing the elevation of the ICMTS to a cabinet-level committee chaired by the DOT Secretary. On July 11, 2005, acting upon this recommendation, the Committee on the Marine Transportation System (CMTS) was established as a Federal interagency committee with the mission to improve the MTS.

The CMTS is charged with providing high-level leadership and improved coordination to promote the safety, security, efficiency, economic vitality, sound environmental integration, and reliability of the MTS for commercial, recreational, and national defense requirements. Additionally, the CMTS is to coordinate Federal budget and regulatory activities that impact the MTS. The CMTS has endorsed the creation of a number of Integrated Action Teams (IATs), including National Strategy and Needs Assessment IATs.

On June 21-22, 2006, the National Strategy IAT held the MTS National Strategy Workshop, attended by over 60 representatives from industry, academia, and government identified the MTS vision, as follows:

-  MTS is established as a national priority;

⁶ US DOT, *An Assessment of the U.S. Marine Transportation System: A Report to Congress*, September 1999.

- ✚ The MTS will have a cohesive and sustainable source of funding;
- ✚ The MTS will have the capabilities of an efficiently managed, safe, integrated, robust, and flexible system;
- ✚ The MTS will have efficient operations and management;
- ✚ The MTS will be environmentally safe;
- ✚ The MTS will be a secure system; and
- ✚ The MTS will be a key element of the nation’s global competitiveness.⁷

In February 2008, the Draft National Strategy for the MTS was released. The National Strategy defined the MTS as consisting of five principal components: navigable waterways, ports, intermodal connections, vessels, and users (commercial, military, and recreational); and performing three key functions: commerce, recreation, and national defense.⁸ The key findings of the Strategy include:

- ✚ The MTS is at a crossroad: while MTS trade is thriving, segments of it are showing signs of strain, which will intensify as cargo and passenger traffic increases.
- ✚ The challenges facing the MTS include: system capacity challenges (including inadequate channel depth and inland waterway maintenance,) safety and security threats, concerns for environmental impacts, and threats of operational disruption.
- ✚ The MTS priorities are: maintaining and sustaining adequate capacity, ensuring safety, security, and environmental stewardship, ensuring resiliency and reliability, and addressing funding needs.

The Needs Assessment IAT was formed to conduct an overall assessment of the current state of the MTS. The need for the assessment was articulated at the initial July 2005 meeting of the CMTS as a high-priority requirement, recommending that a comprehensive analysis be conducted to assess “current state and the future needs of each Federal and non-Federal component modes of the MTS.” The need for this assessment was also previously addressed in a resolution from the MTS National Advisory Council (MTSNAC) in a request to the DOT Secretary.

Study Approach

As noted above, the initial SOW drafted for the MTS Needs Assessment in 2006 had specified that an assessment of the full scope of the MTS condition be conducted, including an analysis of the system’s operational and infrastructure requirements, identification of the gaps and potential solutions, and a set of recommendations to be presented as part of a Report to Congress. The cost of this assessment was estimated at \$1.5 million.⁹ However, the required funding in support of the full scope of the study has not been available. The

⁷ Proceedings of the MTS National Strategy Workshop, July 2006.

⁸ National Strategy for the Marine Transportation System: A Framework for Action, Committee on the Marine Transportation System, February 2008, Draft.

⁹ David Grier and Dr. Sandra Knight, “MTS Assessment IAT Status,” presentation to the CMTS Working Group, October 17, 2006.

present study represents a scaled-down version of the original SOW, with a total funding level of approximately \$280,000 for all seven tasks.

The scaled-down scope of the present study is intended to support the CMTS goal of targeting the most critical “actionable” elements of the MTS. The study will conduct a baseline assessment of the current state of the MTS and the associated challenges by preparing six task reports. This is Task 1 of six reports. The tasks outlined in the Volpe Center Reimbursable Agreement (RA) VH-99 will address system challenges arising from system risks and vulnerabilities, barriers to meeting the performance demands of global trade, and the potential solutions for promoting system resiliency, as follows:

- Task 1 – MTS Infrastructure
- Task 2 – MTS Economic and Productivity Challenges
- Task 3 – MTS Environmental Challenges
- Task 4 – MTS Safety
- Task 5 – National Security
- Task 6 – MTS Institutional Challenges
- Task 7 – Summary Report.

The above focus areas are consistent with the directions provided in the President’s Ocean Action Plan to “develop outcome-based goals for the MTS and a method for monitoring progress towards those goals.” The tasks are also consistent with the priorities developed at the National Strategy Workshop in June 2006, and those outlined in the February 2008 *Draft National Strategy*. The completion date for the full MTS Assessment is scheduled for 2009.

This Task 1 Report examines the MTS physical infrastructure. It assesses the baseline and forecast characteristics of the MTS physical infrastructure. This is done within a risk assessment and reliability framework, analyzing the present and projected threats to the continued performance of the infrastructure, the identified system vulnerabilities, and the anticipated countermeasures and the factors that would enhance system resiliency.

This study evaluates the baseline performance of each of the four components of the MTS physical infrastructure: navigable waterways (including harbor channels and locks and dams); ports (container and bulk facilities); intermodal connectors; and vessels. Note that the MTS users and functions, as identified in the National Strategy, will be addressed in forthcoming tasks. The MTS functions and users with respect to global and domestic commerce and the needs of the commercial users will be addressed in Task 2 (Economic and Productivity Challenges). Other functions, recreational user issues, and support systems related to national security, safety, environmental stewardship, and institutional issues will be addressed in the context of the remaining Tasks 3 through 6 of this study.

The study approach to infrastructure condition assessment is based on a standard risk assessment methodology, which includes an overview of the components of the MTS infrastructure system (Section 1), followed by a conceptual framework for identifying the infrastructure threats and vulnerabilities, and the consequences of exploitation of the

vulnerabilities (Section 2). The approach to assessment of infrastructure resiliency is based on the principles of resiliency engineering (Section 3). Sections 4 through 7 apply the principles of risk and resiliency to each of the infrastructure components.

For constructing the risk and resiliency assessment framework, the report has relied on available facility condition findings and the statistical trends in maritime infrastructure maintenance projects to identify the associated threats, vulnerabilities, and resiliency for each infrastructure component. The following aspects of the analytical approach should be emphasized:

- The intent of the risk and resiliency analysis has been to provide a high-level assessment for each component of the MTS infrastructure based on the available secondary data.
- The desired output has been development of a preliminary risk and reliability analysis framework to be tested as a proof-of-concept test for the resiliency concept in this and future task reports and for implementation of the National Strategy goals.
- The purpose is not to conduct a formal risk and vulnerability assessment; nor is it to conduct a condition assessment. Rather, the goal is a high-level system-wide baseline assessment of the MTS infrastructure within the analytical framework created.
- The focus of threat and vulnerability assessment for this task is on the physical condition of the infrastructure and the associated economic risks of disruption and not on economic, safety and security risks *per se*. To the extent that many MTS infrastructure risks arise from safety and security vulnerabilities, their relevance to infrastructure resiliency is addressed only briefly in this report. The future reports will address the economic, security, environmental, and safety risks in more detail.

The report relies on existing research and information sources such as the USACE Waterborne Commerce Statistics Center (WCSC) data, the Maritime Administration (MARAD) reports, the Bureau of Transportation Statistics (BTS) databases, and the data sources identified by the Data IAT, among others.

This report includes the following sections:

- Section 1 – The Marine Infrastructure System
- Section 2 – Risk and Vulnerability Assessment Elements
- Section 3 – Infrastructure Resiliency Elements
- Section 4 – Navigable Waterways: Characteristics, Risks, and Resiliency Status
- Section 5 – Ports: Characteristics, Risks, and Resiliency Status
- Section 6 – Intermodal Connections: Characteristics, Risks, and Resiliency Status
- Section 7 – Vessels: Characteristics, Risks, and Resiliency Status
- Section 8 – Findings and Next Steps

Section 1. The Marine Infrastructure System

The MTS Infrastructure Components

The U.S. marine infrastructure network encompasses the navigable inland waterways, harbor channels, ports and terminals, locks and dams, levee systems, and vessels and equipment that support commercial cargo, passenger, and military navigation as well as non-transportation uses of the waterways for recreational and commercial activities. The MTS consists of approximately 26,000 miles of navigable waterways and inland, intracoastal and coastal channels, including 12,000 miles of commercially-active navigable channels and 2,342 miles of Great Lakes and St. Lawrence Seaway.¹⁰

In this report, the four components of the MTS infrastructure, as identified in the National Strategy, are reviewed and their implications for the performance of the maritime system and the attendant risks and vulnerabilities are assessed.¹¹ Sections 4 through 7 characterize the physical and usage attributes of these four infrastructure components:

- ✚ Navigable Waterways. These include harbor channels, coastal and ocean areas, the Great Lakes/Saint Lawrence Seaway System, inland waterways and their locks and dams.
- ✚ Ports. These include container and bulk terminals, marine transportation facilities where vessels transfer cargo and passengers, and recreational access facilities;
- ✚ Intermodal connections. These include access links and bridges at the land-water boundary that allow the transfer of cargo and passengers between modes;
- ✚ Vessels. These include the vessels – oceangoing, coastal, and inland vessels – and equipment that move cargo, containers, and people within the system.¹²

The Elements of a “Systems” Concept

From a systems’ perspective, the MTS is a complex system that is geographically and functionally diverse, consisting of interdependent physical, functional, and support systems comprised of multiple parts, units, and subsystems (including surface transportation.) The system consists of a network of maritime operations that interfaces with the shoreside infrastructure and land-side intermodal connections as part of the broader global and domestic commercial supply chain functions and military operations.

¹⁰ The total mileage of the fuel-taxed inland waterways is reported as 10,867 miles. Table 3-1, *Freight Facts and Figures 2006*, Office of Freight Management and Operations, FHWA, DOT, http://www.ops.fhwa.dot.gov/freight/freight_analysis/nat_freight_stats/docs.

¹¹ Note that the User component of the MTS is described in future task reports.

¹² *National Strategy for the Marine Transportation System: A Framework for Action*, the Committee on the MTS, Draft, February 2008. As noted above, the National Strategy also lists the Users of the MTS as a component of the MTS infrastructure. For this project, the MTS Users are described in Tasks 2 through 6.

To evaluate MTS infrastructure challenges, we need to first define what we mean by a system. A system is characterized as a complex composite of parts, units, and subsystems that together perform the required functions and operations that help maintain the integrity and boundaries of the subject entity. A system is characterized by interdependency among component parts and the complementary nature of the core functions and supporting systems. Some of the characteristics of complex systems are open boundaries and information feedback loops that create chain-effects and a complex path of causality that is often not based on simple one-way cause-and-effect relationships.¹³

The concept of a “system of systems” – a term used to emphasize system complexities and operational interdependencies involved in all critical infrastructure systems – would accurately apply to the MTS and its parts, units, and subsystems. For the purposes of this study, the following definitions of the MTS components apply:

A Part: The smallest component of the system that is likely to be identified. When analyzing the MTS infrastructure, these parts may include locks and dams, segments of the harbor channels, intermodal connections, or small vessels and tugboats.

A Unit: A functionally related collection of parts. For MTS, these include a small marine port, its harbors, terminal facilities, cargo, and intermodal access.

A Subsystem: An agglomeration of units that make up the principal components of the MTS; examples include global gateways and complex international container ports, major integrated cargo terminals, integrated navigation technology systems, and large-scale vessel systems.¹⁴

The significance of identifying the component parts of any system lies in the manner in which the system’s parts, units and subsystems interact. In an attempt to define simple and complex systems, Princeton University’s Charles Perrow has related system complexity to the probability of occurrence of what he refers to as “normal accidents.” Perrow defines an “accident” as “a failure in a subsystem, or the system as a whole, that damages more than one unit, and in doing so disrupts the ongoing or future output of the system.”¹⁵ Perrow characterizes the systems that are most prone to systemic accidents through two concepts: “interactiveness” and “tight coupling.” Systems with a high level of interactiveness or lack of specified business practices or standard operating procedures can be prone to malfunction because the interactions can confuse the operators; tight coupling can prevent speedy recovery from an accident. In a linear system (e.g., a system of locks and dams,) if a part or a unit fails the impacts on the upstream and downstream systems can be known and controlled. In a system in which the component parts serve multiple functions and are tightly coupled (e.g., in a large tanker or containership with complex communications and

¹³ See, for example, the concepts of the general systems theory developed by Ludwig von Bertalanffy.

¹⁴ Adapted from Charles Perrow, *Normal Accidents: Living with High-Risk Technologies*, Princeton University Press, 1999.

¹⁵ Charles Perrow, *Normal Accidents: Living with High-Risk Technologies*, Princeton University Press, 1999.

display systems) interactions among the parts can happen in what Perrow calls an “unexpected sequence.” Perrow defines tightly coupled systems as those that:

- Have more time-dependent processes: they cannot wait or stand by until attended to;
- The sequences are more invariant: B must follow A because that is the only way the system will work;
- The overall design of the process allows only one way to reach the production goal (e.g., the journey’s path or inputs in the production process cannot be varied);
- Have little slack: quantities must be precise; resources cannot be substituted for one another; wasted supplies may overload the process; and a failed equipment entails a shutdown because temporary substitution is not possible.

The issues relating to tight coupling and interactiveness in complex systems are further discussed below in the context of resiliency engineering.

Section 2. Risk and Vulnerability Assessment Elements

Risk analysis is commonly based on methodologies that calculate risk as the algebraic product of the conditional probability of an adverse event occurring during a defined time period, and the consequences. For economic risks, consequences equal the monetary losses. For non-economic risks involving safety, security, or environmental consequences, the impacts may be monetized and numeric equivalents to economic costs estimated if a formal benefit-cost analysis is conducted. The non-economic consequences of waterway disruptions may be calculated as order-of-magnitude estimates, using equivalent dollar values representing the nation's willing to pay to avert risks to safety or security, or lessen the catastrophic environmental consequences of transportation-related incidents.

The scope of this study, however, does not require a formal benefit-cost analysis. Nor does the scope entail a formal risk and reliability analysis or condition assessment. The study approach is based on using readily available studies and impact estimates to conduct a high-level baseline analysis of the MTS risk and resiliency status.

Conventional risk analysis involves a three-part process for assessing system threats, vulnerabilities, and consequences of adverse events (Risk Assessment); identifying preventive and mitigating options (Risk Management); and communicating the decisions for implementing the mitigating measures (Risk Communication).

The common approach in the first step of risk analysis is to develop scenarios that assess the risks to the operations of any complex infrastructure system by asking the following three questions:

- *What can go wrong?*
- *What is the likelihood that it would go wrong?*
- *What are the consequences?*

Answers to these questions require a systematic process of “risk assessment.”

In a standard risk assessment, the MTS infrastructure risks would be defined as the following relationship between the prevailing threats – natural, man-made, and systemic – posed by the domestic and international maritime activities, the likelihood that these threats will be realized and lead to operational disruptions, and the severity of consequences:¹⁶

$$R = pT \times C$$

Where:

¹⁶ Descriptions in this section are adapted from Yacov Y. Haimes, *Risk Modeling, Assessment, and Management*, Wiley Series in Systems Engineering, 1998; and Yacov Y. Haimes, “Roadmap for Modeling Risks of Terrorism to the Homeland,” *Journal of Infrastructure Systems*, June 2002.

R = Risk of disruption or failure in any of the MTS parts, units or subsystems

p = Probability of threat realization

T = *Threat*: probability that the condition of any of the MTS infrastructure components/subsystems (including waterway condition, operational factors, natural and man-made events) will lead to facility closure, accidents, or other disruption.

C = *Consequences*: criticality, severity, impacts, and resulting damages.

Threat (T) can be further broken down as a product of *exposure* to sources of threat, and the present *vulnerabilities*:

$$T = E \times V$$

Where:

E = Probability that the *exposure* of the MTS subsystem to external and internal threats (as defined below) will increase the risks involved in an adverse event or disruption.

V = Probability that the *vulnerabilities* inherent in the MTS facilities, waterways, terminals, cargo or vessels, and the absence of safeguards to prevent disruption or mitigate systemic failures, will lead to a disruption.

After the preliminary assessment of the potential risks, the process of “risk management” begins, in which the decision-makers ask:

What can be done?”

The risk management process involves identification of the countermeasures and preventive solutions, analysis of tradeoffs and costs and benefits, and calculation of the anticipated impacts of the solutions on future operations and events.

The processes involved in constructing a risk model, based on the guidelines provided in Professor Yacov Haimés’ seminal work on risk modeling, are to define the following concepts (with references to MTS added as examples of applications of concepts):¹⁷

Objective Functions: Maximizing waterway and landside capacity, throughput, and efficiency, and minimizing operational and maintenance/upkeep costs; minimizing the safety, security, and environmental threats.

State Variables: Size, condition and dimensions of the MTS, traffic and trade volumes, vessel activities, available technologies.

¹⁷ Yacov Y. Haimés, *Risk Modeling, Assessment, and Management*, Wiley Series in Systems Engineering, 1998.

Constraints: Channel depth, funding limitations, required commercial service levels/performance, legacy assets and equipment, intermodal efficiency and highway “roadability”/conspicuity, and regulatory requirements.

Decision Variables: Planned facility improvement projects, technology deployment initiatives, enforcement and implementation of security/safety/ environmental programs and regulations.

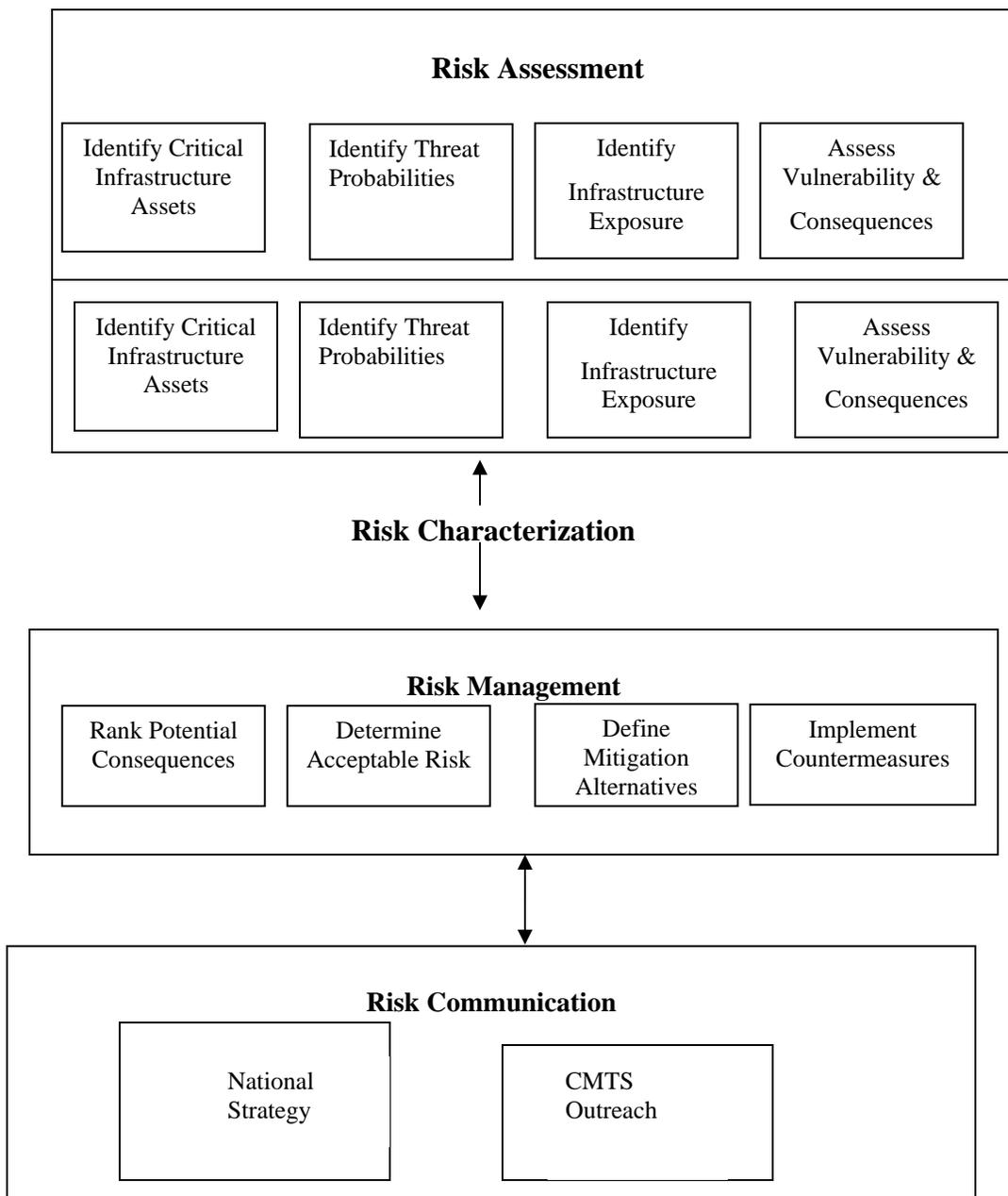
Random Variables: Frequency and magnitude of marine accidents and spills, weather-related disruptions, natural hazards/disasters, labor strikes, military deployments, terrorist actions, equipment reliability.

Exogenous Variables: Emergence of new international trading routes and partners, global economic fluctuations, location of consumer markets, changes in foreign trade routes and operational productivity.

These concepts will serve as guiding principles for the MTS assessment conducted in this report. As noted earlier, this report is not a formal risk assessment, but rather an informal high-level assessment of the threats and vulnerabilities inherent in the MTS infrastructure, and a preliminary evaluation of the “risk management” issues, as adapted from the National Research Council (NRC) risk analysis guidelines.¹⁸ Figure 1 depicts a conceptual framework for the three components of risk analysis: risk assessment, risk management, and risk communication.

¹⁸ National Research Council (NRC), *Minding the Helm: Marine Navigation and Piloting*, 1994.

Figure 1 - A Risk Analysis Framework



Source: Adapted from National Research Council (NRC), *Minding the Helm: Marine Navigation and Piloting*, 1994.

Critical Infrastructure Elements

The MTS infrastructure components that make them critical to the nation are dictated by the economic needs of the private sector users and shippers and the mission-critical MTS elements supporting Federal agencies such as the USACE, U.S. Coast Guard (USCG), U.S.

Department of Defense, (DOD), U.S. Department of Agriculture (USDA), U.S. Department of Commerce (USDOC) and U.S. Department of Transportation (U.S. DOT).

Identifying the criticality of the MTS infrastructure components involves a ranking and prioritization process. For instance, the USACE may rank and prioritize the critical infrastructure components of the MTS according to the following criteria:¹⁹

1. Ability to provide navigation/transportation service
2. Available alternate waterways
3. Probability of casualty or injury resulting from asset failure
4. Degree of navigation dependency
5. Interdependence with other critical segments
6. Environmental impact
7. Functional importance
8. Relative vulnerability to attack
9. Replacement cost
10. Replacement downtime.

Threat Elements

The process of identifying system threats involves estimating the potential threats and the probability that they would materialize. The assessment would involve probabilistic calculations for adverse events that, among others, could include:

- Disruptions related to natural disasters and weather;
- Disruptions related to the aging infrastructure and delayed maintenance;
- Disruptions related to inadequate capacity;
- Disruptions related to military surge deployments;
- Disruptions related to unintended incidents, spill, and collisions; and
- Intentional threats, labor strikes and acts of terrorism or trade protectionism.

Exposure Elements

Exposure is defined in terms of the system size and dimension; it determines the extent to which infrastructure elements have the potential for unintended failure (accident) or can be “exploited” through intentional attacks. Exposure factors exert a broad array of influence on infrastructure risk, given their critical importance to a facility’s operations and the benefits arising from them. Exposure factors contribute to the probability that vulnerabilities will be exploited, but would also enhance the benefits resulting from the operation of the asset.

The following MTS attributes are examples of MTS characteristics that, while a contributor to a facility’s exposure to threat, also contribute to the value of infrastructure assets:

¹⁹ The above list of criticality is used as an example of “critical asset factors” derived from a presentation to the AASHTO Transportation Task Force entitled “A Guide to Highway Vulnerability Assessment,” April 24, 2002.

- Miles of navigable assets
- Volume of assets (number of locks, dams, terminals, etc.)
- Ton miles and twenty-foot-equivalent units (TEU) of cargo transported
- Tonnage of cargo transported on the infrastructure segments
- Age/operational life cycle
- Value of cargo/traded goods using the infrastructure
- Number of vessels
- Type and size of vessels using the infrastructure
- Railroad access; motor carrier access and availability
- National security value of military equipment using the infrastructure.

Vulnerability Elements

Vulnerability can be defined as an intrinsic property of the MTS infrastructure that points to weaknesses that can be exploited or lead to system failure. These systemic vulnerabilities are indicative of the probability that factors such as high-exposure or under-maintained infrastructure facilities will lead to system disruption. Factors contributing to the vulnerability of an MTS infrastructure component include facility size and visibility, exposure to adverse conditions, inadequate facility maintenance, unprotected access, and site-specific hazards.

The formal process of assessing a facility's vulnerability involves identification of system-wide threats, identification of indicators and warnings that could signify a potential for malfunction, and evaluation of the functions and exposure levels to potential threats for each component of MTS assets. The process also involves scoring the MTS assets according to their vulnerability to disruption and probability of loss of system functions. Factors contributing to an MTS asset's vulnerability include:

- Dependence of a high percentage of some commercial activities on the waterway segment/asset;
- Concentration of hazardous cargo at the facility;
- Failing and aging locks and dams;
- Identifying and handling contaminated dredged materials;
- Operational dependence on specialized equipment and harbor conditions;
- Propensity of the location to be prone to natural disasters;
- High profile national status leading to facility serving as a target for man-made disruptions and intentional attacks;
- High profile national security facilities serving as targets for man-made disruptions and intentional attack;
- Domestic environmental and tax laws; and
- Size and weight and operational capability laws and limitations.

Elements of Consequence Severity

Identification of the risks involved in the disruption of an MTS infrastructure component includes assessment of the potential magnitude of the impacts, given the probability that the

high impact events will occur. Included in the factors that contribute to an event severity are:

- Potential for loss of life and injuries;
- Extent of economic losses from a disruption;
- Potential for non-fatality safety risks;
- Potential for cascading chain effects;
- Potential for national security breaches;
- Potential for adverse environmental impacts; and
- Potential for not meeting military deployment mission timelines.

Included in economic losses from high consequence events are the costs associated with such things as:

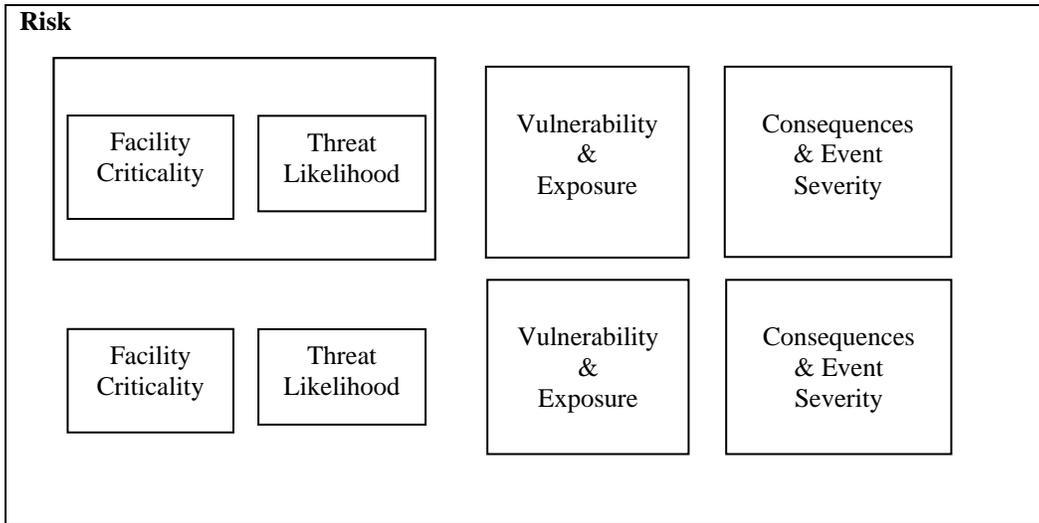
- Loss of global gateway functions;
- Impact of the losses of trade value, as they ripple throughout the port region;
- Costs of downtimes;
- Lock/tow queue costs;
- Losses due to lock unavailability;
- International losses owing to loss of “loaded-empty” cycles; and
- Negative impact on the National economy.

Severity analysis would entail an assessment of the interdependencies within the system and chain effects of the disruption – economic, transportation, and operational – throughout the maritime infrastructure system. Within this context, if the hazard persists over long periods, the number of vulnerabilities will grow and the probability of adverse chain effects will rise dramatically, even if each of the components may be of a statistically low-probability event. Figure 2 summarizes the components of risk.

Factors contributing to the likelihood that a disruption within a segment of the MTS will become a high-consequence event include:

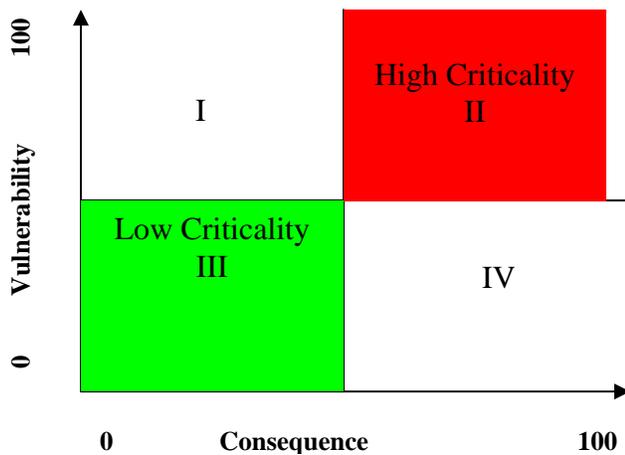
- Facility’s trade dependence (e.g., major international container port)
- Facility’s geographic and market size
- Postponed or delayed maintenance
- Major component failure due to interdependencies among parts
- Cascading effects
- Downstream impacts

Figure 2 - Components of Risk: Threat, Vulnerability, and Consequence



Assessment models that conduct consequence analysis develop scores that have been calculated based on engineering and operational assessments for each facility. For instance, the findings of such models could be incorporated in a facility's scores on vulnerability and consequence severity and be plotted on a matrix with four quadrants to identify the criticality of the facility, as shown in Figure 3.

Figure 3 - Balancing Facility Vulnerability and Event Consequence



Potential Countermeasures

Two sets of potential countermeasures are available for reducing MTS infrastructure vulnerabilities and mitigating the consequences of disruption and incidents. Potential countermeasures can be grouped into preventive measures and mitigative response strategies:

- *Preventive measures.* These include technological and operational strategies that lessen the likelihood of the threats being realized and reduce the identified vulnerabilities (including due diligence analysis of proposed state and Federal laws and regulations);
- *Mitigative response strategies.* These include measures for alleviating the damages and reducing severity of the impacts and consequences.

Preventive and mitigative countermeasures can be viewed as part of the nation's risk mitigation and threat reduction strategies (i.e., national preparedness) that include:

- *Preparedness:* Use information and intelligence resources to identify threats
- *Detection:* Stop incidents before they happen
- *Prevention:* Reduce our vulnerability to threats
- *Response:* Respond to and mitigate the consequences of an incident
- *Recovery:* Help return to normal conditions

The MTS elements of the National Preparedness Strategy have been delineated in the Department of Homeland Security (DHS) National Infrastructure Protection Plan (NIPP).²⁰ With a focus on security, the NIPP identifies the preparedness elements for critical infrastructure/key resources (CI/KR) as:

- Component security
- Interface security
- Infrastructure security
- Network security

The first of the two sets of preventive and mitigative countermeasures available for reducing MTS infrastructure vulnerabilities include design-based measures such as:

- Design safeguards
- Built-in mitigation components
- Built-in structural redundancy
- Engineered robustness and target hardening
- Design elements to enhance fault tolerance
- Incident prevention and deterrence components (including training and exercises)
- Detection devices, sensors, and monitoring systems
- Maritime domain awareness components
- Surveillance technologies

²⁰ *The National Infrastructure Protection Plan (NIPP)*, DHS, 2006, Annex B.

- Navigational tools.

The second set of potential countermeasures relates to infrastructure investment strategies that expand the scope and scale of the MTS infrastructure and enhance its functionalities. For instance, many investment projects that would expand waterway or port capacity could serve as mitigative solutions for alleviating congestion bottlenecks, re-routing cargo away from other capacity-constrained facilities, and avoiding the attendant economic consequences. However, such investments could also potentially create new regional and facility congestion challenges by enabling the improved segments of the infrastructure to become larger conduits of cargo and potentially create new bottlenecks.

Many of the above-mentioned countermeasures are elements of infrastructure resiliency. Their contribution to MTS resiliency is examined in Section 3. However, no details are provided on these countermeasures in this report, since the focus is on infrastructure challenges and the risks and vulnerabilities associated with these. Technological solutions, countermeasures, and preventive strategies will be addressed in future reports.

Section 3. Infrastructure Resiliency Elements

Resiliency originates in system attributes and safeguards that reduce the probability of a single-point failure. The principles of “resiliency engineering” involve adaptive problem solving focused on maximizing system strengths, addressing system weaknesses, and deploying effective countermeasures. Resiliency engineering has four major components:²¹

- a) Access to information and intelligence that make the system adaptive to disruption;
- b) System conditions that serve as preventive measures, make the system more fault tolerant, and reduce the totality of the events that “can go wrong;”
- c) Availability of redundant system components that can mitigate the vulnerabilities;
- d) Presence of factors that can reduce severity of the consequences.

Sustainability is a concept often used synonymously with resiliency. Sustainability has been defined as “*meeting the needs of the present without compromising the needs of the future.*”²² The concept has been used by the USACE in the context of managing marine infrastructure assets in a sustainable manner, defined as:

- Managing assets to minimize risk and provide acceptable levels of service;
- Prioritizing investments to add capacity, modernize system, maintain integrity;
- Conducting condition assessments;
- Conducting multi-year planning not on project-basis, but at the system-level;
- Identifying the need for – and constraints to – reliable financing streams.²³

Analysis of the existing and future MTS resiliency could be conducted based on the principles of system adaptiveness, fault-tolerance, redundancies, and mitigative buffers that reduce severity of consequences:

- a) A resilient MTS infrastructure is adaptive and flexible. It has access to information and operational intelligence that monitor the facility boundary conditions and guard against potential threats, allowing the system to adapt to changing conditions and respond to incidents with agility. A resilient MTS has enhanced performance margins through access to real-time data and monitoring systems that provide maritime domain awareness (MDA). The National Infrastructure Protection Plan (NIPP) has referred to MDA as:

*“the effective understanding of anything associated with the global maritime...that could impact the security, safety, economy, or environment
.....”* [The NIPP goal of resiliency has the following objective]: “*security*

²¹ Discussions of resiliency are loosely based on Erik Hollnagel, David D. Woods, Nancy Leveson, editors, *Resilience Engineering: Concepts and Precepts*, Ashgate, 2006.

²² Definition of sustainability is derived from the widely accepted definition proposed by the World Commission on Environment and Development.

²³ David Grier, “Waterway Services, Issues and capacity: the Corps of Engineers’ Role,” Midwest Agricultural Transportation Conference, Naperville, Illinois, August 8, 2007.

partners will reduce the risk associated with key nodes, links, and flows with critical MTS area to enhance the overall MTS survivability and continue to develop flexible contingency plans.”²⁴

- b) A resilient MTS infrastructure has components and attributes that make it more fault-tolerant. These attributes reduce system threats (i.e., the number of things that can go wrong) and vulnerabilities (i.e., the probability that if something does go wrong the damages are minimal and the system can recover rapidly). These include design-based capabilities that make the infrastructure robust, and enable it to absorb attacks and resume normal operations shortly after a disruption.
- c) A resilient MTS infrastructure has built-in redundancies that help reduce vulnerability to single-point failures. Such systems have built-in layers of safeguards and parallel functionalities that enable the system to adapt to malfunction in one subsystem by shifting to backup capacity.
- d) A resilient MTS infrastructure has mitigative operational conditions that work as buffers to help reduce the severity of the consequences in the event of a disruption. These buffers will enable the MTS component parts to recover a stable state and continue operations after major disruptions. These mitigation strategies focus on the “failure mode” rather than “source of disruption.”²⁵ In other words, effective mitigation strategies focus on the capability to respond to MTS failures such as disrupted ship-to-shore communications, grounded vessels, or disabled container lift capacity; not on strategies geared to responding to specific threats such as terrorist attacks or hurricanes. These mitigative strategies can potentially lead to more effective response and less severe consequences.

Resiliency can also be analyzed within the framework of tight-coupling/interactiveness developed by Perrow, as discussed in Section 1. Perrow has illustrated the concept of tight coupling with the example of a navigation system involving ship operations, radio communications, the weather/tide/water level changes, and other ships in the vicinity. As a ship enters a crowded channel, it encounters not only the weather changes, but also bank effects (the suction created as it passes close to the underwater bank of a channel), tides and current flow, wrecks and rocks, bridges, tows and other ships, a crowded radio channel, and navigation lights mixed in with the lights of port and harbor facilities and communications towers. Perrow presents four quadrants developed from the juxtaposition of tight coupling and interactiveness – where the coupling ranges from loose to tight, displayed on the X axis – and the degree of interactiveness ranges from linear to complex – displayed on the Y axis. Within these quadrants, Perrow places the “marine transport system” in quadrant 1 (signifying tight-coupling with linear interactions); in contradistinction with the placement of a nuclear plant in quadrant 2 (tight-coupling with complex interactions.)²⁶ For instance, the position of the MTS in quadrant 1 (signifying tight-coupling with linear interactions) in

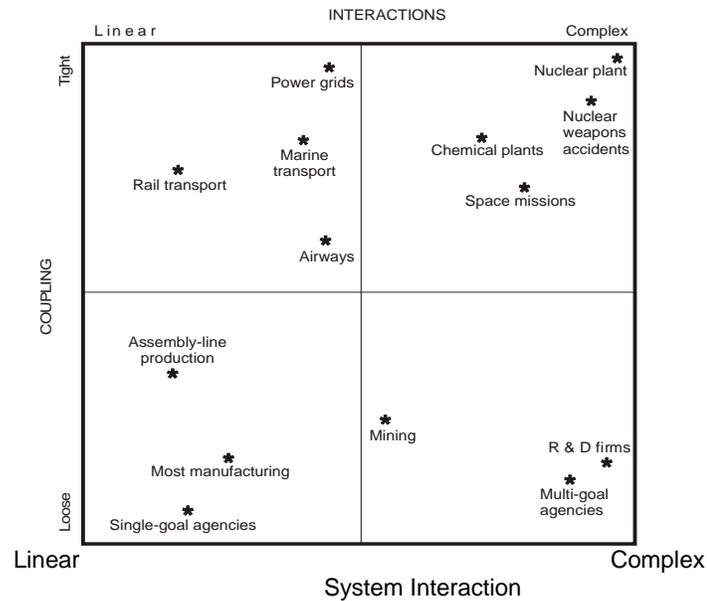
²⁴ *The National Infrastructure Protection Plan (NIPP)*, DHS, 2006, Annex B, p. 29.

²⁵ Based on James B. Rice, Jr. “Supply Chain Response to Terrorism: Creating Resilient and Secure Supply Chains,” August 8, 2003.

²⁶ Charles Perrow, *Normal Accidents: Living with High-Risk Technologies*, Princeton University Press, 1999.

Figure 4 is in contradistinction with the placement of a nuclear plant in quadrant 2 (signifying tight-coupling with complex interactions.)

Figure 4 - Marine Transportation Risks: System Interaction and Tight Coupling



Adapted from: Charles Perrow, *Normal Accidents, Living with High Risk Technologies*, Princeton University Press, 1999.

Writing about the elements that enhance the resiliency of the nation’s critical infrastructure, security expert Stephen Flynn offers this description of a resiliency:

“A resilient society is one that won’t fall apart in the face of adversity....Making infrastructure resilient makes them less attractive targets for terrorists. And preparing for the worst makes the worst less likely to happen.”²⁷

The MTS National Strategy IAT, in its February 2008 Draft National Strategy describes the elements of a national strategy for enhancing MTS resiliency:

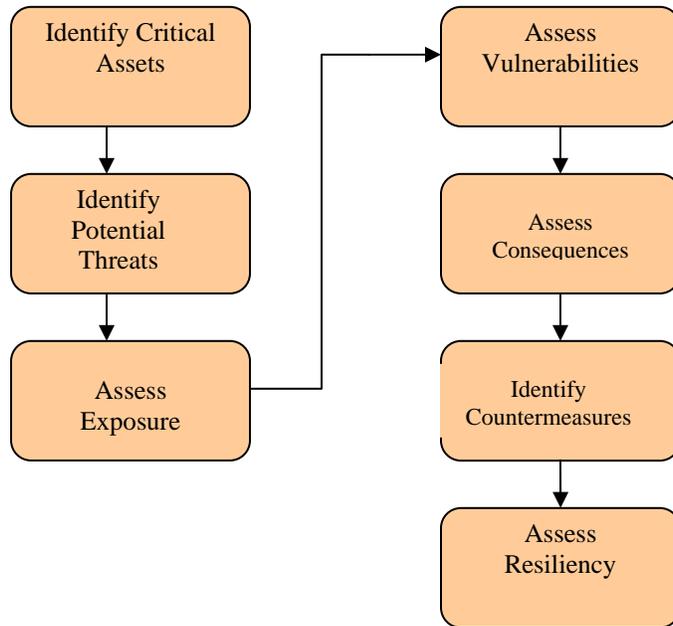
“Protecting MTS efficiency and resiliency requires providing ports and infrastructure with layers of operational capability, increasing target hardiness and improving the quality and capacity of the intermodal connectors that complete internal movement of the passengers and goods.” [The Strategy recommends] “decreasing the physical vulnerability of these assets through new design criteria or improvements in order to mitigate the consequences of an attack or event affecting communications and critical systems, it may be possible to achieve an overall reduction in risk to the MTS.”²⁸

²⁷ Stephen Flynn, *The Edge of Disaster: Rebuilding A Resilient Nation*, Random House, 2007.

²⁸ *National Strategy for the Marine Transportation System: A Framework for Action*, February 2008, p. 52.

Figure 5 incorporates the processes involved in risk analysis and resiliency by linking the processes for vulnerability assessment and countermeasure identification to the steps involved in assessing system resiliency.

Figure 5 - MTS Infrastructure Risks and Resiliency Assessment Process



Section 4. Navigable Waterways: Characteristics, Risks, and Resiliency Status

The U.S. navigable waterways include the harbor channels and locks and dams. The National Strategy defines the MTS navigable waterways as an extensive infrastructure that includes:

“...coastal and ocean areas, the Great Lakes St. Lawrence Seaway System, the Mississippi, Ohio, and Columbia River Systems, the Gulf Intracoastal Waterway, and Arctic waterways.....Navigation on the MTS is supported and facilitated by a system of canals, locks, dams and aids to navigation.”²⁹

Risks to the navigable waterway system are a function of an array of factors, including the physical dimensions of the waterway channels, vessel characteristics, size and loading requirements, economic considerations relating to competitive pressures on containerships, scheduling and transit time requirements designed to maximize revenues per port call, and extraneous factors such as weather and natural or man-made disasters.

For each component of the MTS infrastructure, this report presents a brief description of the infrastructure, and potential risks and vulnerabilities, including:

- Facility characteristics: size, landside capacity/throughput and channel depth, facility maintenance status and physical constraints;
- Potential threats and vulnerabilities: What can go wrong? What is the likelihood that the infrastructure conditions would adversely impact the facility capacity and throughput? What are the vulnerabilities that would increase the probability that the threat will be realized and the system functions will be disrupted?
- Potential consequences: What is the likelihood that high-consequence events would occur?
- System resiliency: What safeguards are in place to enable the system to withstand disruption? What countermeasures and redundancies are available?

²⁹ *National Strategy for the Marine Transportation System: A Framework for Action*, the Committee on the MTS, Draft, February 2008.

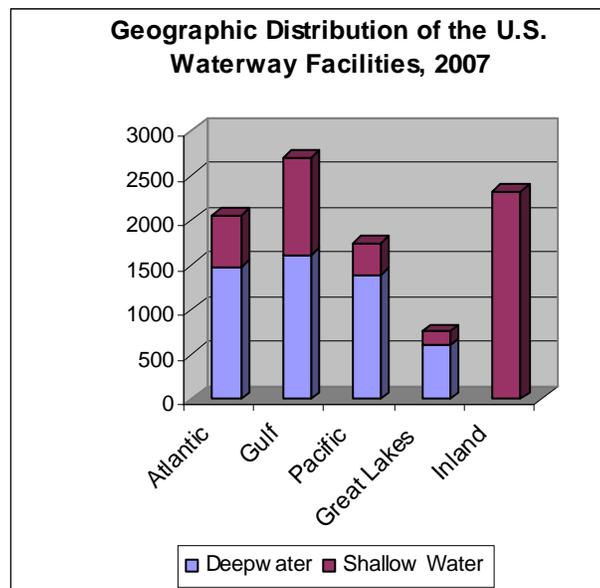
4-1 Inland and Intracoastal Waterways and Harbor Channels

Characteristics

The MTS consists of 25,000 miles of navigable inland and intracoastal waterways, including 12,000 miles of commercially active inland waterway navigable channels and 2,342 miles of Great Lakes and St. Lawrence Seaway.³⁰

The USACE has reported a total of 9,584 “commercial facilities” in the Atlantic, Gulf, and Pacific coasts, Great Lakes, and Inland waterways, each categorized according to channel depth and usage (cargo, service, unused.) Waterways greater than 12 feet are classified as deep water (with the exception of the 14-15 foot portions of the Columbia and Snake rivers.)³¹ The U.S. waterway facilities include a total of 5,066 deepwater facilities, and 4,518 shallow water facilities. No deepwater inland waterway facilities are identified in the USACE report (Figure 6).

Figure 6 – U.S. Waterway Facilities by Geographic Region, 2007



Source: Volpe generated chart based on USACE, “The U.S. Waterway System – *Transportation Facts*”, Navigation Data Center, December 2007

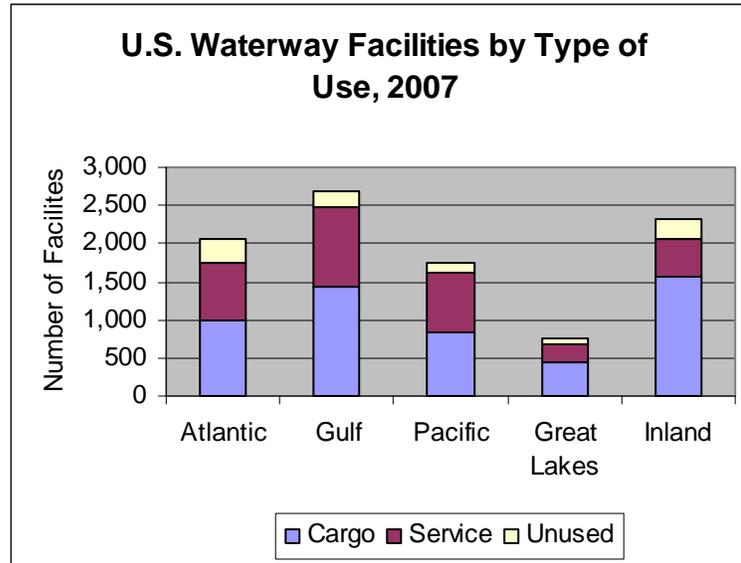
By usage, the harbor channels consist of 5,279 cargo facilities, 3,319 passenger/service facilities, and some 986 “unused” facilities.³² Waterway facilities by type of use are depicted in Figure 7.

³⁰ Office of Freight Management and Operations, Freight Facts and Figures, 2007, FHWA, USDOT.

³¹ The USACE uses criterion of 15 feet to define “deep water.”

³² USACE, The U.S. Waterway System – *Transportation Facts*”, Navigation Data Center, December 2007; <http://www.iwr.usace.army.mil/NDC/factcard/fc07/factcard.pdf>

Figure 7 - U.S. Waterway Facilities by Type of Use, 2007



Source: Volpe generated chart based on USACE, “The U.S. Waterway System – *Transportation Facts*”, Navigation Data Center, December 2007

Threats and Vulnerabilities

Threats to the viability of navigable waterways, as defined in Section 2, include anything that “can go wrong” – i.e., the events that can potentially disrupt the waterway navigation – and the factors that increase the probability that something would go wrong – i.e., the vulnerabilities and system weaknesses that make the disruption more likely.

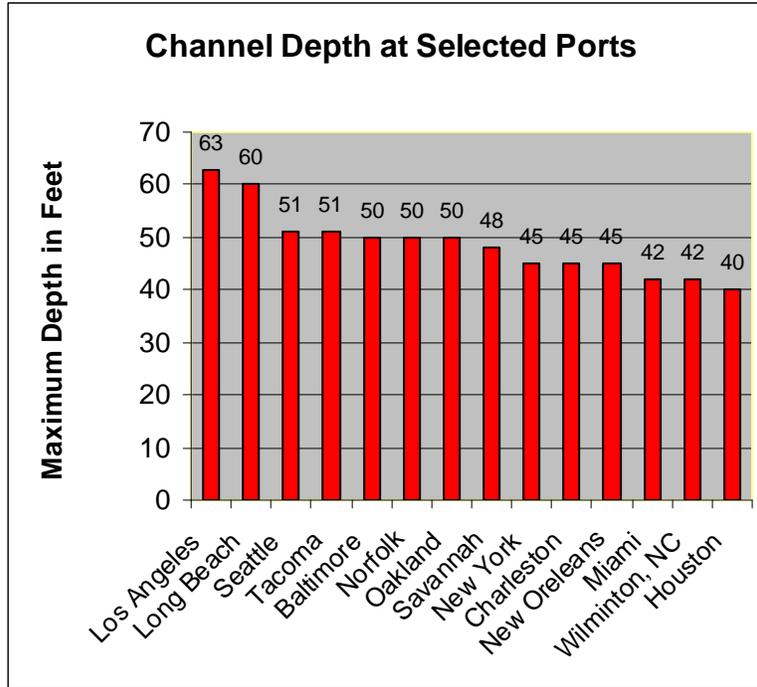
A key factor that contributes to the likelihood of a disruption in the navigable waterways is the growing gap between the existing channel depths and draft requirements of the vessels using the waterways. Inadequate channel depth to accommodate the increasingly larger ships that call at U.S. ports is likely to increase the likelihood of a disruption in navigation.

As the size of vessels serving the U.S. ports has grown, the U.S. waterways have not kept up with the dredging needs to maintain the required depth. Most of the new containerships serving U.S. ports require channel depths of over 45 feet. In the past two decades, the depth requirement for new vessels has grown from 39 feet in 1984, to depths of over 48 feet today.³³ Only a handful of ports today have the required channel depth needed to serve larger modern cargo vessels, as depicted in Figure 8. (Trends in vessel size and container

³³ See channel depth data for representative ports on: http://www.port-of-charleston.com/term_and_infra/charleston/channelspecs.asp; <http://www.vaports.com/Facilities/facilities.htm> http://www.panynj.gov/DoingBusinessWith/seaport/html/regional_port.html <http://www.portofoakland.com/maritime/terminal.asp> <http://www.portseattle.org/seaport/cargo/> http://www.portoflosangeles.org/facilities_container.htm

and bulk port channel depth requirements are evaluated at greater length in sections 5 and 7).

Figure 8 - Channel Depths at Selected U.S. Ports



Source: Volpe generated chart based on data from National Dredging Needs Study of U.S. Ports and Harbors: Update 2000, May 2003, IWR Report 00-R-04.

Note: Data indicate depths for Federally maintained channels at mean low water (MLW) for depth construction underway at the time of the report.³⁴

Funding constraints have been a key contributing factor to the growing gap between channel depth needs and the number of completed channel deepening projects. Before 1986, the Federal government paid 100 percent of the costs of harbor dredging. In the Water Resources Development Act (WRDA) of 1986, the Federal share dropped to 40 percent for channel depths of over 45 feet, requiring greater cost-sharing by non-Federal payers, through the following formula:

Channel Depth	WRDA '86 Cost-Sharing Rule for Federal Share
20 ft or less	80%
20-45 feet	65%
Over 45 feet	40%

The *National Dredging Needs Study* (NDNS), conducted for the USACE in 2000 and updated in 2003, has made the following observation about the U.S. waterway channel depth constraints:

³⁴ Note: Channels cited for Los Angeles and Long Beach refer to channels that lead directly to major container terminals; other locations at both ports may be deeper. Federal channels at Baltimore and Norfolk do not lead directly to container terminals at these ports.

“Although U.S. ports are currently comparable to foreign ports in terms of dockside infrastructure, channel depth remains an obstacle. This is particularly true for ports along the Atlantic that expect to service new generations of containerships.”³⁵

Other factors contributing to an increase in the probability of a disruption in the navigable waterways and harbor channels are natural events. Major storms may have the effect of altering channel depths or courses, obstructing channels with debris, or destroying or moving equipment and aids to navigation. Major oil or hazardous substance spills can have serious consequences, and lead to extended waterway closures while spill response measures are brought into action. The harbor channels are also vulnerable to potential man-made threats such as mines (and the attendant need for detection and sweeping by naval craft), as evaluated in a Transportation Research Board (TRB) report.³⁶ Together, these threats have the potential to jeopardize the continued operations of the MTS serving domestic and foreign commerce.

Consequences of Disruption in Harbor Channels

The consequences of unmet channel depth and harbor-side throughput capacity needs may be economic costs (including vessel delays and the growing number of “constrained calls”) as well as the potential loss of life, injuries, and environmental damages that can occur as a result of a disrupted navigation.

Economic costs of the disruption include traffic delays caused by inadequate channel depth and unavailability of some harbor facilities on a full-time basis. Because of inadequate channel size, many of the highly-used U.S. harbor channels today are available only a fraction of the time. The CMTS analysis of the level of funding support needed to maintain the most highly used Federal navigation channels showed that a key segment of these channels (referred to as the center channel or half-width of the channels) is available only 35 percent of the time. This condition is counter to the USACE five-year plan to achieve 95 percent half channel availability for these projects.³⁷

The growing number of “constrained calls” – defined as cases in which a vessel’s design draft plus a safety clearance exceeds channel depth restrictions – has been another consequence of the inability of the U.S. waterways to meet the channel depth requirements of the vessels. The National Dredging Needs Study of U.S. Ports and Harbors (NDNS) has identified the magnitude and timing of needed harbor improvements to accommodate future vessel sizes and vessel calls projected at U.S. waterways in 2020 and beyond. It has concluded that without the planned channel improvement projects, the total number of “constrained calls” by 2020 would be about 25 percent of the total vessel calls. The NDNS

³⁵ USACE, “National Dredging Needs Study of U.S. Ports and Harbors, Update 2000,” May 2003.

³⁶ Transportation Research Board, “Marine Salvage Capabilities: Responding to Terrorist Attacks in U.S. Ports - Actions to Improve Readiness”, 2003.

³⁷ Draft CMTS Report to the President, dated 11/14/07.

predicted that completion of the planned projects nationwide by 2020 would reduce constrained calls by half.³⁸

Given that many major West Coast ports are operating today at near capacity because of the rapid growth in container traffic, the economic consequences of capacity shortfalls at these congested U.S. ports could also be severe if significant volumes of traffic are diverted to alternative gateways. Underscoring the economic consequences of inadequate funding for MTS maintenance operations is a recent report by the TRB, National Academy of Science (NAS), on challenges of infrastructure financing. The report identifies inadequate maritime funding mechanisms for system maintenance as an alarming trend, warning:

“Lack of system preservation and rehabilitation produces a downward spiral...The price of short-term savings from deferred maintenance, however, is proportionately greater rehabilitation cost later...Raising the visibility and developing support for system preservation is critical to the 21st century transportation system.”³⁹

Loss of life and injury consequences of inadequate channel capacity and depth may also be significant, as identified in the analysis conducted by the CMTS, which points out the potential threats to navigation safety from “light-loading” or “lightering”.⁴⁰ (Threats to user safety and loss of life issues will be addressed in a future task report on MTS Safety Challenges.)

Resiliency and Mitigating Factors

Three attributes of the MTS waterway facilities: their even regional distribution, the large number of secondary deepwater terminals, and the significant number of unused or underutilized terminals, could potentially contribute to MTS resiliency. The diverse geographic distribution of the nation’s ports and terminals is a potentially significant factor in bolstering the system resiliency. As noted above, the U.S. navigable waterway system has some 6,500 commercially active ocean and gulf facilities, 2,300 inland river port facilities, and 750 Great Lakes facilities.⁴¹ The fact that the U.S. marine ports and waterways are evenly distributed throughout the nation could potentially contribute to the resiliency of the inland waterways. Availability of alternate terminals and cargo loading facilities enhances the built-in positive redundancies in the MTS, given the vulnerability of the waterways to disruption, particularly weather related events. More efficient utilization of unused port capacity would reduce traffic concentration and risks of disruption.

Figure 9 illustrates the distribution of the navigable waterway facilities in the U.S., showing that 21 percent of the facilities were located on the Atlantic Coast, 18 percent on the Pacific Coast, 24 percent on the inland rivers, 29 percent on the Gulf Coast, and 8 percent on the Great Lakes.

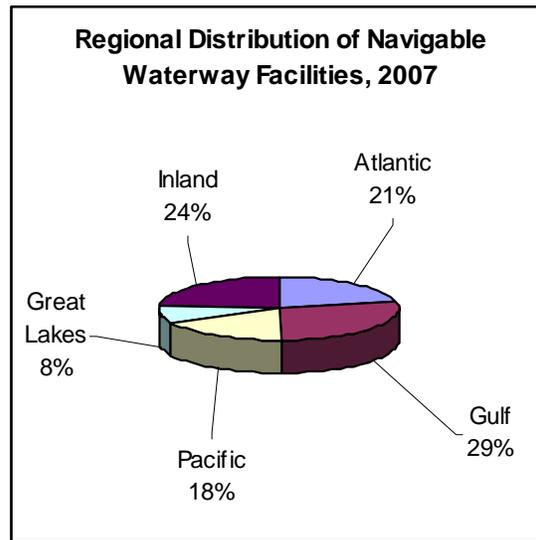
³⁸ USACE, “National Dredging Needs Study of U.S. Ports and Harbors, Update 2000,” May 2003; pp. 183-185. Note that these forecasts are dated and new forecasts will be used when available.

³⁹ TRB, *Critical Issues in Transportation*, National Academy of Sciences (NAS), 2005.

⁴⁰ Draft CMTS Report to the President, dated 11/14/07.

⁴¹ USACE, *Transportation Facts*, 2007.

Figure 9 - Dispersed Regional Distribution of the Navigable Waterway Facilities, 2007



Source: Volpe generated chart based on data from USACE, U.S. Waterway System – *Transportation Facts*, 2007

The large number of deepwater port facilities available in all regions of the U.S. further enhances the potential resiliency of the MTS. The Waterborne Commerce Statistics indicate that approximately 5,000 of the MTS waterway facilities are deepwater and 4,400 shallow water facilities. Of the 5,000 deepwater terminals in the U.S., only a fraction – approximately 300 terminals (or 6 percent) – handles significant volumes of commercial traffic. About half of these 300 deepwater terminals are identified by the Waterborne Commerce Report as “selected.” These selected terminals handle more than 1,000,000 tons of cargo annually. Of these, there are approximately 55 ports that handle more than 10,000,000 tons annually, and have channel depth of over 40 feet. Deepwater and shallow water facilities by region are as follows (and presented graphically in Figure 5):

- Atlantic Coast - 1,473 deepwater and 587 shallow water facilities
- Gulf Coast - 1,606 deepwater and 1,093 shallow water facilities
- Pacific Coast - 1,387 deepwater and 363 shallow water facilities
- Great Lakes - 600 deepwater and 154 shallow water facilities
- Inland river system - 2,321 shallow water facilities.⁴²

⁴² Based on data from USACE, U.S. Waterway System – *Transportation Facts*, 2007. Note that there are deep water facilities on the inland waterway system as well, but the source does not identify them.

Finally, a mitigating factor that could potentially relieve some channel depth constraints may be the large number of unused facilities. Between 1996 and 2007, the total number of unused facilities grew from 770 (8.2 percent) to 986 terminals (or 10.3 percent of all waterway facilities) distributed relatively evenly through all regions, as depicted in Figure 6. Though it may be an indicator of suboptimal facility utilization or inadequate terminal service levels, the large number of unused inland facilities could potentially serve as a positive factor in enhancing MTS resiliency.

Resiliency of the Gulf area marine and rail facilities in the aftermath of hurricane Katrina was in many respects remarkable. The region's port facilities, levees, dams and offshore oil refineries suffered severe damages estimated at billions of dollars. The initial maritime damages were estimated at over \$10 billion, including \$1.7 billion for damages to the five ports in the Gulf (mostly through blocked waterways, damaged locks and bridges, and destroyed port assets); approximately \$5 billion for insured losses to oil refineries; and \$4.5 billion for damaged levees. Concentration of refineries in the storm-damaged Gulf area contributed significantly to the size of the damage. But most services were resumed relatively rapidly, partly because of the redundancies in the system. The shippers and operators that had the agility to move cargo traffic operations to alternate locations shortly after the hurricane hit the Gulf region were best able to resume operations rapidly.⁴³

The resiliency of the harbor channels, as measured by the facilities' ability to respond effectively to disruptions caused by inadequate maintenance and capacity constraint, could potentially be significant if some of the available system solutions and mitigative measures are deployed. Diversion of traffic away from highly congested to less congested ports is made feasible because of the large number of underutilized facilities. Given the large concentration in the top 15 ports, a diversion to other deepwater ports would be feasible without high-cost tradeoffs in terms of degraded service performance or penalties in terms of longer routes. The MTS research community has identified a number of strategies that could serve as effective countermeasures for mitigating the risks of inadequate channel depth or harbor capacity:

- LoadMax, or the River Level Reporting and Forecasting System, is a tool developed through an initiative by the Columbia River ports and users of the deep-draft channel to maximize cargo lifts on ocean freighters without deepening the channel. LoadMax is a planning tool that helps pilots and captains set departure times and vessel speeds to take advantage of tides and fresh water flows. Using LoadMax, vessels can be loaded to the maximum depth allowed for a safe vessel transit. The participants in the initiative conducted a Feasibility Study for the option of deploying LoadMax as a substitute to channel deepening. Based on an analysis that included expert testimony from system users and developers, the study determined that while incremental improvements to the

⁴³ Illustrating the importance of access to redundant terminal location to avert prolonged disruption in traffic is the realignment decision made by the Kansas City Southern Railroad (KCSR) in the aftermath of hurricane Katrina. KCSR, by diverting traffic away from the hurricane ravaged parts of the region was able to promptly resume service and serve many Class I railroads, including the Norfolk Southern railroad, after shifting the interchange points for its east-west traffic on its short-line Speedway to Meridian, Mississippi, and Shreveport, Texas. Source: Progressive Railroading, October 2005.

LoadMax system were possible, these improvements would not be a full substitute for the benefits generated by a three-foot deepening project. The study concluded that even though LoadMax is not a perfect substitute for all channel-deepening projects, the system confers significant benefits to the users and that the ports and Columbia River users should continue to invest in LoadMax for improvements in their river level forecasting capability. These improvements, the study concluded, will aid vessel loading in both the 40-foot and 43-foot channels.⁴⁴

- Sediment management programs for disposal of contaminated dredged material offer other strategies for mitigating the problems associated with channel deepening. The Environmental Protection Agency (EPA) has estimated that excessive sediment erosion, transport and deposition cause damages of approximately \$16 billion annually in North America. The U.S. spends about \$800 million annually on dredging sediments from locations where too much has been deposited. Excessive sediment in rivers, reservoirs, or estuaries may contribute to high turbidity, loss of flood carrying capacity and sediment deposition in navigable waterways. Yet in other locations, a shortage of sediment causes coastal erosion, stream bank erosion, and wetland loss. Many water resource projects are designed to remedy local sediment problems, and sometimes create even larger problems some distance away. Efficient sediment management may offer an effective solution to many of the current challenges.⁴⁵ Disposal of contaminated sediments has also created significant challenges. Identifying beneficial uses of dredged material has been proposed as a solution to the large volume of sediments dredged each year. Data indicate that only 5-10 percent of all dredged materials are contaminated, and that sediment erosion and loss of habitat are often more damaging than contamination. The need for more efficient tools and information systems for management of sediment risks has been recognized. One innovative approach is the development of tools for tracking the volume of dredged material to increase their beneficial use.
- Many analytical tools have been developed to mitigate the impacts of adverse MTS infrastructure conditions. Among these tools is a model developed for the Coastal Structures Asset Management that illustrates mitigation strategies that will help enhance the resiliency of the waterways maintained by the USACE. Rather than prioritizing the repair schedules based on the physical condition of the waterway assets, these analytical tools use other decision factors based on the assessed risks and severity of consequences. The following Text Box shows an example of decision-making tools used for FY06-funded work at the Engineering R&D Center (ERDC), Coastal and Hydrological Laboratory (CHL), for prioritization of repairs based on failure consequences.

⁴⁴ See AAPA, <http://aapa.files.cms-plus.com/pdf> and http://www.channeldeepening.com/channel_econ_QA.asp

⁴⁵ EPA, "Dredged Material Management: Action Agenda for the Next Decade," EPA842-B-04-002, July 2003, based on a workshop sponsored by the National Dredging Team, January 23-25, 2001, Jacksonville, Florida.

- The CMTS efforts for standardization of data used for navigation technologies have gained a momentum in Federal support. The CMTS, reporting on the comprehensive analysis of the Harbor Maintenance Trust Fund (HMTF), notes a beneficial by-product of CMTS' review of the safety and inefficiency implications of the delays and vessel light-loading when confronted with inadequate channel depth. This beneficial by-product is represented by the successful outcomes of the efforts to standardize the presentation of bathymetric data for both USACE and the National Oceanic and Atmospheric Administration (NOAA) electronic navigation charts (ENC). The CMTS believes that standardization of ENC data will lead to improved efficiency in MTS data acquisition and display.⁴⁶ The MTS might also benefit from extending standardization of data and terminologies to include cargo, vessels, and infrastructure. The Office of Naval Intelligence is currently working on standards for data in support of search for anomalies in the system. The involved Federal agencies have stressed the need for appointing a lead agency for setting the standards and determining the role of CMTS regarding data sharing and standardization (Note: Institutional and data-sharing issues will be addressed at length in Task 6 of this project.)

⁴⁶ Draft CMTS Report to the President, date 11/14/07.

4-2 Locks and Dams

Characteristics

The 12,000 miles of inland and intracoastal waterways that are maintained by the USACE are made navigable by approximately 200 commercially active locks and dams. USACE is responsible for 275 lock chambers at 230 sites, but due to funding shortfalls, only 196 of the commercially-active lock sites and 240 lock chambers currently receive funding.⁴⁷ About 171 of these lock sites are located in designated fuel-taxed waterways.

The design life of an average lock is 50 years. Currently, over half of the lock chambers in the U.S. waterway system have exceeded their design lives. The USACE is also responsible for inspection and maintenance of the Federal levee system. Annually, the Corps inspects some 2,000 levee units (13,000 miles of levees). Most levees built by the USACE are turned over to State or municipalities who then assume maintenance responsibility. There are also many non-Federal facilities built by local communities. All non-Federal facilities, if properly maintained and operated by the owner, are eligible for Federal rehabilitation assistance. The safety of these levee systems is of concern for Federal and local entities.⁴⁸

Threats and Vulnerabilities

Unavailability of the inland lock and dam system, the associated disruption in navigation due to unscheduled closures and delays, and the potential for loss of life and property damage due to dam failures pose significant threats to the viability of MTS infrastructure.

Aging locks, levees, and dams, coupled with lack of funding for maintaining them, and inadequate lock size for accommodating modern vessels are key vulnerabilities that place the viability of the MTS waterway system at risk. More than half the locks in the inland waterway system are over 50 years in age. Many of the locks in need of maintenance and repair have not received the needed funding.

Undersized locks, i.e., locks that require breaking up tows at each lock and reassembling them once through the lock, represent a related area of vulnerability. Lock queues and bottlenecks add to operating costs and transit times.

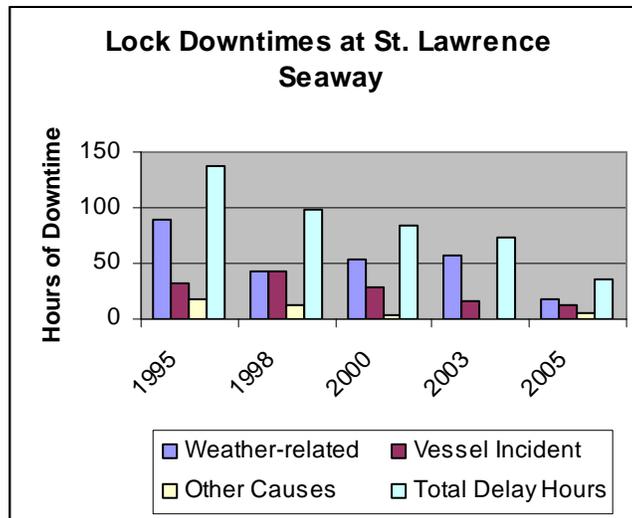
Vulnerability to adverse weather and vessel incidents accounts for the majority of the lock downtimes. In 2005, the U.S.-maintained locks at the St. Lawrence Seaway, for instance, reported nearly 40 hours of downtime due to weather-related causes, vessel incidents, and other causes (Table 10.) (Weather-related causes include poor visibility, ice conditions, and high wind; other causes contributing to lock problems include lock equipment malfunction,

⁴⁷ The USACE US Waterway System – *Transportation Facts*, 2007 has reported that the USACE owns or operates 257 lock chambers at 212 sites.

⁴⁸ USACE, New Release, “U.S. Army Corps of Engineers Provides Locations of Unacceptably Maintained Levees,” February 1, 2007.

civil interference, pilotage, and water level and flow causes.)⁴⁹

Figure 10 - Lock Downtimes by Cause of Closure



Source: Volpe generated chart based on BTS data and <http://www.greatlakes-seaway.com>

The nation's dams are also suffering from lack of maintenance and modernization funds. According to a recent study by the Urban Land Institute, engineers have identified 3,500 unsafe dams in the U.S., and not enough funding has been available for repairing them.⁵⁰

Adequate funding for levee and dam maintenance has not been available either.⁵¹ This funding shortfall has compounded the effect of aging locks and created a backlog of maintenance and repair work. The results have been increasing downtimes and higher risks of a major component failure. The Urban Land Institute report cited above warns against the consequences of failure to repair the dams:

“Failures risk significant loss of life and substantial property damage. In the wake of dam construction years ago, many new communities across the country have been developed obviously in downriver flood plains, assuming breaches were not a threat.”⁵²

To estimate the gap between the actual and optimal funding levels, the USACE Lakes and Rivers Division (LRD) has developed tools, assessment models, and needs assessment criteria for improving lock performance and improving the resiliency of the system. In 2006, LRD drafted a report on the agency's Uniform Performance Standards used to rate 68 projects and provide a 5-year perspective on the status, needs, and expectations for Ohio

⁴⁹ BTS, <http://www.bts.gov> and <http://www.greatlakes-seaway.com>

⁵⁰ Urban Land Institute, *Infrastructure 2007: A Global Perspective*, 2007. <http://www.uli.org/AM/>

⁵¹ USACE provides maintenance funding out of the General Revenue funds. Funding for lock and dam rehabilitation is provided through Inland Waterway Trust Fund.

⁵² Urban Land Institute, *Infrastructure 2007: A Global Perspective*, 2007. <http://www.uli.org/AM/>

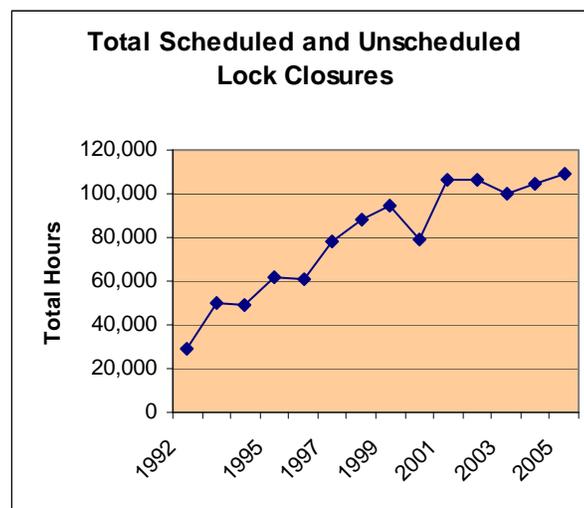
River Basin and Great Lakes navigation. The report showed that 50 of the 68 projects were rated below their acceptable level.⁵³

Consequences

The consequences of inadequate performance for the MTS locks, dams and levees include shipping delays due to frequent unscheduled facility closure, economic costs of delays and disruptions, and potential loss of life and property due to dam and levee failure.

Navigation lock unavailability and lock closures have grown between 1992 and 2005, from approximately 30,000 hours in 1992, to nearly 110,000 hours in 2005. The nearly fourfold increase consisted of about 60,000 hours of scheduled and 50,000 hours of unscheduled lock downtimes (Figure 11).⁵⁴

Figure 11 - Total Scheduled and Unscheduled Lock Closures



Source: Volpe produced chart based on data from the USACE, David Grier, August 8, 2007.

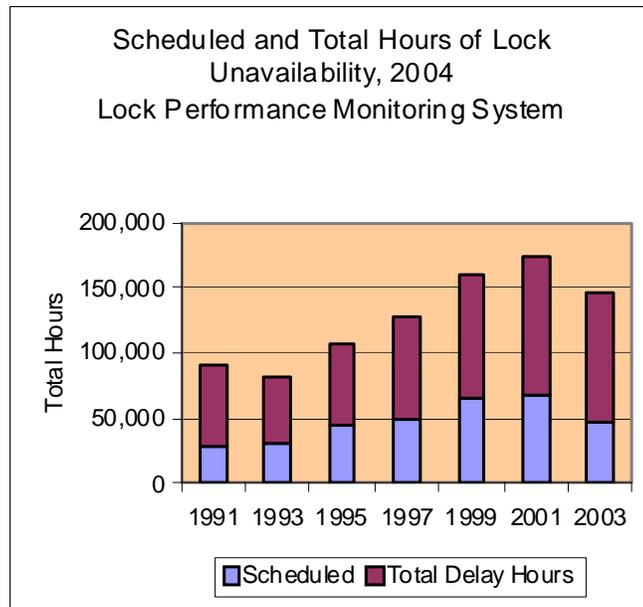
The growth in lock downtimes has been primarily due to a rise in unscheduled lock closures. Data from the USACE Lock Performance Monitoring System show the relatively more rapid rise in unscheduled lock closures between 1992 and 2005 (Table 12).⁵⁵

⁵³ Stuart D. Foltz and David T. McKay, *Condition Assessment Aspects of an asset Management Program*, USACE, August 2007, p. 87-88; LRD Project Performance Level. The LRD report included the following information: lock statistics; navigational benefits, funding needs, and network level planning needs; 10-year actual and optimal out-year funding by FY for LRD and by project (FY01-FY11). [e.g. for FY01-06 actual funding = ~ \$150 million; for FY07-FY11 Optimum Funding = ~\$180 million; general and specific performance level rating and minimum acceptable levels for each project: A= no compromise; B= Minimal compromise; C=moderate compromise; D = significant compromise; F = Extreme compromise.

⁵⁴ David Grier, "Waterway Services, Issues and Capacity: the Corps of Engineers' Role" presentation to the Midwest Agricultural Transportation Conference, Naperville, Illinois, August 8, 2007.

⁵⁵ David Grier, "Waterway Services, Issues and Capacity: the Corps of Engineers' Role" presentation to the Midwest Agricultural Transportation Conference, Naperville, Illinois, August 8, 2007.

Figure 12 - Trends in Lock Unavailability Due to Unscheduled Closures



Sources: Volpe generated chart based on USACE data for Lock Performance Monitoring System, 2004

The time cost of lock queues and bottlenecks have been estimated at over 550,000 hours annually, costing the users \$385 million in added operating costs. The queues result from traffic building up as cargo enters the rivers for transit during lock downtimes. An extended shutdown of any of the lowermost locks in any area would result in extensive shipping delays affecting entire regions and industries. Such shutdowns have occurred repeatedly in the past due to lock malfunction and extreme flooding events.

For the Federally-maintained levee system, the consequences of levee failure due to poor maintenance are potentially catastrophic. According to a USACE report released in February 2007, there are some 121 levee units – accounting for 6 percent of the 2000 levee units inspected by the USACE – that are in unacceptable condition.⁵⁶ The Urban Land Institute report cited above has the following warning about the failure of the levees damaged in Louisiana in the wake of the 2005 hurricane Katrina:

“...levees built and patched over the past 150 years breached and overflowed. For decades, officials knew that levees had been slowly sinking and realized protective barrier islands and wetlands along the coasts had been destroyed....A patchwork of local levee districts and the Army Corps of Engineers undertook ad hoc repairs, but political initiative was lacking to initiate the expensive steps to shore up the entire flood protection system and fend off potential catastropheThe price tag for tax

⁵⁶USACE, New Release, “U.S. Army Corps of Engineers Provides Locations of Unacceptably Maintained Levees,” February 1, 2007.

payers was too high, but a fraction of the \$110 billion in Federal aid committed in the storm's wake.”⁵⁷

To avoid the adverse consequences of the Louisiana levee failure, the California legislature enacted a \$9.5 billion bond issue to upgrade sinking levees around the low-lying areas in the Sacramento/San Joaquin Delta, reports the Urban Land Institute study, cautioning that:

“Engineers warn that planned enhancements from the recent bond issues will not shore up levees enough to sustain damage from predicted 6.5 earthquakes or worse that could strike the region at any time. . . . If the Cassandra warnings ever come true, \$9.5 billion will seem like a drop in the bucket compared to possible damage. . . . The total investment needed to bring all 79,000 dams nationwide into safety compliance totals \$30 billion, while the Federal government provides less than \$10 million annually to the states for such programs. Most cash-strapped states do not give dams and levees high priority either.”⁵⁸

The Urban Land Institute report concludes:

“ A combination of underfunding, unchecked development, and a blind eye to obvious dangers suggests taxpayers face a choice of paying more today or multiples tomorrow for a potential cascade of predictable, tragic Katrina-like outcomes.”

Supporting the above warnings about the need for long-term investment to avert natural hazards is a RAND study reporting that in the U.S. the average annual losses from natural hazards amount to about \$17 billion, with about 62 percent of the losses attributed to weather-related events. Annual losses from floods alone were estimated at \$3 billion. The study pointed out that while the numbers of lives lost due to natural hazards such as hurricanes and floods has declined, the associated costs of these events have escalated. To underscore the escalating monetary costs of natural hazards, the study pointed out that between 1978 and 1989, the Federal Emergency Management Agency (FEMA) paid out about \$7 billion in disaster relief funds; in the next dozen years, between 1990 and 2002, the payouts increased fivefold, to over \$39 billion.⁵⁹

Resiliency and Countermeasures

Several studies have identified a number of countermeasures for addressing lock and dam performance, including the Carnegie Mellon University SmartLock system, the University of Virginia Lock Upgrade study, and the Oak Ridge National Laboratory (ORNL) user fee study.

The SmartLock system is a technology initiative conducted to identify effective countermeasures for addressing performance of the MTS locks and dam system. The Port of Pittsburgh Commission, in coordination with the Carnegie Mellon University conceived the SmartLock system. Working with towing companies and other stakeholders, the team developed a prototype system based on the same principles used for the air traffic control

⁵⁷ Urban Land Institute, *Infrastructure 2007: A Global Perspective*, 2007, p 32.

⁵⁸ Urban Land Institute, *Infrastructure 2007: A Global Perspective*, 2007, p 32.

⁵⁹ RAND, *Assessing Federal Research and Development for Hazard Loss Reduction*, Charles Meade and Megan Abbott, prepared for the Office of Science and Technology Policy, 2003.
http://www.rand.org/pubs/monograph_reports/2005/MR1734.pdf

system. This navigation, networking, and communication system establishes links between the tow and the lock and gives the pilot of the tow greater knowledge as to the position of the tow relative to the lock. This allows the operation of the lock to continue and speeds the locking process during periods of low-visibility and adverse conditions. The installation of the lock components of the SmartLock system costs about \$40,000 per lock, and about \$20,000 per boat or tow.⁶⁰ This system would need to be implemented over a broad stretch of river in order to demonstrate its economic efficiency.

The University of Virginia Lock Upgrade Study is an example of a study conducted to address the problems of inadequate river lock system. The study proposed a set of alternative solutions for integration, including: a) lock upgrade and replacement, b) iModal, an intermodal information technology solution, and c) a transportation consortium:

- a. Lock Upgrade and Replacement: The proposed lock modernization strategy consists of a phased approach to upgrading the system that involves identifying candidate locks in need of repair, and investigating how to decrease scheduled outages due to mechanical failure, increase lock throughput, and integrate new construction technology to lower the costs associated with building a new lock.
- b. iModal: The goal of this tool is to find a solution for shipping cargo in the most efficient manner, taking into account tradeoffs of time and cost, independent of any specific mode. The tool creates a centralized, web-accessible software system and associated service that will seamlessly integrate all aspects of container-on-barge (COB) shipping with the existing intermodal system. The tool would serve as a single point of collaboration between waterway shippers, lock control towers, port authorities, terminal operators, bridge tenders, distributors, and manufacturers/shippers. The software system would be developed by an independent 3rd party intermodal operator, allowing the intermodal COB service providers to offer point-to-point shipping service utilizing truck, rail, air, ocean barges, and inland waterways. The tool would integrate the following technologies:
 - Inventory tagging, with a radio frequency identification (RFID) system for identification of cargo on barges and in containers, with required information about route;
 - Brokering: a system for providing automated brokerage service, matching up shippers with carriers, allowing barge operators and truckers to utilize empty containers and find loads for return trips;
 - Real-time tracking: allowing all shipments to be tracked online in real time, utilizing data collected at each terminal, with location identification help from a Global Positioning System (GPS) device attached to each barge.

⁶⁰ Ron DeParma, New Technology could Help Boats Navigate Thick Fog, Pittsburgh Tribune-Review, October 5, 2005

The output of the iModal tool is a Network Diagram for the five river ports in the system, St. Louis, Cincinnati, Memphis, New Orleans, and Pittsburgh. Locations of rail and truck terminals are identified as hubs in the network. The spokes in this network represent the optimal combination of modes (water, rail, truck) with the optimal paths determined through algorithms based on maximum and minimum transport costs per ton-mile and maximum weight. The tool produces approximate cost of shipping 40 tons of cargo between the five cities in the network for each mode of transport. For instance, to ship 40 tons of cargo between St Louis and Cincinnati, iModal estimates that it costs \$2,808 by truck, \$463 by rail, and \$276 by barge.

- c. Transportation Consortium: The study envisioned the consortium to operate as a separate entity that derives its revenues from fees paid by shippers, operators, government grants and contracts, and fuel taxes. The consortium is planned for the purpose of improving throughput, traffic management, and situational awareness for shippers and customers. The Consortium operations will be driven by iModal through a collaborative, open information network that would market the service to shippers and carriers and
- Provide improved security for cargo, containers, ports, data, tugs, barges, tows and vessels;
 - Manage external technologies such as automatic identification system (AIS), vessel traffic services (VTS), Electronic Chart and Display Information System (ECDIS) and Voyage Data Recorder (VDR);
 - Provide optimized scheduling to find optimal paths over all modes, eliminate empty containers/barges, and broker return trips;
 - Coordinate inspection of containers and barges through RFID tracking, and other homeland security measures;
 - Provide real time cargo/container/barge tracking and inventory control with RFID and GPS location devices;
 - Facilitate interfaces for intermodal information sharing with standardized data formats and supply chain management;
 - Provide situational awareness regarding unscheduled outages with estimated wait times, rerouting capabilities, real-time port and lock status updates, weather and tidal forecasts, bridge opening schedules, river depth changes, chart updates, and dredging activities.

Another potential solution to the high cost of maintaining the lock and dam system has been identified in studies conducted on the feasibility of user fees to pay for lock and dam maintenance. The Oak Ridge National Laboratory (ORNL) conducted a study for the U.S.

Department of Energy (DOE) to estimate the benefits of collecting fees at locks as a non-structural alternative for the Ohio River Mainstream study.⁶¹ The ORNL evaluated the feasibility of charging a fixed annual dollar-per-ton fee for each lock. The purpose would be to maximize the national economic development (NED) benefits (or the “social optimum”). The study evaluated both short- and long-term congestion fee systems. While longer-term fees are based on the unique traffic patterns prevailing at the lock, short-term fees are typically imposed on a seasonal/daily/hourly basis during high congestion periods, with the goal of reducing congestion at locks, to spread traffic or move it off system. Short-term fees require modeling individual shipments and need to account for the NED costs of changing schedules or moving off system.

⁶¹ M. Hilliard, I. Bush, et al., “Modeling Optimal Congestion Fees within the Ohio River Navigation Investment Model,” ORNL, UT-Battelle, undated document

Section 5. Ports: Characteristics, Risks, and Resiliency Status

The MTS commercial port infrastructure is impacted by three key constraints: a) the gap between the ports' channel depth/capacity and the draft requirements of the vessels calling at these ports; b) the concentration of vessel activities at these ports; and c) unique facility vulnerabilities to weather-related and man-made disruptions. These constraints are addressed in this section separately for container and bulk ports.

5-1 Container Ports

Characteristics

The U.S. container port infrastructure is characterized by two key constraints: a) a widening gap between the capacity/channel depth requirements of the shipping vessels calling at these ports and the ability of the ports to meet them; and b) high concentration at the top 5-10 container ports.

In 1997, almost 80 percent of all container traffic was handled among the top 10 intermodal ports (8.3 percent of the ports numerically). By 2007, this figure had risen to 85.3 percent. During the same time frame, concentration of all import and export activities from the top 30 ports rose from 98.8 to 99.3 percent.

The widening gap between the draft requirements of the container vessels calling at U.S. ports and the existing harbor channel depths has led to a growing number of containership "constrained calls," as addressed in Section 4-1. As noted earlier, a "constrained call" is a vessel call where the vessel's design draft plus a safety margin exceeds channel depth. Constrained calls adversely impact the large shipping vessels calling at the U.S. ports because of the additional costs and delays entailed. The USACE NDNS described earlier has identified the magnitude and timing of needed harbor improvements to accommodate future vessel sizes and the number of vessel calls anticipated at U.S. harbors in 2020 and beyond.⁶²

Concentration of the container shipping activities at a handful of ports is another key infrastructure constraint. The top five container ports (LA/LB, New York, Seattle/Tacoma, Savannah and Charleston) grew by 57 percent between 2001 and 2006. The top 10 ports (which in addition included Norfolk, Oakland, Houston, Miami, and Port Everglades) grew by 54 percent over the same period (Figure 13). In 2006, the top 10 U.S. container ports accounted for over 90 percent of U.S. international containerized trade measured in TEU, up from 78 percent in 1995.⁶³

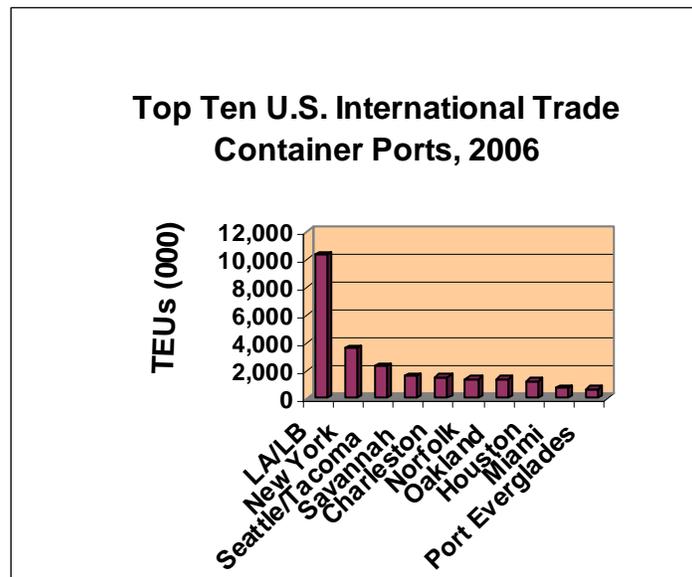
The trend in concentration of container traffic at a few large ports has become intensified as increasingly larger and more specialized vessels have entered the market. Some 56 percent

⁶² USACE, The National Dredging Needs Study of Ports and Harbors: Update 2000," IWR Report 00-R-04, May 2003.

⁶³ MARAD, U.S. Water Transportation Statistical Snapshot, May 2007.

of the U.S. containerized merchandise trade (15.5 million TEUs) passed through West Coast ports in 2006, up from 42 percent in 1980. The growth reflects in part the growing trade volume with China and South East Asia, and the geographic proximity of the West Coast ports to this region (Figure 12). Ports of Los Angeles and Long Beach (LA/LB) together accounted for 38 percent of the total TEU traffic in 2006. On the East Coast, Port of Savannah showed the highest rate of growth (94.5 percent) between 2001 and 2006, reflecting the expansion in U.S. container trade with Latin America and changes in shippers' decision to divert shipment away from congested West Coast Ports, as described below.⁶⁴

Figure 13 - Top 10 U.S. Container Ports, 2006



Source: Volpe generated chart based on data from MARAD, *U.S. Water Transportation Statistical Snapshot*, May 2007

Threats and Vulnerabilities

Among the events that can go wrong at the nation's container ports, based on the definitions of threats and vulnerabilities provided in Section 2, are the threats of disruption in port operations due to capacity constraints and congestion-related delays. Other potential threats to container ports include man-made disruptions – labor strikes, military deployments or terrorist attacks – as well as accidents, spills, and natural disasters.

The vulnerabilities at the U.S. container ports that could increase the probability that the potential threats to port operations could be realized stem from: a) inability to close the growing gap between vessel draft needs and the ports' existing channel capacity; and b) landside and harbor-side congestion caused by high concentration of traffic at a handful of container ports.

⁶⁴ Eric Wolfe, NOAA, has pointed out the practice of mini-land bridge and micro land-bridge has contributed to the trends in concentration of traffic, noting that micro land bridge accounts for 12 percent of all container traffic.

System vulnerabilities stemming from the ports' inability to close the gap between vessel draft needs and their existing capacity are in part driven by the high capital investment costs of deepening the harbor channels and modernizing the landside and harbor-side container handling facilities. The high cost of paying for new infrastructure to accommodate larger vessels has in turn been a major contributing factor to the growing container port concentration. Accommodating the growth in the size of today's containerships requires significant levels of capital investment – not only for dredging the channels and deepening the berths, but also paying for improved landside capacity and for larger cranes, container storage and marshalling yards, and advanced information systems. The fact that only a limited number of ports have made those investments has reinforced the trends in concentration of container traffic at the top 5-10 ports, as pointed out in a recent Bureau of Transportation Statistics (BTS) report.⁶⁵

Consequences of Container Port Disruption

The consequences of the risk factors outlined above – the gap between channel depth/capacity and the vessel requirements and a high concentration of traffic at a few top container ports – include: a) loss of trade revenues and the attendant costs and operational disruptions arising from shipper/carrier uncertainty about reliability of the service; and b) loss of excess capacity, and the attendant narrowing of the operational margin of error.

- a. Loss of trade revenues arising from an actual or anticipated port closure has been manifested through economic losses to port regions and emergence of new networks of shipping lanes and cargo handling facilities. A recent Congressional Budget Office (CBO) study estimated the economic costs of disruptions by developing scenarios similar to the 2002 West Coast labor dispute. The CBO study examined two scenarios: a 1-week shutdown and a 3-year shutdown of operations at the Ports of Los Angeles and Long Beach. The one-week shutdown was estimated to lead to losses between \$65 million to \$150 million per day, with an estimated loss of \$450 million for an average week of shutdown. The 3-year shutdown was estimated to lead to greater losses, estimated to amount between 0.35 percent and 0.55 percent of the Gross Domestic Product (GDP), equivalent of a loss of \$45 billion to \$70 billion per year. The CBO study assumed that in the aftermath of the closure, the backlog of ships waiting to enter ports would be resolved by a number of strategies, including carrier flexibility to shift port calls to alternative ports, reconfigured supply chains (albeit at higher costs), and the possibility that producers might turn to domestic sources of supply and consumers consume a different mix of goods.⁶⁶ The CBO study attempted to correct for the previous high-end estimates of \$1.96 billion per day in losses from the 10-day 2002 shutdown of the Southern California container ports.⁶⁷

⁶⁵ BTS, *America's Container Ports: Delivering the Goods*, March 2007

http://www.bts.gov/publications/americas_container_ports/html/port_concentration.html

⁶⁶ Congressional Budget Office (CBO), *The Economic Costs of Disruptions in Container Shipments*, March 29, 2006. http://www.cbo.gov/ftpdoct/71xx/doc7106/03_29_container_shipments.pdf

⁶⁷ The estimated losses of \$1.96 billion per day were based on Martin Associates, *An Assessment of the Impact of West Coast Container Operations and the Potential Impacts of an Interruption of Port Operations*, 2000.

The loss of trade revenues from inadequate channel depth or landside terminal capacity has been estimated to be on the rise, partly because of the rising value of the container trade. These economic losses have been exacerbated by the greater vulnerability to disruption found at the large and severely congested container ports. As noted above, high levels of traffic concentrated at a handful of ports add to the risks of disruption, despite the geographic dispersion of U.S. container ports. This point has been underscored by the fact that eight of the top 10 U.S. container ports ranked by TEU volume are also in the top 10 ports ranked by cargo value.

Rising congestion and infrastructure construction costs have led to a growing uncertainty about the reliability of the large container ports, as a consequence of which some shippers and carriers have changed their cargo distribution channels and practices in order to limit the impact of port/terminal capacity problems or waterway closure. These practices have included shipper/carrier efforts to incorporate redundancy (e.g., multiple distribution center locations and additional vessel calls) in their supply chains and vessel rotation to ensure shipment reliability. One manifestation of this strategy has been the emergence of “import distribution centers” by national retailers to handle the new container distribution and vessel routing patterns. Among the consequences of this strategy has been the rapid growth in some smaller ports as a result of the shippers’ and carriers’ search for alternative ports of call, as demonstrated by the sharp increase in ocean-borne containerized cargo volume at the Port of Savannah.⁶⁸ [Note: The economic ramifications of these trends will be examined in greater detail in Task 2.)

- b. Loss of excess capacity is another adverse consequence of the rapid growth of the U.S. container trade, which can potentially have a cascading effect by further exposing the ports to threats of disruption, narrowing the port’s operational margin of error, and reducing the ports’ ability to resume normal operations. By one estimate, terminal excess capacity at marine terminals will disappear by 2011.⁶⁹ This projected loss of container ports’ unused capacity represents a looming vulnerability, leading to the reduced resilience of the waterway system and its diminished ability to return to normal operating conditions after disruptions in shipping operations. Currently, container transport demand at North American marine terminals stands at 400 million TEUs, with a utilization rate of 78.7 percent (representing a capacity level of about 500 million TEU.) Planned TEU capacity growth by 2011 will have reached 672 million TEU, but expected demand will have also increased to 672 million TEU, making the utilization rate 100 percent. There will be no excess capacity left.⁷⁰ (Figure 14). The impacts of current recession on

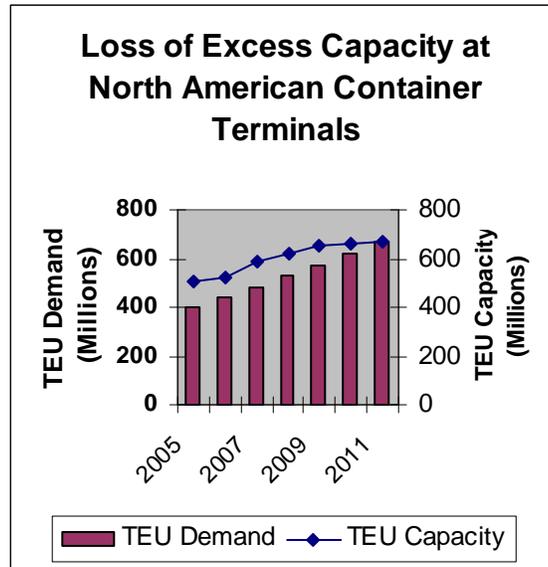
⁶⁸ BTS, *America’s Container Ports: Delivering the Goods*, March 2007.

⁶⁹ Note that the estimates for this analysis are derived from John Vickerman; more recent estimates from Global Insight (presumably more reliable) are not available at this point.

⁷⁰ Drewry Shipping Consultants data, reported in John Vickerman, “Global Ports & Containerization Development: Choke Points and Opportunities,” Presented at the Fourth Annual Grain & Oilseed Transportation Conference, Memphis, Tennessee, March 26, 2007.

the pushing out the dates of maximum capacity will be addressed in Task 2 Report.
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Figure 14 - Loss of Excess Capacity at North American Container Ports



Source: Volpe generated chart based on data reported in John Vickerman, "Global Ports & Containerization Development: Choke Points and Opportunities," March 26, 2007.

Resiliency and Countermeasures

Expanding the MTS container handling capacity through better utilization of the existing deepwater ports that are not part of the top 5-10 container ports is key to the nation's ability to be resilient in the event of container port capacity shortfalls and service disruptions. The above-cited CBO study on the economic impacts of container port shutdowns has addressed the significance of the factors that contribute to the resiliency of a port. The study analyzed the role of the factors that enhance a port or shipping region's resiliency in terms of the extent to which ports, shippers, producers, and carriers are capable of reducing the backlog of ships waiting to enter ports through: a) flexibility to expand capacity at alternative ports; b) ability to reconfigure supply chains to use alternative sources; and c) ability to turn to domestic sources of production input or consuming a different mix of goods.⁷²

In a study conducted by the Waterfront Coalition in 2005, the following recommendation pertaining to container port congestion was made:

"Promote and improve infrastructure to support Asian trade to the East Coast and Gulf Coast. In addition to support for alternative gateways on the West Coast, many US importers and exporters with distribution networks east of the Mississippi *could*

⁷¹ Threats posed by surface transportation issues, including truck driver shortage, emission limitations, and revenue inadequacy among railroads are also relevant, as pointed out by Eric Wolfe, NOAA.

⁷² Congressional Budget Office (CBO), *The Economic Costs of Disruptions in Container Shipments*, March 29, 2006

make better use of the Eastern gateways, and move cargo via “all water” services through the Panama Canal and the Suez.”⁷³

The *Waterfront Coalition Report* further called for the need for carrier strategies for utilizing the East Coast ports in response to shift of the Asian manufacturing centroid to Southeast Asia:

“Carriers should expand and improve Asia to East Coast service through the Suez Canal. Shipments from South China can be routed to ports of New York and New Jersey (NY/NJ) and Virginia through the Suez Canal with transit times that are only 1-2 days longer than shipments routed across the Pacific Ocean through the Panama Canal.”

The *Waterfront Coalition Report* also noted the severe congestion problems at the national container ports and intermodal railroads serving these ports, particularly the Southern California ports, and made extensive recommendations with a number of Action Items based on the responses of the MTS stakeholders, including:

- ✚ Improve productivity, efficiency, and throughput of all American blue-water ports by:
 - making harbor trucking a profitable business by improving their “turn times” and reducing wait times;
 - operating ports during extended hours, with the PierPass fee system serving as a model; develop regional or national chassis pools;
 - rethinking the “Free Time” and make terminal demurrage policies more efficient and reduce the “bunching” of trucks calling a terminal;
 - developing a port wide Truck Appointment Systems, modeled after initiatives such as the Internet Portal FIRST developed at NY/NJ;
 - spreading out vessel sailing and arrivals in the Trans-Pacific Trade to make maximum use of terminal capacity; and
 - developing “Best Practices” for measuring capacity and productivity at ports and terminals to keep the industry from “flying blind” in terms of knowing how much additional volumes of exports and imports can be handled before the system becomes overloaded.

⁷³ Waterfront Action - National Marine Container Transportation System: A Call to Action, Waterfront Coalition, May 2005; <http://www.portmod.org/news/press/White%20Paper.htm>.

✚ Encourage the development of Oakland, California, and Pacific Northwest ports as key alternative Asian gateways; to ensure these ports handle an increasing share of the trans-Pacific trade:

- Improve rail service from alternative western gateways; and address other issues that impede Oakland serving as a Transload Center for imports;
- Support the California Inter-Regional Intermodal System (CIRIS), a shuttle train between the Port of Oakland and one or more points in the Central Valley designed to divert container movements from truck to rail, and re-establishing rail service between Martinez and Tracy; examine the feasibility of the City of Shafter Shuttle Train;
- Invest in intermodal rail to increase the velocity of equipment moving container cargo and address choke pints at East-West choke points (particularly in support of the Chicago CREATE project; and
- Support East Coast rail projects such as the Port Elizabeth Express Rail.⁷⁴

5-2 Bulk Terminal Facilities

Characteristics

The U.S. waterborne commerce in 2008 amounted to 2.5 billion metric tons of cargo shipped. Foreign commerce accounted for 1.5 billion metric tons (62 percent); and domestic coastwise, inland waterways, Great Lakes, and other shipping lanes accounted for the remaining one billion metric tons of cargo shipments (38 percent).

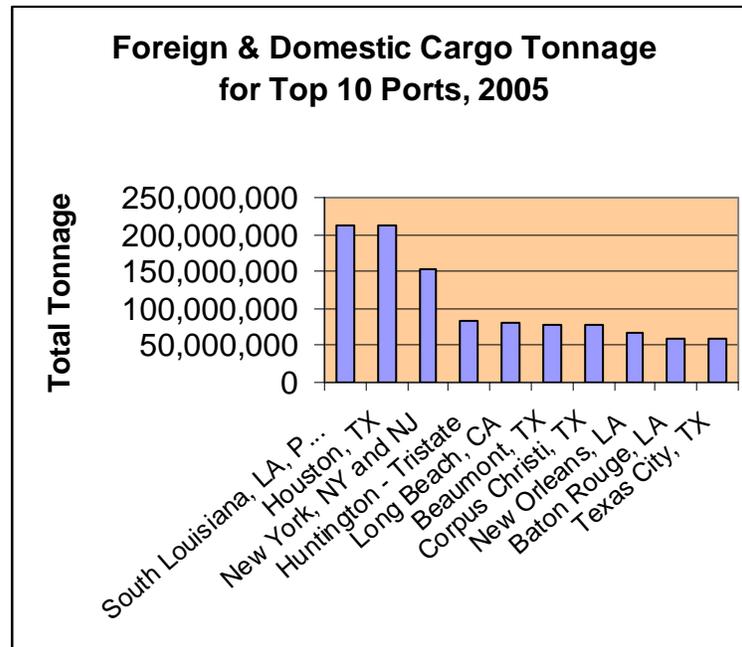
Cargo shipped by waterborne transportation in the U.S. consists predominantly on bulk cargo. However, the U.S. domestic and foreign commodity markets represent two distinct markets that are impacted differently by international trade forces. About 85 percent of the domestic tonnage of the MTS shipments, and 72 percent of the foreign tonnage of the shipments, are in bulk commodities. Tankers carry about 58 percent of the tonnage in wet bulk commodities (primarily petroleum); non-liner vessels carry about 27 percent of the weight in dry bulk cargo (for commodities such as grain, coal, and iron ores); and liner vessels carry the remaining 15 percent of the tonnage in containers. Commodities carried in domestic trade are distributed as follows: inland waterways carry 624 million metric tons of bulk cargo; domestic coastwise ports carry 267 million metric tons; and the Great Lakes carry 115 million metric tons.⁷⁵

⁷⁴ Other issues relating to U.S. Canada trade, including the US Harbor use fees, emission limitations, and currency exchange rates have been pointed out as relevant by Eric Wolfe, NOAA.

⁷⁵ Domestic coastal traffic in bulk cargo include cargo carried on non-contiguous territories between mainland and Puerto Rico, Alaska, Hawaii, and other US Pacific Islands; coastwise trade along the Atlantic, Gulf, and Pacific coasts, and between these coasts and the St. Lawrence Seaway; and Intracoastal trade between Atlantic, Gulf, or Pacific coasts by way of the Panama Canal.

The USACE, using different metrics to measure the volume of waterborne commodity shipments, reports that the top 150 U.S. ports in total tonnage for domestic and foreign trade carry 3.7 billion tons of cargo – with 1.9 billion tons shipped in foreign trade (52 percent) and 1.8 billion tons in domestic trade. The top 10 ports, carried 1.1 billion tons, accounting for 29 percent of the total volume (the top 10 ports transport a larger share of the foreign trade shipments (56 percent.) Figure 15 shows the top 10 U.S. ports in bulk freight tonnage.

Figure 15 - Top 10 U.S. Ports in Domestic and Foreign

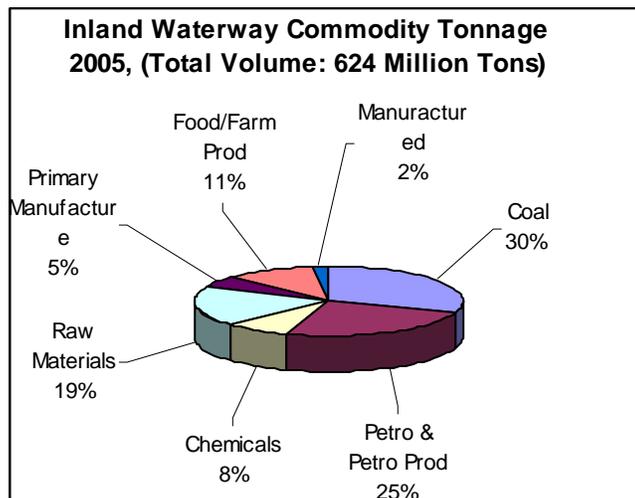


Source: Volpe generated chart based on data from USACE, Navigation Data Center, Waterborne Commerce Statistics Center, Tonnage for Selected Ports in 2005.

<http://www.iwr.usace.army.mil/NDC/wcsc/portname05.htm>

For bulk commodities carried on the inland waterways, coal accounts for the largest share of tonnage (30 percent), followed by petroleum/petroleum products (25 percent), raw materials (19 percent) and grain and farm products (11 percent) (Figure 16).

Figure 16 - Bulk Commodity Tonnage Shipped on Domestic Trade



Source: Volpe generated chart based on USACE Waterborne Commerce data.

Threats and Vulnerabilities

Threats to bulk port infrastructures stem from the probability of disruption and port closure due to vulnerabilities from harbor depth/capacity constraints, natural catastrophic events, and incidents stemming from the hazardous nature of the bulk cargo handled in these ports.

Capacity shortages have become a growing problem at some bulk facilities. Between 2001 and 2005, bulk traffic grew at a steady average annualized rate of 3.06 percent. Bulk ports have experienced some minor congestion as concentration at top 10 bulk ports has grown.

Capacity constraints at bulk ports are in part driven by lack of adequate investment in facility modernization and equipment. This is in turn a consequence of the low per-unit value of the bulk cargo carried on the waterways in domestic trade. Because cargo fees and funding priorities are tied to the value of cargo carried, the low value of bulk commodities often works against adequate funding for facility maintenance and upgrade at bulk ports. Also contributing to the low revenue base for the bulk ports is the relatively short length of haul for bulk domestic cargo. Because port revenues from cargo handling are distance based, the increasingly short length of bulk, break-bulk, general cargo, on the waterways makes most bulk port shipping operations vulnerable to facility under-maintenance. Traffic data indicate a steadily declining trend in the length of haul for domestic shipments: average length of haul for all domestic waterborne commerce has declined from approximately 800 miles in 1986 to about 500 miles in 2004. For coastwise cargo, the average miles-per-ton has declined from over 1,800 miles in 1986, to roughly 1,250 miles in 2004.⁷⁶

⁷⁶ Source: BTS http://www.bts.gov/publications/freight_in_america/html

Finally, the geographic susceptibility of bulk port facilities to natural disasters is a key contributor to the vulnerability of these facilities to disruption. Seven of the top 10 U.S. bulk ports as represented by cargo tonnage volume are in the Gulf region. This concentration of dry and wet bulk trade along the coastline from Texas to Florida implies a significant vulnerability to major storms, as demonstrated in the aftermath of Hurricanes Katrina and Rita in 2005. Ports located in Southern Louisiana and in the mouth of the Mississippi are the arterial channel for the Midwest and the central south regions, as well as much of the petrochemical industry.

Consequences

The economic and loss-of life consequences of a major disruption in the nation's bulk ports are potentially significant, given the vulnerabilities outlined above. The economic losses and disruptions in the flow of bulk freight through these facilities are potentially significant given the dependence of the economy on the movement of such critical bulk commodities as grain and petroleum.

Loss of life consequences of bulk port incidents are also potentially significant given the catastrophic outcomes of incidents caused by weather-related events and accidents triggered by the hazardous nature of the cargo handled.

Resiliency and Potential Countermeasures

Expanding the MTS bulk cargo-handling capacity through better utilization of the existing deepwater facilities not currently part of the top 10 bulk ports would be an effective measure for making the nation's ports more resilient in the event of a major disruption in the flow of critical bulk commodities. A number of recent studies on the feasibility of SSS along four potential domestic traffic lanes have found several bulk and break-bulk commodities that could be shifted to barge with the potential to generate significant economies of scale and cost savings. The study found that SSS could be particularly competitive for heavy break-bulk shipments, hazardous cargo, and bulk chemicals that currently move over the road. The report identified significant interregional container flows of commodities (for instance, some 10 million containers are shipped over the road per year from the Gulf to the New York region) that could potentially move by water and prove competitive with other modes for service.⁷⁷ The SSS initiatives currently underway include the Gulf Coast Self-Propelled Vessel Initiative, the Albany Express barge service, the Bridgeport barge service from the Port Authority New York/New Jersey (PANY/NJ), and the Norfolk-Richmond service. (Note: SSS and Marine Highway transportation strategies are examined in greater detail in Section 7 of this report and in future task reports.)

⁷⁷ Based on the testimony of Mr. Connaughton on February 15, 2007. The text of the OST study has not been made available.

Section 6. Intermodal Connections: Characteristics, Risks, and Resiliency Status

Characteristics

Intermodal connectors, including bridges, are defined as transfer points between “all freight modes involved in general cargo transportation (ship, rail, and truck), taken as a system for moving freight from origin to destination by its most efficient means.”⁷⁸ Intermodal access issues that impact MTS infrastructure performance include:

- Size and operating characteristics of shipping fleets;
- Ports’ landside and waterside throughput capacity;
- Availability and throughput capacity of rail lines, particularly double-stack trains; and
- Adequacy of road access.

Intermodal connectors – road and rail access routes as well as pipelines – are the linkages at the land-water boundary that allow the transfer of cargo and passengers between transportation modes. Intermodal connectors are sometimes referred to as the “first” or “last” miles between the port and the main highways. The National Highway System (NHS) includes connectors for the following MTS components:

- 1,400 connectors, including NHS connections to 519 freight terminals;
- Intermodal connectors to 253 “ocean and river ports”, 211 rail terminals, and 61 pipelines; and
- Connectors to 907 passenger terminals, including 59 ferry terminals.⁷⁹

Federal bridges are another component of the intermodal connectors. Federal law prohibits the construction of any bridge across the navigable waters of the U.S. unless first authorized by the USCG. As part of the permitting process, the USCG is required to apply a systematic interdisciplinary approach to assess the social, economic, and environmental effects of such a project, conducted by the Bridge Administration Program (BAP) to ensure that that the bridge does not pose unacceptable safety and environmental impacts.

Threats and Vulnerabilities

A key threat to the viability of MTS facilities is disruption in operations due to deficient or overloaded intermodal connectors. The system vulnerabilities that increase the probability that the threats could be realized are the weaknesses that stem from: a) missing or deficient port access links; b) structurally defective bridges; and c) congestion induced by inadequate capacity on key access links. Intermodal connectors are often considered the “weakest link” in the MTS network, creating vulnerabilities that have been a major contributor to disrupted maritime operations.

⁷⁸ NRC, *Landside Access to U.S. Ports*, Special Report 238, Transportation Research Board (TRB), 1993.

⁷⁹ Federal Highway Administration, “NHS Intermodal Freight Connectors A Report to Congress”, December 2001

Missing or deficient intermodal access links have been identified as more severe at the nation’s ports than at other intermodal terminals. The NHS 2000 Connector Report to Congress found connectors to marine port facilities to have twice the percentage of mileage with pavement deficiencies when compared to other facilities. A National Cooperative Highway Research Program (NCHRP) study based on the NHS report identified 253 connectors to port terminals (ocean and river), comprised of 532 miles of highway connection. The study assessed a total of 660 terminals and 1,222 miles of connectors, and found that the condition of 12 percent of the total pavement (as a percentage of the connector of mileage) was poor or very poor. By terminal type, 15 percent of the intermodal connectors at ocean/river port terminals were deemed poor or very poor. Table 1 summarizes the NCHRP findings.

Table 1 - NCHRP Findings on the NHS Connectors

All 253 NHS Port Terminals	Share of Ports Rated as Deficient
Connector Condition	
Inadequate Travel-way Width	24%
Inadequate Shoulder Width	46%
Lack of Stabilized Shoulders	31%
Tight Turning Radii	38%
Drainage/Flooding	16%
Overall Port Terminal Condition Rating	
Pavement Rated Poor/Very Poor	15%
Rated as having 4 or more Deficiencies	20%
Rate as having 1-3 Deficiencies	48%
Rough Rail Grade-Crossing	38%
Delays at Rail Crossings	19%

Source: NCHRP, “Integrating Freight Facilities and Operations with Community Goals: A Synthesis of Highway Practice”, NCHRP Synthesis 320, 2003

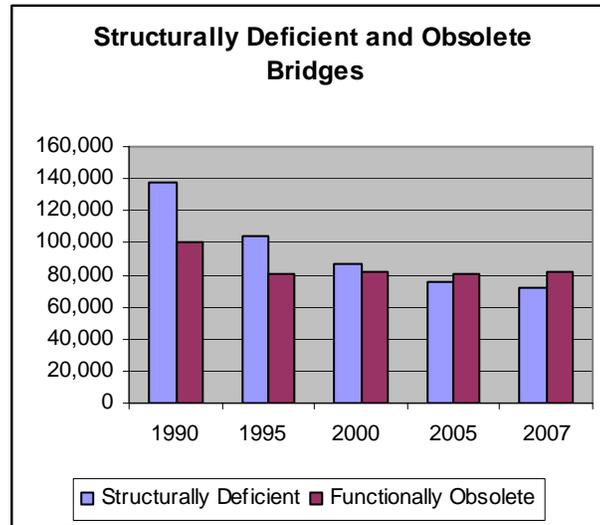
Structurally deficient bridges also represent a significant MTS vulnerability. In 2007, there were 600,000 bridges in the US. According to the National Bridge Inventory (NBI), a database maintained by the FHWA Office of Bridge Technology, 72,264 (12 percent) of these bridges were “structurally deficient,” and another 81,257 (14 percent) were “functionally obsolete.”⁸⁰ Figure 17 depicts the trend in the number of structurally deficient and obsolete bridges.

Bridges, built to accommodate vessels built decades ago, are often obsolete in their design. Many of the key bridges spanning channels leading from major ports are too short to accommodate newly constructed taller vessels. Vessel operators currently have to resort to extra ballast, lowering masts, and timing transits under bridges to coincide with lowest possible tides. Even so clearances of only a few feet are becoming more common. These solutions pose additional risks to vessel, bridge, and port capacity. NOAA has developed sensors capable of measuring real-time bridge height accurately to within a few inches. This technology, coupled with the extraordinary measures tall vessels are forced to resort

⁸⁰ FHWA, National Bridge Inventory, <http://www.fhwa.dot.gov/bridge/>

to, will only suffice until even taller vessels are built or until enormously expensive taller bridge replacements are completed.⁸¹

Figure 17 - Trends in the Number of Structurally Deficient and Obsolete Bridges



Source: Volpe generated chart based on FHWA data reported:
http://www.ops.fhwa.dot.gov/freight/freight_analysis_fr_con/chap_3.htm

Finally, inadequate intermodal access capacity has been a major contributor to port congestion and operational disruptions. Two recent studies by the American Association of State Highway and Transportation Officials (AASHTO) and the NCHRP have emphasized the need to address inadequate intermodal connector capacity at the nation's freight gateways.

- ✚ A 2007 AASHTO Report has stressed the need for improving highway capacity and intermodal highway access to the nation's international trade and marine facilities, given the intensity of trade flows along the nation's freight corridors, military supply movement routes, and intermodal connectors. Relying on the oft-cited forecast that by 2030 international exports and imports will account for 60 percent of the U.S. GDP, AASHTO predicts that the volume of containers shipped to and from U.S. ports will increase from 40 million to 110 million by 2020. Stressing the need for more infrastructure maintenance funding, AASHTO makes comparisons between the U.S. and China, pointing out that China annually spends 9 percent of its GDP on infrastructure, while the U.S. spends only 0.93 percent of its GDP on infrastructure maintenance and investment.⁸²
- ✚ A May 2007 NCHRP report has identified three broad MTS-related infrastructure connectors and corridors as key contributors to congestion, recommending that these facilities be funded by freight-related user fees from outside the Highway

⁸¹ Comment of Captain David McFarland, NOAA, October 14, 2009.

⁸² AASHTO "A New Vision for the 21st Century," July 2007.

Trust Fund as part of 25-year initiative called Critical Commerce Corridors. The initiative would enable states to add capacity to freight gateways and upgrade highway bottlenecks through the following intermodal/port projects:

- 14,000 miles of Trade Corridors, estimated to cost \$58 billion;
- 400 lane miles of intermodal “last mile” connectors, at an estimated cost of \$12 billion;
- 1,000 miles of Fort-to-Port Routes, with costs to be determined at a later date.⁸³

Lack of adequate rail capacity also contributes to MTS vulnerability. A recent CBO study stressed the importance of rail access, capacity, and on-dock throughput for the performance of the nation’s container ports. The study documented that in the late 2004, a slowdown in distribution of imports at the nation’s ports was caused by the capacity constraints experienced by the railroads serving major container ports.⁸⁴

Exacerbating access constraints are pressures to add capacity to port facilities without the associated intermodal capacity improvements. Development of new and improved terminals cannot alone solve port capacity challenges if the intermodal access problem is not addressed. Experts have emphasized the need to make terminal and operational improvements in tandem with adequate connector capacity.⁸⁵

Consequences of Disruption

The economic costs of traffic delays due to congested MTS access links are significant. Highway interchanges at the nation’s major ports and intermodal terminals are the largest contributors to highway bottlenecks and delays, as a recent study on highway freight bottlenecks conducted for FHWA indicated. The study found that 40 percent of the total delays on the nation’s highways are caused by bottlenecks, i.e., recurring congestion at interchanges where the volume of traffic routinely exceeds the capacity of the roadway, resulting in stop-and-go traffic flow and long backups. Among interchanges with the largest number of delay hours were urban freeway interchanges at urban freight corridors (such as highway access to the Ports of LA/LB or NY/NJ), reporting an estimated 124 million hours of delay in 2004.⁸⁶

Safety risks and economic costs of obstructive marine rail bridges have also contributed to the potential challenges posed by deficient MTS intermodal connectors. As one recent USCG report remarked:

“It has been said that a waterway is no more efficient than the most inefficient and restrictive bridge within the waterway system. A case in point is the CSX

⁸³ NCHRP, National Cooperative Highway Research Program (NCHRP), *Future Options for the National System of Interstate and Defense Highways*, NCHRP Project 20-24 (52), May 2007.

⁸⁴ CBO, *Freight Railroad Transportation: Long-Term Issues*, January 2006.

<http://www.cbo.gov/ftpdocs/70xx/doc7021/01-17-rail.pdf>

⁸⁵ A. Ashar, National Ports and Waterways Institute, “Long-Term Development Trends of US Ports”, presented to TRB, 2004.

⁸⁶ Cambridge Systematics, “An Initial Assessment of Freight Bottlenecks on Highways: A White Paper”, October, 2005.

Transportation swing bridge across the Mobile River at mile 13.3 near Hurricane, Alabama. This obstructive bridge creates a critical choke point in a large navigable waterway system..... [The bridge] not only curtails the movement of commercial tows to either above or below the drawbridge, but also eliminates a critical equipment and evacuation route for emergency responders. This single restrictive bridge seriously degrades the improvements provided by the locks, dams and modern navigation system in the entire regional (Black-Warrior Tombigbee) waterway system. On average, 16.5 million tons of cargo per-year are transported past this bridge. The delays caused by the bridge cost the navigation industry over \$8.2 million per year in extra costs.”⁸⁷

The costs of inadequate access capacity often come in the form of excessive delays and bottlenecks. Some West Coast ports handle over 20,000 trucks and 30 trains per day. The connectors at these ports have had serious extended delays in recent years, and truck traffic on these links is projected to double or triple in the coming years. A recent study by the U.S. Chamber of Commerce has emphasized the adverse consequences of inadequate intermodal access to the U.S. ports:

“...the U.S. port and intermodal freight system is now being operated in many areas at the limits of its maximum capacity. Should any component of the system break down, more than one fourth of the economy will be crippled. [The report recommended] ...dedicating more resources for the critical and often neglected ‘last mile’ connecting the National Highway System to intermodal freight facilities, particularly our ports.”⁸⁸

Resiliency and Mitigating Factors

As mitigation measures, U.S. container ports have begun taking a system-level approach to enhancing intermodal connector throughput. These ports are now looking beyond their jurisdictional boundaries to plan comprehensive system improvements. Ports taking this approach have included the Port Authority of New York and New Jersey (PANY/NJ), the Port of Oakland, and the Port of Los Angeles. Planning efforts have included construction of on-dock rail, improved access links, and implementation of business processes that could increase container velocity inside and outside port terminals.⁸⁹ Some of the measures have included:

- Extended gate hours
- Congestion pricing
- Trucker appointment systems and measures to improve chassis “roadability”
- Off-dock container yards
- High-speed rail shuttles

⁸⁷ USCG *Proceedings*, Dr. Kamal Elnahal, “Bridges are the Critical Links in Shaping Tomorrow’s Waterways”, Office of Bridge Administration, Summer 2007.

⁸⁸ U.S. Chamber of Commerce, *Trade and Transportation: A Study of North American Port and Intermodal Systems*, 2003.

⁸⁹ Thomas Ward (DMJM), “Port Congestion Relief: Attacking the Entire Chain”, undated, <http://www.dmjmharris.com/media/4437.pdf>.

- Integrated maritime and rail movement
- Expanded rail connections
- Automated yard marshalling and inventory control
- Automated gate processing systems.

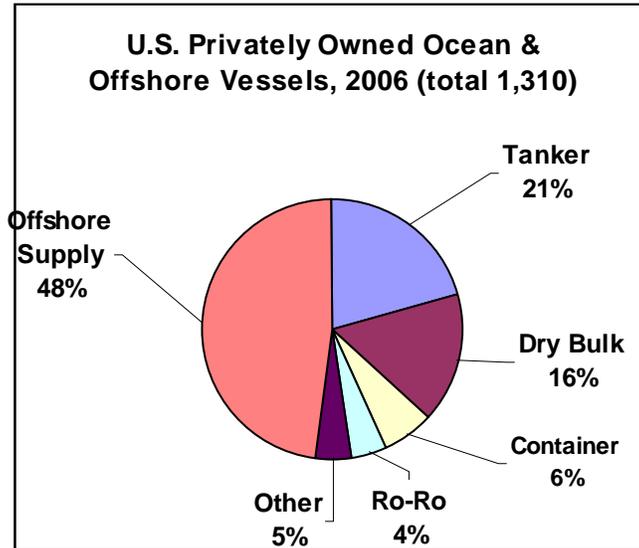
Corridor-wide initiatives to implement system-wide solutions have also served as effective countermeasures. One example is the Freight Action Strategy for the Everett-Seattle-Tacoma Corridor (FAST) initiative in Washington state, which involved eliminating all at-grade rail crossings in the corridor. Another is the ExpressRail overpass at Port Newark/Elizabeth in 2002, which involved construction of a rail overpass to the PANY/NJ on-dock rail yard that serves the adjacent marine terminal. Before the construction of the overpass, train traffic to the railyard had to cross over the main truck road in the port terminal complex, causing significant delays. Another example is the Alameda Corridor, which included a 10-mile railway trench, eliminating conflicts at 200 at-grade intersections with surface streets.

Section 7. Vessels: Characteristics, Risks, and Resiliency Status

Characteristics

As of year-end 2006, there were about 40,000 privately-owned U.S. vessels available for operation in U.S. domestic and foreign trade. About 97 percent of these vessels (38,842) operate in domestic trade on coastal and inland waterways. The remaining 3 percent (1,310) operate in ocean transport for foreign trade and for offshore oil exploration. In total, approximately 6,900 U.S.- and foreign-owned vessels make about 65,000 calls at U.S. ports. Over the past five years, the largest growth has been in offshore supply vessels (OSV) serving offshore oil exploration and in double-hull tankers (Figure 18).

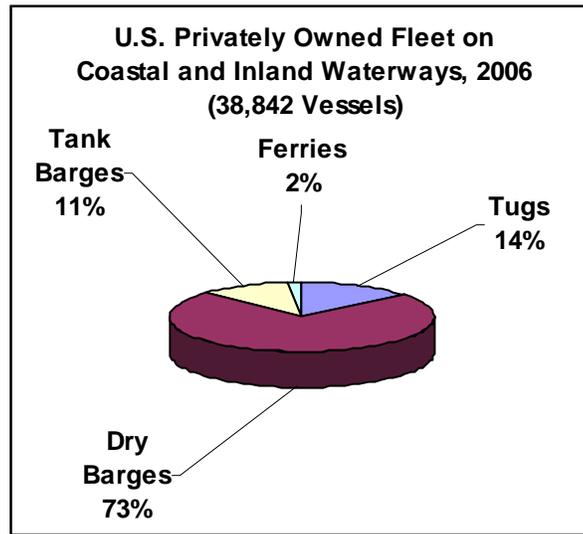
Figure 18 – Privately-Owned Foreign Trade Ocean Transport and Offshore Vessels



Source: Volpe generated chart based on MARAD data on *Fleet Indicators, U.S. Privately Owned Fleets, 2001-2006*.

The composition of the domestic fleet operating in coastal and inland waterways is depicted in Figure 19.

Figure 19 - U.S. Privately-Owned Fleet on Domestic Coastal and Inland Waterways



Source: Volpe generated chart based on MARAD data on Fleet Indicators, U.S. Privately Owned Fleets, 2001-2006, based on Clarkson Research Service, Vessel Registers, www.clarkson.net and USACE, Vessel Detail Files, www.usace.arm.mil/ndc

The total number of U.S. vessels (commercial and recreational) using the waterways in 2004 was approximately 13 million, as shown in Table 2.

Table 2 Total number of Commercial and Recreational U.S. Vessels on the U.S. Waterways, 2004

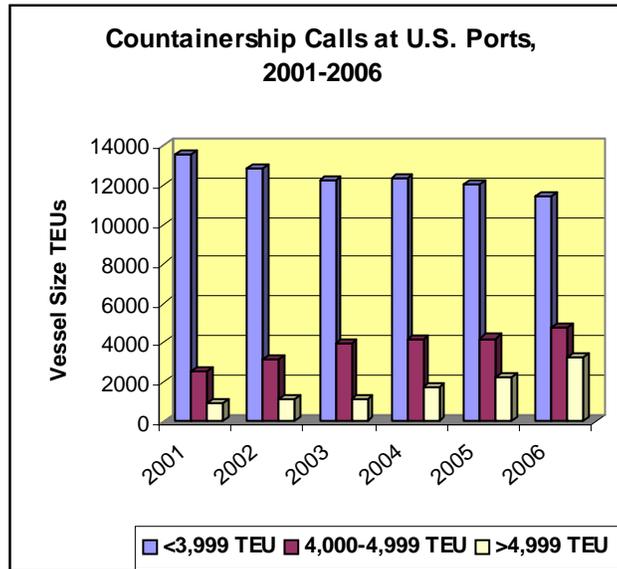
Total Number of U.S. Vessels on Waterways	
Oceangoing vessels (steam and motor ships of 1,000 gross tons and over)	412
Self-propelled vessels (dry-cargo and/or passenger, offshore supply vessels, rail-car ferries, tankers, and towboats)	8,994
Non-Self-propelled vessels (dry-cargo barges, tank barges, rail-car floats)	31,296
Registered Recreational Boats	12,781,476
Total	12,840,000

Source: BTS, Table L-6, http://bts.gov/publicActions/transportation_statistics_annual_report/2006/html

The tonnage capacity and under-keel draft requirements of the vessels calling on the U.S. ports have continued to increase. TEU container capacity of some of the containerships calling at the U.S. ports is about 9,000 to 10,000 TEU, with vessel drafts of up to 46 feet. Future forecasts are for 12,000 TEU ships with vessel drafts of 49 feet, with several expected to be in service by 2010. There are projections of even larger vessels of 14,000

TEU-capacity with vessel drafts of 50 feet for entry in the U.S. market.⁹⁰ Figure 20 shows the changes in size distribution of the container vessels calling at U.S. ports in the past decade.

Figure 20 - Trends in Size of Containerships Calling at U.S. Container Ports, 2001-2006



Source: Volpe Center generated chart based on MARAD Data, *U.S. Water Transportation Statistics Snapshot*

Post Panamax vessels of over 4,000 TEU account for most of the new containership fleet calling at the U.S. ports. Between 2002 and 2007, containerships with lesser capacity were increasingly replaced by larger ones, largely “post-Panamax” vessels, as overall containership size increased by 13 percent and 19 percent as measured by total deadweight tonnage and TEU, respectively (Figure 21).⁹¹

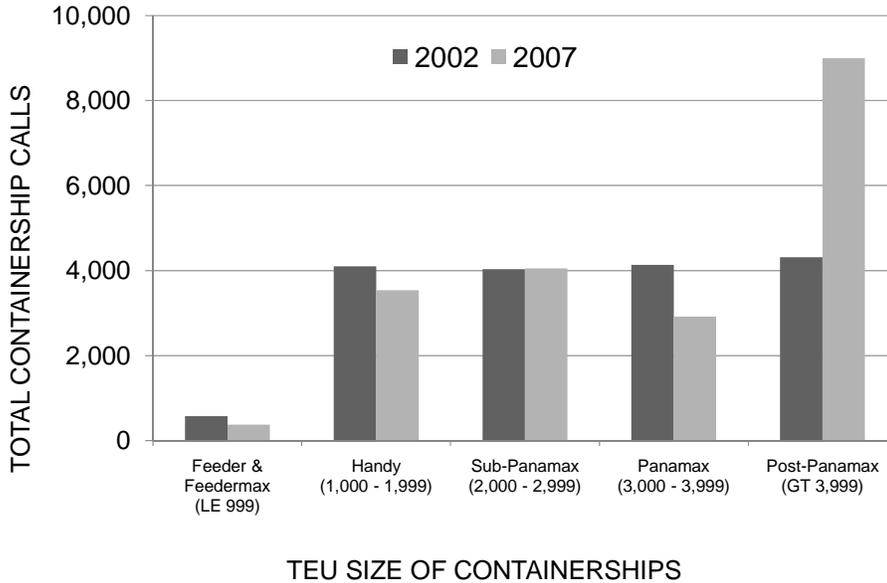
⁹⁰ CDM and the Tioga Group, *Maritime Transportation System: Trends and Outlooks*, Final Report, Report submitted to the USACE, March 13, 2007.

⁹¹ The current Panama Canal has a limit of 965 feet (length), 106 feet (beam) and 39.5 (draft). This nominally limits a ship to less than 4,000 TEUs. With the completion of the third set of locks in 2014, the Canal will be able to handle ships carrying up to 13,000 TEUs.

Figure 21 - Growth in Containership Sizes Calling at U.S. Ports, 2002-2007

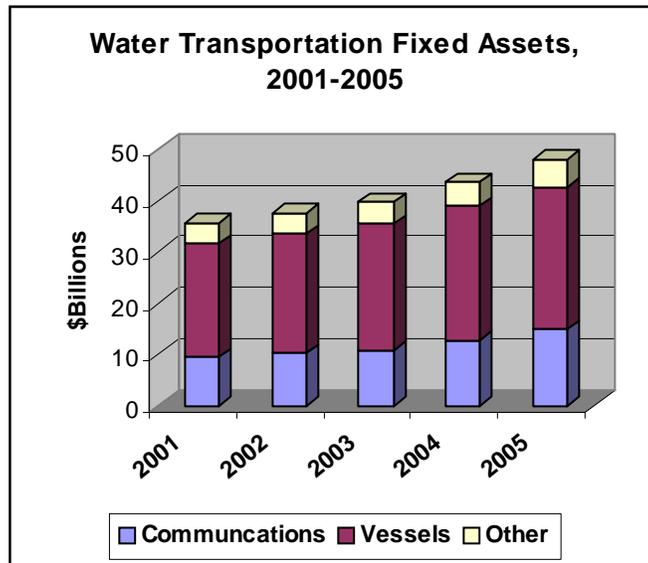


LARGER CONTAINERSHIPS ARE CALLING AT US PORTS



Vessels constitute the largest share of the U.S. water transportation fixed assets, which in addition to vessels include communications systems and structures. MARAD has defined fixed assets as “produced assets” that are used repeatedly or continuously in the process of production, and include equipment, vessels, software, and structures, valued at \$48 billion in 2005. Vessels accounted for over 52 percent of the value of the nation’s fixed water transportation assets. Between 2001 and 2005, the total value of these fixed assets increased by 35 percent. Growth in the value of water transportation fixed assets as shown in Figure 22.

Figure 22 - Water Transportation Fixed Assets



Source: Volpe produced chart based on MARAD data on macroeconomic indicators, “US Water Transportation Statistical Snapshots,” with data obtained from Bureau of Economic Analysis, Fixed Assets Accounts, www.bea.gov

Included in the water transportation fixed assets is container lift equipment. As a key component of the nation’s portside infrastructure, availability of equipment for moving containers from ships to shore and cranes with adequate height, reach, and capacity, is a key requirement for ports desiring expanded container trade. The costs of these assets are high and often beyond the reach of smaller ports.

Threats and Vulnerabilities

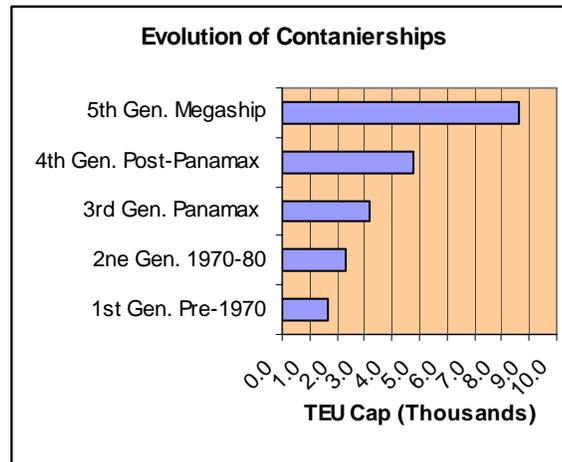
The vessel- and fleet-related components of the MTS contribute to the performance of the marine infrastructure but also impact its vulnerabilities and capacity challenges. The same factors that improve the productivity of large marine vessels also create infrastructure problems.

Disruptions caused by inability of the ports’ berths, bridges, and harbor channels to accommodate the growing size of ocean-going vessels are key threats to the viability of the nation’s container ports and bulk terminals. The system vulnerabilities that increase the probability that the threats will be realized include: a) the growing gap in the depth requirements of containerships and tankers calling at the U.S. ports, and the available harbor depth to accommodate them; and b) the growing number of vessel calls; and c) the high investment costs for purchasing container lift or bulk product handling equipment.

The gap between the required vessel draft and available harbor depth in the U.S. has been pointed out in a recent analysis conducted by MARAD in the agency’s 2006 *Report to Congress*. According to the report, the average size of containerships calling at U.S. ports was 17 percent larger than the size of vessels calling at ports elsewhere in the world. The

report explained that one reason for the larger average size of the vessels calling at U.S. ports, and hence the growing gap between the vessel draft needs and the available channel depth, is the scarcity of small U.S. feeder vessels and SSS services. The report points out that in Europe and Asia, smaller feeder vessel and SSS services handle most of the intra-European and intra-Asian trade.⁹² The size of a feeder ship is between 2,000-3,000 TEU, instead of the 6,000-plus TEU vessels routinely calling on coastal ports. Figure 23 illustrates the trend in the growing size of the containerships calling at the U.S. container ports.

Figure 23 - Evolution of Containerships



Source: John Vickerman, “Global Ports & Containerization Development: Choke Points and Opportunities,”2007.

The U.S. container ports for the most part have not been able to keep up with the growing harbor/berth depth requirements of the modern containerships. The high costs of accommodating the rising size and volume of the vessels calling at the U.S. ports have jeopardized the continued operation of many MTS terminal facilities. These costs are significantly different for bulk and container ports, and include the expansion of channel and berth depth, improved land-side port capacity, expenses for intermodal lifts and loading and unloading equipment in mechanized intermodal terminals, and equipment purchases for processing bulk products. The costs constitute limiting factors for the expansion of the MTS infrastructure.

Bulk ports also have infrastructure capacity problems, though the needs are different from the needs of container ports. Many of the nation’s major dry and wet bulk ports are not currently capable of accommodating the largest bulk ships. For instance, dry bulk carriers of 150,000 to 200,000 deadweight (dwt) call at the Norfolk coal terminal, but the port cannot accommodate the very large bulk carriers of 300,000+ dwt since their drafts requirements are too deep for the port’s channels. Many bulk ports also restrict operation of the largest bulk ships for environmental considerations (e.g., the tonnage restrictions imposed on the Trans Alaska Pipeline System (TAPS) oil tankers entering the Strait of Juan de Fuca and Puget Sound).

⁹² Maritime Administration, *Annual Report to Congress*, Fiscal Year 2006.

Also exposing ports to threats of disruption is the growing number of port calls at the nation's top load centers. Vessel calls at the U.S. container ports have increased sharply in the past two decades, contributing to capacity constraints at the landside and waterside and increasing the probability of disruption and delay. Between 2001 and 2006, containership calls at U.S. ports increased by 25 percent; calls by ships between 4,000 TEU and 4,999 TEU increased by 86 percent; and calls by ships of over 5,000 TEU increased by 240 percent. During the same period, the average TEU per call increased from 2,800 TEU to 3,500, and the number of containership calls increased from 17,000 per year to 19,500 per year.⁹³

Another weakness in the MTS that prevents smaller ports to be more efficiently utilized is the inability of the smaller ports to meet the demands of the large cargo vessels for landside and waterside capacity and pay for the associated expenses of lift equipment and terminal upgrade. The high capital expense necessary to service the larger ships is often a barrier to terminal modernization. These high costs have a dampening effect on the feasibility of the inland waterways to serve as a viable alternative to over-the-road or rail transport for containerized cargo.

Finally, a network-related area of vulnerability is the lack of integration of maritime traffic in the nation's freight movement system for pricing and mode choice. In a 2005 feasibility study prepared by the University of Virginia on the inland waterways intermodal transportation system, the study team explored alternative means of augmenting transport capacity to alleviate capacity and congestion constraints facing the U.S. intermodal system.⁹⁴ The report found that the Inland River Container Services (IRCS) are not fully integrated with the intermodal system, resulting in underutilization of a highly cost-effective transport alternative. The report cited the nation's lock and dam system that is in serious state of disrepair as a key factor impeding the integration of the intermodal system with the existing river facilities.

Consequences of Trends in Vessel Size

The consequences of the system weaknesses outlined above – i.e., air gap restrictions, unavailability of small feeder vessels and container lift equipment, or the gap in vessel draft requirements and the available channel depth – are not only the direct costs incurred by vessel delays and loss of trade revenues (as outlined in Sections 4 and 5), but also the foregone opportunities for expansion of waterborne domestic commercial transportation service and underutilization of the vast MTS resources. Studies have suggested that the feasibility of offering container-on-barge (COB) service at small coastal ports and inland terminals is to a large extent contingent on the availability of high-cost intermodal lift equipment. For many smaller ports, these costs pose a barrier to better utilization of the available MTS facilities.

⁹³ MARAD, *U.S. Water Transportation Statistical Snapshot*, MARAD, May 2007

⁹⁴ "Inland Waterways Intermodal Transportation System Design and Feasibility Analysis" prepared by the University of Virginia for MARAD in May 2005

Mitigating Solutions and Resiliency

Promoting the use of smaller feeder vessels and implementation of short-sea-shipping (SSS) and the Marine Highway Program initiatives are among strategies that have proven effective for reducing the adverse infrastructure-related, environmental, and economic consequences of a transportation system dominated by large vessels and highway-based freight movement. By serving as a component of the nation's layered critical infrastructure, SSS and the MARAD Marine Highway Program can potentially help mitigate infrastructure vulnerabilities to disruptions caused by natural disasters, recurring incidents and traffic bottlenecks, and congestion at large commercial ports. The underutilized components of the MTS infrastructure have the potential to enhance the resiliency of the critical infrastructure by offering an effective layer of system redundancy for cargo and passenger transportation.

SSS is generally defined as “commercial waterborne transportation that does not transit an ocean.” More broadly defined, SSS refers to waterborne transportation of commercial freight between domestic ports using inland and intracoastal waterways. The U.S. DOT has begun playing an active role in promoting SSS to relieve highway freight traffic congestion. In 2003, then DOT Secretary Mineta presented SSS as an intermodal alternative to congested ports. On February 15, 2007, Sean Connaughton, the MARAD Administrator appeared before the Subcommittee on Coast Guard and Maritime Transportation, Committee on Transportation and Infrastructure, to provide a testimony about the DOT policy on the development of the American Marine Highway Initiative (MHI). Mr. Connaughton described progress on the DOT initiatives in support of SSS, including steps to develop a North American Short Sea Shipping Electronic Information Clearinghouse, establishing the Short Sea Shipping Cooperative Program (SCOOP), and promoting SSS along the I-95 Interstate Highway, as supported by the I-95 Corridor Coalition. He reported on a study conducted for the U.S. DOT Office of the Secretary (OST) on the feasibility of SSS along four potential domestic traffic lanes or corridors within the U.S. that found:

“the primary economic advantage of SSS is its ability to generate significant economies of scale by moving large numbers of highway trailer-loads on a single vessel, providing numerous labor, energy, environmental, and infrastructure advantages.”⁹⁵

The OST-sponsored report emphasized that SSS could be particularly competitive for heavy shipments and hazardous cargo and bulk chemicals that currently move over the road. The report identified significant interregional container flows (e.g., 10 million container shipments that move on the highway each year from the Gulf to the New York region) that could potentially move by water and prove competitive with other modes for service.⁹⁶

⁹⁵ The testimony of Mr. Sean T. Connaughton, Administrator, MARAD, before the Subcommittee on Coast Guard and Maritime Transportation, Committee on Transportation and Infrastructure, February 15, 2007.

⁹⁶ Based on the testimony of Mr. Connaughton on February 15, 2007. The text of the OST study has not been made available.

On March 5, 2007, DOT released a draft copy of the *American Marine Highway Development Act*, proposing the establishment of pilot programs to encourage the use of domestic waterways, and the designation of “Marine Highway Corridors” to implement the pilot programs and focus public and private efforts to use the waterways to relieve congestion.

On December 19, 2007, HR 6, the Energy Independence and Security Act of 2007, was signed. Subtitle C (Marine Transportation) of HR 6, Section 1121- Short Sea Transportation Initiative, amends Title 46 USC by adding Chapter 556, Short Sea Transportation [See Text Box].

HR 6 - Energy Independence Act
Subtitle C - Marine Transportation
Section 1121 – Short Sea Transportation Initiative
Chapter 556 – Short Sea Transportation

Section 556 consists of the following elements:

- **§55601 Short Sea Transportation Program:** Requires that the DOT Secretary establish a Short-Sea Transportation (SST) Program and designate a number of SST projects to be conducted under the program to mitigate landside congestion. The program elements include strategies to encourage the use of SST through the development and expansion of: 1) documented vessels; 2) shipper utilization; 3) port and landside infrastructure; and 4) marine infrastructure strategies by state and local governments. The program is also required to designate SST routes and corridors that would offer waterborne alternatives to land transportation of freight and passengers.
- **§55602 Cargo & Shippers:** Requires that memoranda of understanding (MOUs) be developed with stakeholders and incentives be provided for funding SST projects.
- **§55603 Interagency Coordination:** Requires that the Secretary shall establish a board to identify and seek solutions to impediments hindering effective use of SST.
- **§55604 Research on SST:** Requires that Secretary of DOT, in consultation with the EPA Administrator conduct research on SST regarding: (1) environmental benefits of SST as an alternative to other modes; (2) technology, vessel design, and other improvements that would reduce emissions and transportation fuel consumption; and (3) solutions to impediments to the SST projects designed under §55601.
- **Section 1122 - Short Sea Shipping Eligibility for Capital Construction Fund:** Designates funding for eligible vessels and activities.
- **Section 1123 – The SST Report.** Requires that no later than 1 year after the enactment of HR 6, the Secretary of Transportation, in consultation with the EPA Administrator submit a report to the Committee on Transportation Infrastructure of the House of Representatives and the Committee on Commerce, Science and Transportation.

Section 8. Summary Findings and Next Steps

This report has created an analytical framework to be tested as a proof-of-concept for a high-level assessment of MTS threats, vulnerabilities, and resiliency. Applying this framework to the assessment of MTS infrastructure risks, the report identified the systemic challenges that arise from the physical characteristics of the MTS infrastructure and the associated safety and operational risks of disruption, and offered a number of potential solutions for promoting system resiliency.

Findings

The assessment of the four elements of the physical MTS infrastructure – navigable waterways (harbor channels and locks and dams), ports, intermodal connectors, and vessels – found:

1. MTS navigable waterways are at risk. Lack of adequate funding for harbor channel dredging and lock/dam/levee maintenance operations is a key contributing factor to the likelihood of a disruption in the navigable waterways. The gap between the existing channel depths and the draft requirements of the vessels using the waterways has grown; as the size of vessels serving the U.S. ports has increased, the U.S. waterways have not kept up with the dredging needs to maintain the required depth. Most of the new containerships serving U.S. ports require channel depths of over 45 feet. In the past two decades, the depth requirement for new vessels has grown from 39 feet in 1984, to about 48 feet today. Only a handful of ports currently have the required channel depth to serve these ever larger modern cargo vessels. Safety risks arising from inadequate maintenance for the dams and levees supporting navigation on the waterways, and the associated economic costs of undersized locks are also significant. Undersized locks contribute significantly to delays since they require breaking up the tows at each lock and reassembling them once through the lock. Navigation delays from lock unavailability or lock closures have grown from approximately 30,000 hours in 1992, to 110,000 hours in 2005, with nearly half of the closures due to unscheduled lock downtimes. Similarly, there is a growing problem with newly constructed vessels being too tall to pass safely under bridges spanning critical waterways. Rebuilding bridges or constructing tunnels pose enormous and potentially prohibitive costs to the ports.
2. The escalating growth in the volume of trade traffic, size of vessels, and number of vessel calls has been a major constraint for the U.S. container and bulk ports. For the most part, the U.S. ports have not been able to keep up with the growing volume of trade and demands of the modern containerships and tankers for harbor/berth depth. The high costs of accommodating the rising size and volume of the vessels calling at the U.S. ports have jeopardized the continued operation of many MTS terminal facilities. The consequences of realization of the potential threats to the nation's ports include: a) loss of trade revenues and the attendant costs and operational disruptions arising from shipper/carrier uncertainty about reliability of

3. Missing or overloaded intermodal connections and inadequate surface transportation capacity pose key threats to the viability of MTS terminal operations. System vulnerabilities that increase the probability that the threats could be realized are the weaknesses that stem from: a) missing or overloaded port access links; b) structurally deficient bridges; and c) congestion induced by inadequate capacity on key access links. The economic consequences of inadequate access capacity are often realized in the form of excessive delays and bottlenecks. Safety risks of structurally deficient bridges can also be potentially catastrophic, as some 12 percent of the nation's bridges are classified as "structurally deficient."
4. Size and service requirements of the vessels used in international trade pose key threats to the viability of the nation's container ports and bulk terminals. Inability of the ports' berths and harbor channels to accommodate the growing size of ocean-going vessels has led to disruptions in port operations. System vulnerabilities that increase the probability that the threats will be realized include: a) the growing gap in the depth requirements of containerships and tankers calling at the U.S. ports, and the available harbor depth to accommodate them; b) the increasing number of vessel calls; and c) the high investment costs for purchasing container lift or bulk product handling equipment. The sharp increase in the number and size of the vessel calls in the past two decades has contributed to capacity constraints at the landside and waterside and increased the probability of disruption and delay. Tonnage capacity and under-keel draft requirements of the vessels in international trade calling at the U.S. ports have continued to increase. Container capacity of some of the largest containerships currently calling at the U.S ports is about 9,000-10,000 TEU, with vessel drafts of up to 46 feet. Future forecasts are for 12,000 TEU ships with vessel drafts of 49 feet, and even larger vessels of 14,000 TEU-capacity with vessel drafts of 50 feet planned for entry in the U.S. market.

Support for the MTS National Strategy Priority Areas

The National Strategy IAT, in its Draft National Strategy Report issued in February 2008, offers a framework for addressing the most pressing challenges to the MTS in five priority areas: capacity, safety and security, environmental stewardship, resilience and reliability, and finance and economics. With respect to infrastructure capacity – the focus area for this Task 1 report – the National Strategy has endorsed a number of priority actions, including:

- a. encouraging the expansion of SSS;
- b. sharing best practices and creating incentives for private sector infrastructure investment to improve operations;
- c. facilitating standardized terminologies, analytical tools and flow-through models to foster increased productivity; and

- d. developing performance measures to assess the productivity of the MTS and the risk of potential infrastructure failure.

This report has provided analytical support for the National Strategy priority actions in a broad spectrum of application areas, including:

- a. *Encouraging the expansion of SSS.* The risk and reliability framework has incorporated supporting evidence for promoting SSS and the marine highway program initiatives. The study offers research evidence in support of the economic viability of SSS for domestic shipping operations. The study also highlights the adverse consequences of factors such as the average size of the vessels calling at the U.S. ports, providing evidence from a recent analysis conducted by MARAD in the agency's 2006 *Report to Congress* that documents the gap between the required vessel draft and available harbor depth in the U.S., explaining that one reason for the larger average size of the vessels calling at U.S. ports, and hence the growing gap between the vessel draft needs and the available channel depth, is the scarcity of small U.S. feeder vessels and SSS services. The report points out that in Europe and Asia, smaller feeder vessel and SSS services handle most of the intra-European and intra-Asian trade. The size of a feeder ship is between 2,000-3,000 TEU, instead of the 6,000-plus TEU vessels routinely calling on the U.S. coastal ports.
- b. *Sharing best practices and creating incentives for the private sector infrastructure investment.* The infrastructure resiliency framework has incorporated lessons learned and best practices in support of initiatives and public or private technology initiatives for mitigating the risks of domestic and international waterborne commerce. By documenting best practices such as the University of Virginia Lock Upgrade Study or the ORNL study on the optimal container fees for inland waterway shipping, and by stressing the extent to which valuable MTS resources have been underutilized, the study underscored the vast opportunities available for expansion of waterborne domestic commercial transportation service. Best practices are also identified based on the advice of nationally renowned maritime security experts such as Stephen Flynn, who has recommended strategies for improving the nation's critical infrastructure resiliency by creating an Infrastructure Resiliency Commission to put together a new process for identifying what needs to be done, establishing priorities, and marshalling the necessary resources. The staff of such a Commission would assemble the input from key agencies with expertise in critical infrastructure to muster resources for creating a resilient system which is less likely to fall apart when accidents occur, and incorporate preventive measures that prepare for disruptions and make the high-consequence events less likely to happen.⁹⁷
- c. *Innovative technologies and analytical tools for improving system productivity.* The report documented the evidence from application of advanced technologies and decision-support tools for improving system productivity and resiliency, including:

⁹⁷ Stephen Flynn, *The Edge of Disaster: Rebuilding A Resilient Nation*, Random House, 2007.

- LoadMax, a water-level forecasting tool that helps pilots and captains set departure times and vessel speeds to take advantage of tides and fresh water flows to allow the vessels to be loaded to the maximum depth;
 - SmartLock navigation and communications system that establishes links between the tow and the lock, giving the pilot of the tow greater knowledge as to the position of the tow relative to the lock, and allowing a steady locking speed during periods of low-visibility and adverse conditions.
 - Opportunities for deployment of advanced technologies such as automatic identification system (AIS), vessel traffic services (VTS), and Electronic Chart and Display Information System (ECDIS) that have proven effective in improving the operational safety and efficiency of the tow and barge systems used on the navigable waterways.
 - Solutions identified to address the inadequate intermodal connector capacity, including countermeasures such as extended gate hours, congestion pricing, trucker appointment systems, off-dock container yards, high-speed rail shuttles, expanded rail connections, automated yard marshalling and inventory control, and automated gates.
- d. *Developing performance measures to assess productivity of the MTS and risks of potential infrastructure failure.* The risk and resiliency analysis framework created in this report for the assessment of infrastructure risks will be applied to the analysis of the remaining MTS components: economic productivity, safety, security, environmental stewardship, and funding/institutional elements. The report has also documented the application of software systems and performance assessment tools such as the Repair, Evaluation, Maintenance, and Rehabilitation (REMR) Condition Index developed by the Coastal & Hydrological Laboratory (CHL), USACE, and the applications based on the EPA Sediment Management Program that uses risk-based tools to assess the dredged material contamination risks, optimal disposal methods, beneficial dredged material uses, and strategies for mitigating the disruptions associated with channel deepening. (For instance research data indicate that only 5-10 percent of all dredged materials are contaminated, and that sediment erosion and loss of habitat are often more damaging than contamination.)

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ACRONYMS

AAPA	American Association of Port Authorities
AASHTO	American Association of State Highway and Transportation Officials
AIS	Automatic Identification System
BAP	Bridge Administration Program
CHL	Coastal and Hydrological Laboratory
CI/KR	Critical Infrastructure Key Resource
CMTS	Committee on the Maritime Transportation System
COB	Container on Barge
DHS	Department of Homeland Security
DOE	Department of Energy
DWT	Deadweight
ECDIS	Electronic Chart Display and Information System
EIA	Environmental Impact Analysis
ENC	Electronic Navigation Chart
EPA	Environmental Protection Agency
ERDC	Engineering Research and Development Center
FAST	Freight Action Strategy for the Everett-Seattle-Tacoma Corridor
FHWA	Federal Highway Administration
GDP	Gross Domestic Product
GPS	Global Positioning System
HMT	Harbor Maintenance Tax
HMTF	Harbor Maintenance Trust Fund
IAT	Integrated Action Team
ICMTS	Interagency Committee for the Maritime Transportation System
IRCS	Inland River Container Services
IWR	Institute for Water Resources
IWTF	Inland Waterway Trust Fund
LA/LB	Ports of Los Angeles/Long Beach
LOOP	Louisiana Offshore Oil Port
LRD	Lakes and Rivers Division
MARAD	Maritime Administration
MDA	Maritime Domain Awareness
MTSNAC	MTS National Advisory Council
MTS	Maritime Transportation System
NBI	National Bridge Inventory
NCHRP	National Cooperative Highway Research Program
NDNS	National Dredging Needs Study
NHS	National Highway System
NIPP	National Infrastructure Protection Plan
NOAA	National Oceanic and Atmospheric Administration
MTSA	Maritime Transportation Security Act of 2002
NED	National Economic Development
NRC	National Research Council
ORNL	Oak Ridge National Laboratory

OSV	Offshore Supply Vessel
PANY/NJ	Port Authority New York/New Jersey
RFID	Radio Frequency Identification
SCOOP	Short Sea Shipping Cooperative Program
SOW	Scope of Work
SSS	Short Sea Shipping
TAPS	Trans Alaska Pipeline System
TEU	Twenty Foot Equivalent
TRB	Transportation Research Board
ULCC	Ultra Large Crude Carriers
USACE	United States Army Corps of Engineers
USCG	United States Coast Guard
USDA	United States Department of Agriculture
USDOD	United States Department of Defense
USDOT	United States Department of Transportation
VDR	Voyage Data Recorder
VLCC	Very Large Crude Carriers
VTS	Vessel Traffic Services
WRDA	Water Resources Development Act
WSCS	Waterborne Commerce Statistics Center
WCUS	Waterborne Commerce of the United States



Appendix B

Report to the Committee on Marine Transportation System (CMTS)

Task 2: Assessment of Economic and Productivity Challenges

December 23, 2009

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Preface

This report is the revised Task 2 deliverable for the Volpe National Transportation System Center (the Volpe Center), Research and Innovative Technology Administration (RITA), U.S. Department of Transportation (USDOT), project to conduct a system needs assessment for the Marine Transportation System (MTS) through a Reimbursable Agreement (RA) VH-99 with the U.S. Army Corps of Engineering (USACE). The report has been prepared by Dr. Bahar Barami, the Volpe Center project manager, and revised to reflect the comments and inputs received from the project sponsors and members of the Marine Transportation System (MTS) Needs Assessment Integrated Action Team (IAT) on the original version of the report released in June 2008, including comments received on August 6, 2009 from Joy Liang, USDOT; and comments by Eric Wolfe, National Oceanic and Atmospheric Administration (NOAA), received on August 21, 2009; and comments by Richard Lolich, MARAD, received on November 20, 2009.

Introduction

This report is Task 2 of six task reports prepared to address the challenges arising from system risks and vulnerabilities and the barriers to meeting the performance demands of global trade. Task 1 of this study examined the MTS physical infrastructure and conducted an assessment of the baseline and forecast characteristics of the MTS within a risk and reliability assessment framework. It analyzed the present and projected threats to the continued performance of the infrastructure, and identified system vulnerabilities and potential countermeasures for enhancing system resiliency.

The National Strategy for the MTS has identified five principal components of the MTS – navigable waterways, ports, intermodal connections, vessels, and users – and has pointed out the extent to which three key functions – commerce, recreation, and national defense – are critically dependent on the health and condition of the MTS components.¹ Task 1 of this project examined the first four components in the context of the MTS Infrastructure components, including the physical capacity characteristics of the ports and navigable waterways. Task 2 Report will focus on the economic components of the MTS functions in support of commerce. Other MTS functions will be addressed in Task 3 (Environmental Challenges), Task 4 (Safety Challenges), and Task 5 (Security Challenges).

This report will build on the risk and resiliency analysis framework developed in Task 1 to conduct an analysis of the economic impacts and risks of MTS. Within this framework, the study estimates the magnitude of the global economic impacts of a disruption in system operations, identifies the vulnerabilities relating to the dependence of the nation's trade system on MTS, and assesses system resiliency with respect to the flexibility of the MTS-dependent supply chains, shippers and vessel operators. The report assesses the extent to which MTS users have access to backup ports and delivery systems, are able to adapt to changing routes and terminals, and have business continuity plans in place for averting supply disruptions.

Sources of data for Task 2 are readily available information and Federal databases, including the Bureau of Economic Analysis (BEA) of the US Census Bureau/Department of Commerce, the USACE Waterborne Commerce Statistics Center (WCSC) data, the Freight Analysis Framework (FAF) data, the statistics released by the Maritime Administration (MARAD) and the Bureau of Transportation Statistics (BTS), and other Federal and industry studies and forecasts on MTS revenues, trade flows, and costs associated with MTS operations. Note that though efforts have been made to access the latest 2007-2008 data, for some data sources such as BEA and BTS the latest available sources of data were earlier years. Also note that only publicly available data have been used for this report. The prohibitive costs of obtaining proprietary forecasts (such as those

¹ National Strategy for the Marine Transportation System: A Framework for Action, Committee on the Marine Transportation System, July 2008.

produced by Global Insight) and databases (such as the PIERS trade data) have precluded their use for this report.

Task 2 Report will examine the operational, economic, and productivity characteristics of the MTS and the user requirements for system performance, including:

- An overview of the current MTS status with baseline data on trade volumes and revenues in the context of GDP and the world economy (Section 1);
- An overview of the global logistics practices that have driven the outsourcing and export-import decisions of the U.S. trading partners (Section 2);
- An evaluation of the economic and productivity costs and consequences of congestion and inadequate access and capacity in the context of the gaps in the physical infrastructure performance identified in Task 1, with an attempt to identify mitigation measures that could potentially enhance MTS resiliency (Sections 3-4).

These trends are presented in the following sections:

- Section 1 – Current Status: Economic Components of MTS Operations
- Section 2 – MTS Operations in the Context of Global Logistics and Supply Chain Practices
- Section 3 – Risk Analysis: Economic Consequences of the MTS Vulnerabilities
- Section 4 – Evaluation of the MTS Economic Resiliency
- Appendix A – A Framework for Analyzing the MTS Risks, Vulnerabilities, and Resiliency (based on Task 1 Report.)

Section 1. Current Status: Economic Components of MTS Operations

1-1 Contribution of MTS to the U.S. Economy

There are several ways of assessing the contribution of the Marine Transportation System (MTS) to the economy. Estimates of the annual revenues and economic output of the U.S. MTS vary according to how the system is defined, what revenues are included, and whether the focus is on the domestic or international components of MTS. One common measure is the Bureau of Economic Analysis (BEA) estimate of the marine transportation sector gross annual economic output. In 2007, the U.S. waterborne transportation gross output was \$36.1 billion, of which \$25.4 billion was in intermediate inputs (including \$21.1 billion in services and \$2.7 billion in energy inputs); and \$10.7 billion in value-added output (including \$5.5 billion in labor and \$4.9 billion in operating surplus.)² Using the BEA estimates, MARAD has reported that the gross output of the U.S. waterborne transportation has risen by 28.5 percent between 2002 and 2007, while the value-added has grown by 53 percent during the same period.³ Another measure of the MTS contribution to the economy is the annual revenues generated for domestic and foreign trade waterborne transportation services, estimated at approximately \$23 billion.⁴ In this report, the contribution of MTS to the economy is assessed in terms of the value of the cargo transported as exports and imports.

The value of the U.S. international exports and imports has continually grown in the past decades in tandem with GDP, and at times at a more rapid pace. The total value of exported and imported goods (not including services) in 2008 was \$3.4 trillion (\$2.1 trillion in imported goods, and \$1.3 trillion in exported goods). When the values of service exports and imports are added, the total value of U.S. trade in 2008 is \$4.3 trillion, as reflected in Figure 1.

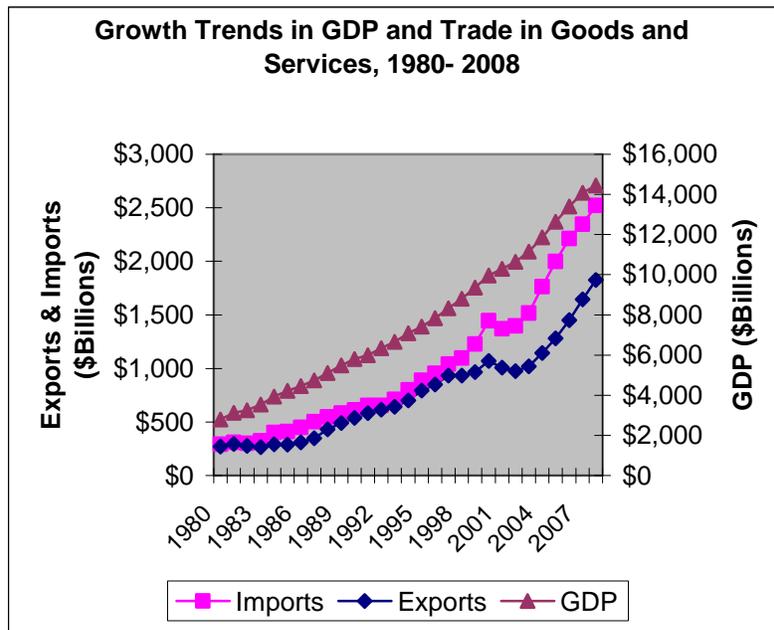
² The Bureau of Economic Analysis (BEA) has defined gross output as the market value of goods and services produced by labor and productive assets in the U.S. Value added is measure of the contribution of each private industry and of government to the nation's GDP, and is defined as gross output minus intermediate inputs. Bureau of Economic Analysis, <http://www.bea.gov>

³ MARAD, *U.S. Water Transportation Statistical Snapshot*, May 2009.

⁴ Table B-4, *BTS Freight in America*, 2006;

http://www.bts.gov/publications/freight_in_america/html/nations_freight.html

Figure 1 - U.S. International Trade in Goods and Services Compared to Growth in Gross Domestic Product (GDP), 1980-2008



Source: Volpe generated chart based on 2008 data from Bureau of Economic Analysis, <http://www.bea.gov>

MTS-dependent cargo has been a leading force in the growth of U.S. commerce and GDP. By weight, about 80 percent of the total tonnage of the U.S. goods exports and imports moves by water. By value, however, a smaller share of the U.S. goods trade moves by water, partly because the contiguous U.S. trade with Canada and Mexico moves mostly by land. When the modes of transport for contiguous and non-contiguous trade are combined, 48 percent of the value of all U.S. foreign trade in 2007 originated in waterborne transportation, accounting for some \$1.6 trillion in MTS-dependent cargo trade value (out of a total cargo value of \$3.4 trillion), equivalent to 12 percent of the \$13.8 trillion GDP in 2007. For non-contiguous trade, however, 63 percent of the value of U.S. foreign-trade originates in waterborne transportation, corresponding to a total value of \$1.5 trillion in waterborne trade out of \$2.2 trillion in non-contiguous cargo transported by all modes in 2007. Waterborne transportation accounts for only 10 percent of the value of cargo transported in contiguous foreign trade with Canada and Mexico (\$93 billion shipped by water out of \$968 billion in value generated for all modes.)⁵

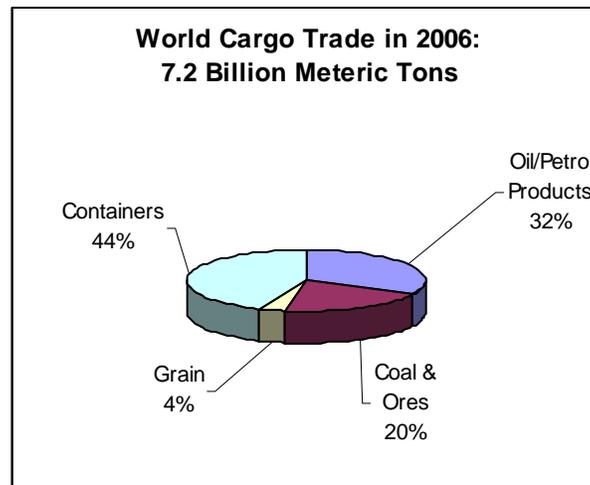
The global economic downturn of the past two years has led to declining volumes of cargo shipments for domestic as well as international commerce. Official statistics on the magnitude of the impact on MTS operations have not been available at this time. The potential implications of the traffic slowdown for port capacity needs are addressed in the sections that follow.

⁵ MARAD, *U.S. Water Transportation Statistical Snapshot*, May 2009, based on data from U.S. Bureau of Census, Foreign Trade Division, <http://www.census.gov/foreign-trade>.

1-2 MTS-Dependent Cargo in World Trade

World seaborne merchandise trade transported 8.6 billion tons of cargo in 2008, nearly quadruple the size of the 2.2 billion tons of cargo transported in 1998. By value, seaborne trade is estimated to have generated \$7.6 trillion in value in 2008. Containerized cargo accounts about 44 percent of total world seaborne shipments, followed by shipments of oil and petroleum products (accounting for 32 percent of the world merchandise trade), and coal and ores (accounting for 20 percent of the world traded cargo.)⁶ Figure 2 provides an overview of the composition of the cargo traded worldwide in 2006.

Figure 2 – Composition of World Cargo Trade

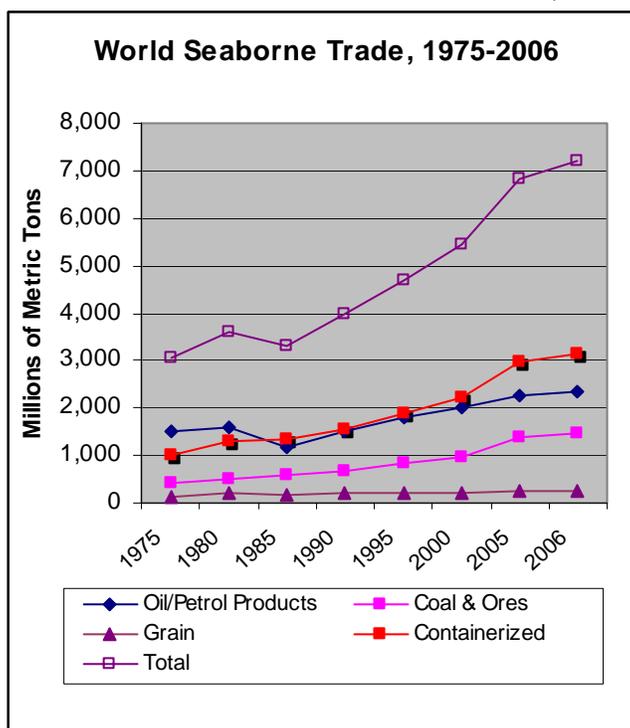


Source: Volpe generated chart based on data from Bureau of Economic Analysis (BEA), 2007.

The volume of world cargo trade in the past three decades has grown significantly. Most of the growth during this period was attributed to the rising shipments of containerized goods (growing from 33 percent of the shipments in 1975 to 44 percent) and coal and ores (growing from 14 percent of the shipments to 20 percent.) The share of oil and petroleum products of the world trade has declined between 1975 and 2006 from 49 percent to 32 percent. Figure 3 shows the trends that have governed the historic transformations of the global seaborne trade between 1975 and 2006, showing that during the past three decades, containerized goods, followed by bulk movements of oil and petroleum products and coal/ore commodities, have been the principal drivers of the sharp rise in global marine shipping.

⁶ Bureau of Economic Analysis (BEA) data and the Institute of Shipping Economics and Logistics, Shipping Statistics Yearbook, 2007.

Figure 3 – World Seaborne Merchandise Trade, 1975-2006



Source: Volpe generated chart based on data from Bureau of Economic Analysis (BEA), 2007.

In terms of twenty-foot equivalent units (TEU) of container shipments, the world maritime container traffic has more than tripled in the past decade, growing at an average annual rate of about 11 percent from 137 million in 1995 to 417 million in 2006. , the most rapidly growing segment of marine transportation in the past two decades has been the seaborne transport of containerized cargo. Contrary to the worldwide seaborne merchandise trade that has been driven by containerized trade, the U.S. maritime trade has been dominated by bulk products, as described in the following section.

1-3 MTS-Dependent Cargo Trade in the U.S. Economy

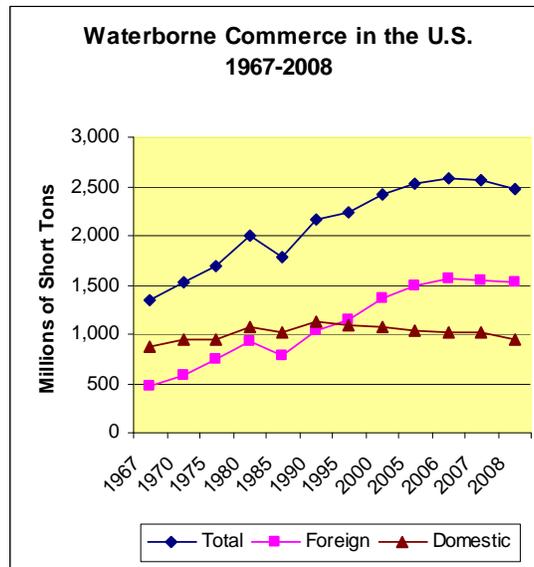
International trade in goods and services accounts for about a third of the U.S. economy. With a total value of \$4.3 trillion, the U.S. export- and import-trade (inclusive of both goods and services) accounts for 30 percent of the \$14.3 trillion GDP in 2008. MTS-dependent share of this trade, estimated at \$1.6 trillion in 2008, accounts for 11 percent of the nation’s economy. The size of the U.S. economy – accounting for about 28 percent of the world’s gross product – and the country’s growing merchandise imports, provide the momentum for the growth in the U.S. waterborne trade, as described below.⁷

⁷ Maritime Trade and Transportation, BTS, December 2007, based on data from International Monetary Fund, www.imf.org, January 2007.

U.S. Waterborne Trade

The U.S. MTS supports the inbound- and outbound-flows of 2.5 billion tons of commercial cargo shipped in domestic and international commerce, a volume that has grown twofold since 1967. Figure 4 depicts the trends in the growth of domestic and foreign waterborne commerce, demonstrating the extent to which the U.S. maritime trade is driven by growth in foreign trade. In the past four decades, the foreign trade shipments have tripled from 500 million tons to over 1.5 billion tons. Figure 4 also depicts the reversal in the composition of the nation's domestic- and foreign-waterborne trade when, beginning in 1993, the foreign waterborne shipments began to exceed domestic shipments. In 2008, 62 percent of the U.S. MTS shipments (1.5 billion tons) consisted of foreign-trade merchandise, with the remaining 38 percent (1 billion tons) shipped for domestic trade. In 1967, foreign trade accounted for only 35 percent of the tonnage carried in U.S. waterborne trade. As noted above, the rise in U.S. imports has been galvanizing the growth of foreign trade shipments. In 2008, imports (inbound freight) accounted for 73 percent of the U.S. foreign waterborne commerce (not shown in the chart); exports (outbound freight) accounted for the remaining 27 percent.

Figure 4 – Trends in Domestic and Foreign Waterborne Traffic



Source: IWR, USACE, *Waterborne Commerce of the United States, Calendar Year 2008, Part 5 National Summaries* (based on preliminary 2008 data.)

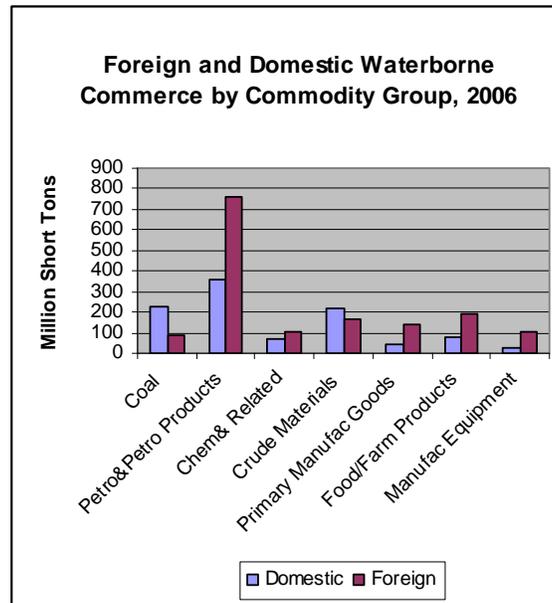
Of the inbound (import) foreign trade, 97 percent is transported in coastal waters, and the remaining 3 percent in Great Lakes for Canadian and transshipment traffic. Of the outbound (export) foreign waterborne trade, 91 percent is in coastal waters, and the remaining 9 percent is in the Great Lakes for Canadian and transshipment trade.⁸

⁸ USACE, *Waterborne Commerce of the U.S. Calendar Year 2005, Part 5, National Summaries, Table 1-2.*

Cargo Composition

The composition of the cargo shipped in the U.S. waterborne trade is dominated by bulk commodities and crude products. This is in clear contrast to the trend in the world trade where containerized cargo dominates the mode of shipment. Predominance of bulk commodities in U.S. waterborne trade is true for both foreign and domestic trade, but more so for the latter. In the foreign waterborne U.S. trade, 72 percent of the shipments are bulk commodities and crude/primary products (petroleum, chemicals, coal, ores/crude products). In the domestic waterborne U.S. trade, 85 percent of the shipments are bulk and crude/primary commodities. Figure 5 shows the composition of the domestic waterborne commerce by commodity group and foreign or domestic destination.

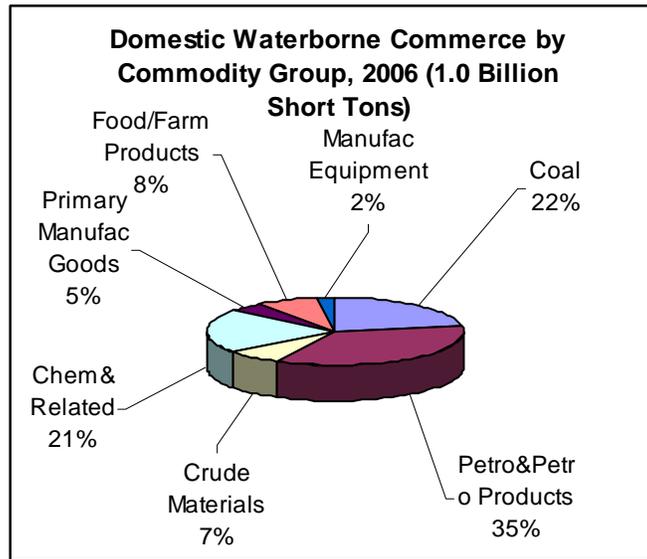
Figure 5 – Comparison of the U.S. Domestic and Foreign Waterborne Commerce by Cargo Type



Source: Volpe generated chart based on data from *Waterborne Commerce of the U.S. Calendar Year 2006, Part 5, National Summaries, Tables 1-5 and 1-11.*

The domestic waterborne commerce in the U.S. is dominated by shipments of dry- and liquid-bulk products. Figure 6 shows that 85 percent of the 1 billion tons of cargo shipped for domestic waterborne commerce is in coal, bulk petroleum, chemicals, and crude materials. Only 15 percent of the shipments have been products that could be containerized (e.g., higher-value manufactured products and food/farm materials.)

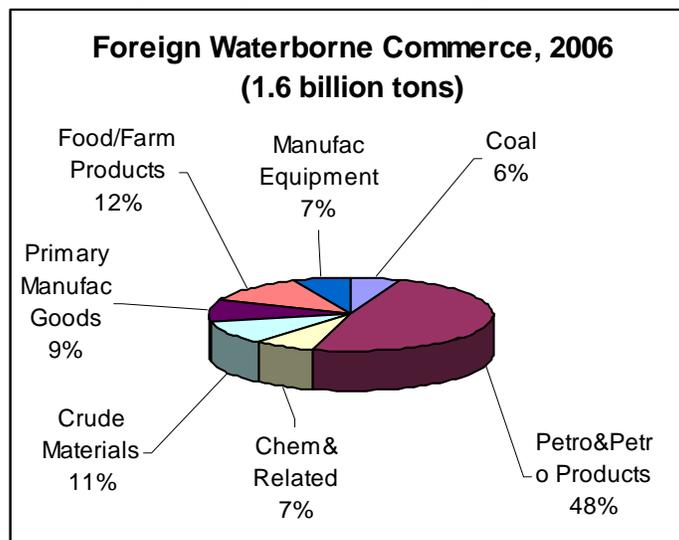
Figure 6 – Cargo Composition for Domestic Waterborne Commerce



Source: Volpe generated chart based on data from *Waterborne Commerce of the U.S. Calendar Year 2006, Part 5, National Summaries, Table 1-11.*

There is a marked difference between the type of commodities shipped for foreign trade and those shipped for domestic trade, even though bulk commodities dominate the volume of cargo shipped in all U.S. waterborne trade. Cargo that can be containerized claims a larger share of the U.S. foreign waterborne commerce. Figure 7 shows that about 28 percent of the U.S. foreign waterborne commerce were products that could be containerized (food/farm products, and manufactured goods and equipment), with the remaining 72 percent in bulk and liquid products.

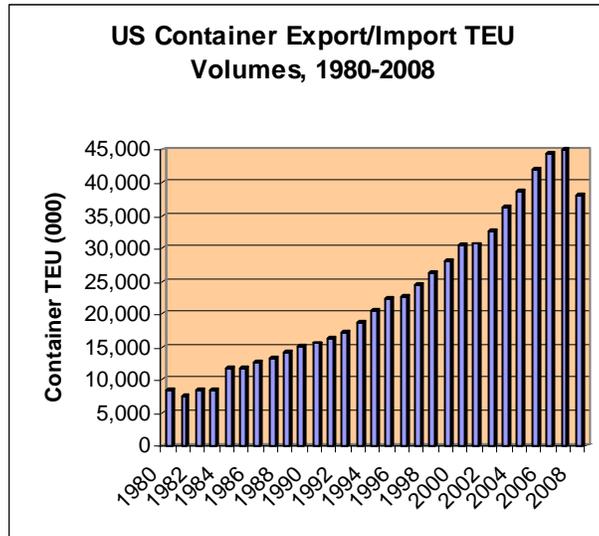
Figure 7 – Cargo Composition for Foreign Waterborne Trade



Source: Volpe generated chart based on data from *Waterborne Commerce of the U.S. Calendar Year 2006, Part 5, National Summaries, Tables 1-5 and 1-11.*

The larger share of containerized cargo is reflected in the rapid growth of the containers transported in domestic commerce. The number of intermodal containers moving the domestic freight – by truck, rail, or water – quadrupled from 3.1 million in 1980 to over 12 million. Measured as twenty-foot-equivalent units (TEU), the volume of container traffic in the U.S. grew from 22.3 million TEU in 1995, to 46.3 million TEU in 2006, representing a total growth of 107.2 percent, and an average annual growth of 6.8 percent.⁹ In 2008, the TEU volume dropped to 38 million in the aftermath of the current economic downturn (Figure 8).

Figure 8 - U.S. Container Export/Import Container TEU Traffic, 1980-2008



Source: Volpe Center generated chart based on American Association of Port Authorities (AAPA), North American Container Ports, 2008

Profile of the Domestic Waterborne Cargo Transportation

The U.S.MTS supports domestic cargo movements, as well as commercial fishing and commercial passenger ferry and cruise services. In terms of the tonnage carried, the domestic share of MTS commerce has shown only a modest growth over the past several decades, as noted previously.¹⁰ Reported revenues for the domestic waterborne transported have declined from a high of \$8 billion in 1993 to a reported \$6.3 billion for 2001, as reported in the 2008 Report of the Bureau of Transportation Statistics, providing no updated statistics for more recent year.

Dominance of low-value bulk commodities is one explanation for the relatively low revenues generated by domestic waterborne transportation. Another explanation for the low level of revenues is the marked decline in the ton-miles carried in waterborne domestic commerce in the past two decades. As noted above in the context of the trends

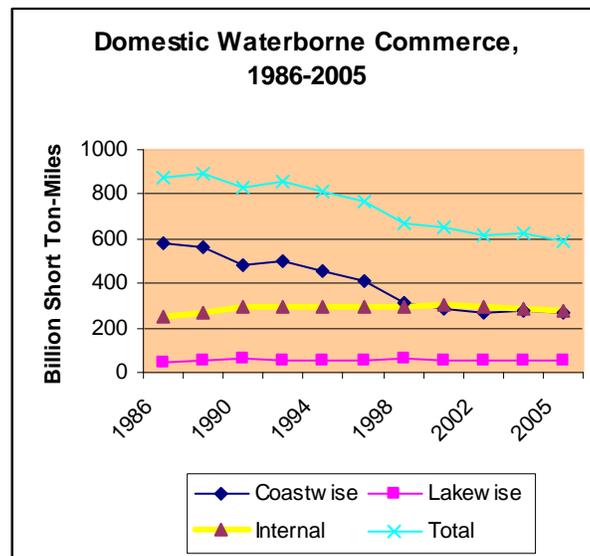
⁹ BTS, *America's Container Ports: Delivering the Goods*, March 2007.

¹⁰ BTS, National Transportation Statistics, 2008, Table 3.18, reports no data beyond 2001 for Domestic Water Transportation.

http://www.bts.gov/publications/national_transportation_statistics/2008/html/table_03_18.html

depicted in Figure 2, the tonnage carried on MTS has remained stable around 1 billion tons in the past decade, whereas the length of shipments has declined steadily. The average length of coastwise shipments declined from 1,496 miles in 1960 to 1,269 in 2004. The total ton miles of domestic waterborne traffic (on coastal, Great Lakes, and inland waterways) declined from 873 billion ton-miles to 591 billion ton-miles between 1986 and 2005 (Figure 9). Coupled with a flat tonnage volume, the declining ton-miles in water transportation is indicative of a domestic freight market dominated by the highway and rail modes in both short- and long-haul lanes. The consequences of the lower waterborne ton miles of freight for the viability of the domestic marine transportation industry are twofold: lower ton-miles reduce the revenues generated in the service, while lower ton-miles also make it harder for a critical mass of cargo volume to be generated. Such a critical mass is necessary in order for short-sea-shipping to flourish into a viable domestic industry.

Figure 9 - Trends in Domestic Waterborne Commerce Ton-Miles, 1986-2005

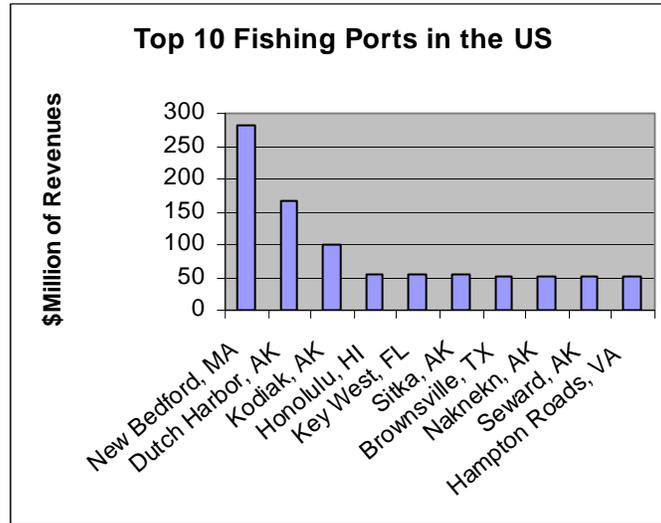


Source: Volpe generated chart based on data from USACE, *Waterborne Commerce of the U.S. Calendar Year 2005, Part 5, National Summaries, Table 1-9*

Trends in Commercial Fishing

MTS supports a commercial fishing industry with an annual value of \$2.4 billion generated in commercial trade of some 4.9 billion pounds of fish caught. By value, the Port of New Bedford, Massachusetts accounts for the largest share of the commercial fishing revenue, with revenues of \$181.2 million (driven in part by the large volume of high-value scallop catch) followed by Ports of Dutch Harbor and Kodiak in Alaska, with 2006 revenues of \$165.2 million and \$101.4 million, respectively. By tonnage, ports in Alaska and Louisiana account for the largest volume of catch (Figure 10.)

Figure 10 - Top Ten Fishing Ports in the US, 2006

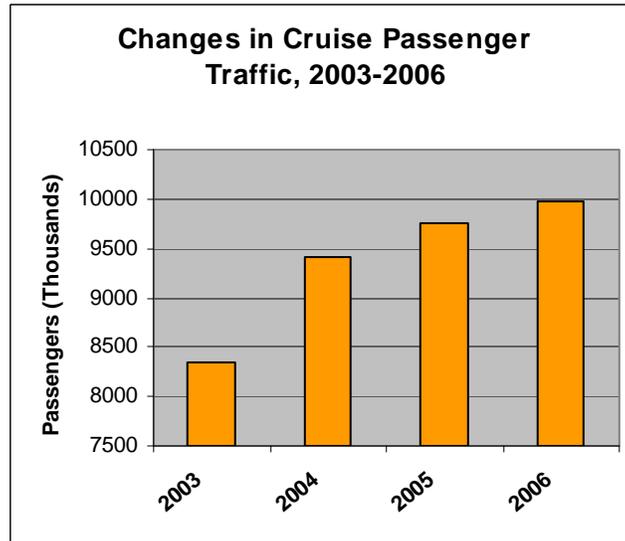


Source: National Marine Fisheries Service, 2006 Commercial Fishery Landings, <http://www.st.nmfs.noaa.gov>

Trends in Passenger Cruise and Ferry Services

Passenger cruise and ferry services constitute a significant component of MTS. In 2006, some 10 million passengers traveled on cruise ships from over 25 destination ports.¹¹ Between 2003 and 2006, the cruise passenger traffic grew by 19.4 percent (Figure 11).¹²

Figure 11 - Changes in Cruise Passenger Traffic



Source: Volpe produced charts based on data from MARAD, *North American Cruise Statistics*, www.marad.dot.gov/marad_statistics

¹¹ MARAD, *North American Cruise Statistics*, www.marad.dot.gov/marad_statistics

¹² MARAD has also issued reports on revenues of the commercial passenger ferry; relevant statistics were not available at the time of completing this report.

To summarize, the domestic segment of MTS is predominantly geared to moving bulk commodities, primarily chemicals, coal, and oil and petroleum products. While the tonnage volume has remained flat at about 1 billion tons, the distances travelled have been shorter, resulting in declining ton-miles of cargo transported over the years. As the distances over which these commodities are transported have become shorter, the revenues generated have also shrunk compared to the prevailing domestic transportation revenues for trucking and rail. This revenue decline has significant implications for viability of domestic marine transport and short sea shipping, as addressed in other sections of this report. Two other segments of the MTS commerce – passenger-cruise and commercial fishing – have experienced a rapid growth in revenues and traffic. The demand for these services is driven by trends in global commodity markets and tourism, with little impact on the revenues generated in domestic waterborne freight transport.

Section 2. MTS in the Context of Global Supply Chains and Logistics

The rapid growth in global trade in the past two decades has been coupled with two parallel transformations in the economy: the emergence of information technology (IT) and electronic commerce (e-commerce) as enabling technologies, and the rise of outsourcing as the dominant mode of industrial production in the US. Together, these forces have galvanized new logistics practices built on IT and shaped by businesses' outsourcing needs. Today's logistics practices – i.e., the process of procurement, transportation and storage of goods and the associated flows of production inputs, from raw materials to finished products – have helped shape the modern supply-chain management practices of the global trading partners.¹³

With the help of advanced IT systems, modern supply chain management principles – defined as the integrated management of the flows of physical goods, funds, and associated information to consumers, from raw materials sourcing to delivery of finished products – have been put into practice through supply management strategies such as “value chain management”, “pull-based inventory control”, “just-in-time (JIT) delivery” and “inventory deferral.”¹⁴

The growing dependence of the U.S. consumers and industrial producers on outsourcing and low-price imported goods has transformed the role of trade in the global economy, as global logistics and supply chain managers have streamlined the way they manage their channels of commerce.¹⁵ Whereas world economies for centuries have relied on trade to maximize a nation's benefits by trading the resources they have in abundance for those they lack, the impact of the new logistics paradigms on how the MTS operates has been profound because vessel operators and carriers compete for their market share by offering lower rates per container or per load. Shippers and manufacturing outsourcers attempt to lower their logistics costs by working closely with vessel operators, third party logistics operators and non-vessel operating carriers (NVO) to manage their production channels

¹³ The Council of Logistics Management (CLM) has defined logistics management as the “process of planning, implementing and controlling the efficient, cost effective flow and storage of raw materials, in-process inventory, finished goods, and related information from point-of-origin to point-of-consumption for the purpose of conforming to customer requirements.” Spotlighting the importance of such integration is the decision of the Council of Logistics Management to change its name to Council of Supply Chain Management Professionals (CSCMP.)

¹⁴ David Simchi-Levi, Philip Kamisky, Edith Simchi-Levi, *Designing and Managing the Supply Chain: Concepts, Strategies, and Case Studies*, Irwin McGraw-Hill, Boston 2000, have defined supply-chain management as a: “set of approaches utilized to efficiently integrate suppliers, manufacturers, warehouses, and stores, so that merchandise is produced and distributed at the right quantities, to the right locations, and at the right time, in order to minimize system-wide costs while satisfying service level requirements.”

¹⁵ Logistics text books tell you that there are at least eight generic functions that must be performed successfully in order for a manufacturing firm's production channels to work smoothly: channels connecting the physical production, ownership, promotion, negotiation, provision of market information, financing, payment, and risk bearing. J. Christopher Westland and Theodor H.K. Clark, “*Global Electronic Commerce: Theory and Case Studies*,” The MIT Press, Cambridge, MA, 1999.

and maximize their profit margin. Implications of these strategies for how MTS-dependent cargo shipments are transported globally are fourfold:

1. Shippers and vessel operators reduce their shipping costs when vessel carriers improve their cargo handling techniques or increase their vessel size that allow them to lower per-unit shipping rates and increase the number of units carried in one shipment. In other words, they generate lower unit-costs due to economies of scale.
2. Shippers get lower shipping rates when vessel operators lower their costs per call by extending the range of destinations and markets they serve at one port call through transshipment of cargo by land-bridge service or by transloading containers in distribution hubs. In other words, they generate greater market reach and lower costs due to economies of scope.
3. Vessel operators help shippers reduce their inventory carrying costs by providing value-added service to reduce retailers' inventory carrying costs through cross-docking and inventory deferral strategies.
4. Vessel operators compete by improving terminal productivity and reducing transit times while optimizing vessel utilization.

These four logistics principles have guided the strategies of today's global vessel operators who are moving the estimated \$1.6 trillion worth of MTS-dependent export- and import-goods.

2-1 Lower Unit-Costs Due to Economies of Scale

Modern vessel operators have enjoyed economies of scale by increasing the size of their cargo vessels and by containerizing dry cargo.

Larger size vessels (both bulk carriers and containerships on fixed route service) reduce per unit shipping costs. The vessels achieve economies of scale by reducing the operating costs for each cargo unit carried or slot served. A 2005 study by the Mercator Group conducted for the Port of Long Beach estimated that an 8,000 TEU vessel in the Asia-US West Coast trade route reduces vessel costs by \$99 per TEU compared to a 4,500 TEU vessel costs. The study also found that a 10,000 TEU vessel produces additional saving of \$51 per TEU in Southern California ports. With an annual volume approaching 15 million TEU in Southern California alone, and tight carrier profit margins, the study concluded that the attraction of larger ships is obvious.¹⁶

In addition to the growing vessel size, containerization of cargo has also helped shippers and carriers reduce their per-unit costs. Prior to containerization, cargo was handled many times from the time it left the shipper's dock and the time it was received by the consignee. Bulk or palletized cargo required consolidation at the port of loading, and

¹⁶ CDM and Tioga Group, "Maritime Transportation System: Trends and Outlooks," Final Report, Report submitted to the USACE, March 13, 2007. p. 43

deconsolidation when it arrived at the port of discharge. Containerization, since its inception 50 years ago, has changed how goods are moved. It has dramatically reduced the direct and indirect costs associated with moving cargo by unitizing the cargo and moving it intact in a single box. Containerization has also made delivery times more reliable, and reduced cargo theft and damage (referred to as inventory shrinkage and pilferage.) In addition, containerization has caused entirely new port configurations to be developed, terminals mechanized, lift equipment to be installed, and new labor rules and business practices to be put in place.¹⁷

A measure of the success of a more efficient goods movement and supply chain management in the past couple of decades is the continued plummeting of transportation and logistics costs as a share of GDP. Total logistics costs, estimated at roughly \$1 trillion, are comprised of the costs of transporting raw materials and intermediate/finished goods (about 60 percent of the total), the inventory carrying costs (about 36 percent), and the administrative and management costs (about 4 percent.) While transportation has been claiming an increasingly larger share of total logistics costs, both transportation and inventory costs have grown at rates below the growth of GDP (As described in Section 2-2.) In the early 1980s, total logistics costs accounted for over 16 percent of GDP; today these expenditures account for roughly 10 percent of GDP. With rising congestion, fuel costs, highway and rail capacity constraints, and driver shortage in trucking industry, however, some industry observers and policy makers have expressed concerns that the costs of logistics as a percentage of GDP will be creeping up.¹⁸

Also helping reduce the costs of moving cargo has been the deregulation of trucking and railroads in the 1980s that facilitated the intermodal expansion of the liner container movement. The 1984 Shipping Act gave liner shipping companies increased ability to provide domestic intermodal service. Land-bridge operations of the vessel operators involved a process of transporting containerized Asian imports from selected Pacific Coast ports to the East Coast markets by rail for the inland movement. Facilitating this process was the development of efficient doublestack intermodal rail service with dedicated trains and cost-effective land-bridge service. The twin development of containerization and deregulation helped spawn unprecedented growth in marine container shipping by drastically reducing logistics costs in the past two decades. Relative to a 1980 baseline, research data suggest that since the deregulation of transportation industry, both transportation and inventory costs have grown at rates below GDP.¹⁹

2-2 Lower Costs and Economies of Scope Due to the Emergence of Inland Distribution Hubs

Three major forces are driving the development of container transloading and inland distribution hubs: a) vessel operators' logistics strategies to reduce costs-per-call by

¹⁷ *The Marine Transportation System and Global Supply Chain*, MTS National Advisory Committee, July 18, 2006.

¹⁸ Consistent measures for periods beyond 2002 are not available.

¹⁹ Based on *Survey of Current Business*, March 2000; Note that the data collected by the Survey of Current Business is no longer available. Other data, based on reports of Transportation in America, 2000, Cass Logistics, June 2001. are no longer available consistently.

selectively calling at large urban ports and then trans-shipping the cargo to other locations;
b) changes in the U.S. production outsourcing and imported goods consumption practices that require extensive sorting and consolidation at inland hubs and distribution centers;
and c) maturing of the Chinese manufacturing structure.

- a. Containership (liner) companies have traditionally achieved economies of scope by selecting a few major ports of call and then redistributing the containers through transshipment through a variety of methods such as land-bridge (by shipping the container by rail to the East Coast, or for continued service between Europe and Asia) or mini-land-bridge service (e.g., by shipping container from Los Angeles to LA to Houston as a substitute for all-water Panama Canal transit.) Today, liner companies are using transloading in addition to transshipment as a cost-saving strategy. Transloading consists of stripping and de-vanning the contents of 20', 40' and 45' marine containers and re-stuffing them into 48' or 53' domestic containers. Transloading import container into larger domestic containers reduces the total costs of moving the container to its final domestic destination. The practice reduces the total transport costs of moving a domestic container because 53' containers have more usable capacity and weigh significantly less, resulting in significant cost savings from transloading cargo from marine containers to 53' domestic containers. Compared to standard 40' containers, a 53' domestic trailer or container provides up to 70 percent more space. A 53' trailer, for instance offers 3,800 usable cubic feet of space, compared to 2,700 feet for a 40' container. In a typical practice, five 40' marine containers can be profitably transloaded into three 53' domestic containers.

The savings from fewer inland lifts and line-haul operating expenses can easily offset the extra costs of transloading and consolidation/ deconsolidation. Another cost advantage of consolidation and transloading is the lower per-unit cost of moving a full truck or container. Today, 53' intermodal containers have become the industry standard and account for 55 percent of all domestic containers. This growth has been accelerated by the rapid growth of transloading activities in Southern California, where 53' boxes account for over 60 percent of the containers transported.²⁰

- b. Changes in the U. S. production outsourcing and import consumption practices have led to a greater demand for distribution centers. There has been a relative decline in the volume of imported manufacturing component parts that arrive from overseas outsourcing location and are destined for industrial locations in the U.S. heartland. The U.S. imports are increasingly destined for final retail consumption instead of being used as raw materials or intermediate components for domestic manufacturing. As a result of his change in the structure of the U.S. manufacturing, big-box retailers have emerged as major importers. This requires that some reconsolidation and value-added services be performed at a location near the final consumption markets.

As supply chain managers have reduced the number of distribution centers – in response to efforts to eliminate warehousing – consolidation at major transportation

²⁰ *The Marine Transportation System and Global Supply Chain*, MTS National Advisory Committee Education Team, Version 4.0, Last Revised July 18, 2006, p. 67

hubs has gained greater prominence. Increasingly, container transload centers are co-located with the regional distribution centers (RDC) near major urban centers or at inland ports serving major marine ports. The consolidation/deconsolidation functions performed involve value-added logistics services such as component assembly, merge-in-transit operations, order allocation postponement, and other warehousing and distribution functions. A major factor in the steamship companies' choice of ports-of-call has been the size of the local consumer market to enjoy the so-called "economies of market density." Liner companies select ports with consumer market attributes – e.g. the urban areas such as LA/LB or New York/New Jersey with large local consumption markets – that maximize the density of demand for the imports.

Distribution hubs reduce total costs by consolidating retail and wholesale distribution in larger facilities located near fewer ports. These facilities serve as mixing centers where cargo from multiple sources and manufacturing countries is transloaded into 53-foot domestic containers for further shipment to regional distribution centers without the intervening stage of warehousing. In addition to transloading, value-added functions such as repacking, assembly, labeling, and production of display kits are performed on the cargo.

- c. Finally the maturing of the Chinese economy has changed the need for handling of imports in the U.S. Chinese manufacturers have begun shipping cargo directly from South China to the U.S. ports rather than assembling and shipping them out of Hong Kong, as was done previously. One implication of this changing structure of the Chinese manufacturing is that the imported retail goods need product customization and assembly operations that can best be performed near the final consumption market. This change has provided further momentum for the practices of transloading, consolidation, and deconsolidation at or near major ports of import in the U.S. In 1985, goods manufactured in China were collected and routed through Hong Kong, where they were consolidated into containers for through-movement. Chinese factories are now easily capable of loading full containers. At the same time, port development in China is maturing so that ports can now support direct trans-Pacific vessel calls.

2-3 Cost Cutting Benefits from Cross Docking and Inventory Deferral Strategies

Strategies for reducing inventory carrying costs have enabled global supply chain managers to use transportation for making two types of substitution: a) they substitute transportation for warehousing to move "inventories on wheel" or for "cross docking" inventories at distribution centers; and b) they use distribution centers for redirecting the cargo and for "inventory deferral" to postpone the release of the imported goods in transload centers until the retailer is ready for it.

Cross docking is the practice of unloading materials from an incoming rail or truck trailer and either immediately loading them on the outbound rail/trailer or placing them in a staging area where inbound materials are sorted, consolidated, and stored until the

outbound load is complete and ready for shipment. This staging may take hours, days, or even weeks, in which case the “staging area” is essentially a “warehouse.” Cross docking can consist of direct transloading of the cargo into domestic containers or, more commonly, coupled with value-added operations:

- *Direct transload* consisting of transfer of waterborne cargo from marine containers directly into domestic 48’/53’ containers or trailers and then immediately shipping them by truck or rail to final destinations. This direct transload process represents a small percentage of the consolidation activity.
- *Value-added cross-docking and transload activities* involving the unloading of the marine containers to a warehouse/staging area to perform the following value-added activities:
 - Manifest verification to establish that the items on the manifest match the contents of the container;
 - Labeling, by attaching a label to an article;
 - Palletizing, by placing stock keeping units (SKU) for a particular store on a pallet in a secure manner for distribution;
 - Shrink wrapping the pallet with plastic to protect it and aid in its transit;
 - Pick and pack assembly of an order of SKU for a specific store and packing it for shipment;
 - Distribution Center (DC) bypass, involving a direct move from the consolidator to a retail store;
 - Merge in transit, involving packaging two different products together,
 - Reverse logistics, involving returning unsold merchandise to the DC.²¹

Inventory deferral, the practice of postponing the release of imported goods until the retailer is ready for them, is emerging as a primary reason for transshipment of containers to inland distribution hubs. With the emergence of major “big box” retailers as the primary importing sector in the economy, major retailers are increasingly receiving shipments of waterborne cargo at their distribution hubs with an unspecified destination. The distribution hubs reduce the retailers’ inventory-ownership costs by deferring the deployment decision from Asia to the U.S. retail destinations for up to 45 days. Deployment delay from Asia to US discharge reduces time interval for distribution to point of sale from 23 days to 6 days. Mathematical calculations have indicated that sales forecast errors typically grow by the square root of lead-time. Moreover, inventory deferral enables the retailer to maintain the same level of sales with 20 percent less inventory, a significant financial saving that reduces not only inventory carrying costs, but the potential product obsolescence.²²

²¹ “Consolidation Activity in the Southern California Area,” BST Associates, prepared for the Alameda Corridor Transportation Authority, March 2004.

²² *The Marine Transportation System and Global Supply Chain*, MTS National Advisory Committee Education Team, Version 4.0, Last Revised July 18, 2006, p. 65.

Both cross-docking and inventory deferral strategies have succeeded in reducing the importers' total logistics costs by substituting truck transportation and inland inventory warehousing for water transportation. The result has been a rapid growth in demand for trucking the import containers. The growth in trucking traffic in major container ports has in essence been an "induced demand", i.e., demand generated by the lower costs of truck transportation relative to other alternatives for processing the imported cargo and delivering the containers to their final destination. As noted in reference to Figure 11 above, with the decline in the transportation component of logistics costs, businesses are shifting resources to use more of the now cheaper truck services. Table 1 shows top 20 U.S. importers and exporters and their container TEU volumes.

Table 1 - Top 20 U.S. Importers and Exporters and Container TEU Volumes

Top 20 U.S. Importers and Exporters			
Top 20 Importers	TEU (000)	Top 20 Exporters	TEU (000)
Wal-Mart Stores, Inc.	292	America Chung Nam Inc.	157
The Home Depot Inc.	182	Du Pont de Nemours 96	104
Target Corp.	173	Wyerhaeuser Co.	96
Dole Food Co.	143	Mead Westvaco	59
Chiquita Brand Int'l. Inc.	103	Dow Chemical Co.	52
Lowe's Cos.	83	Caergill Inc.	51
Heineken USA Inc.	75	International Paper Co.	50
Interbrew SA	60	Daimler Chrysler	47
Payless shoe Sources Inc.	55	Georgia-Pacific Group	48
General Electric Co.	49	Proctor & Gamble	48
Pier 1 Imports Inc.	47	Cellmark Group	45
Kmart Corp.	46	Altria Group Inc.	45
Samsung Electronics	46	Tyson Foods Inc.	44
American Honda Motor Co.	46	BASF Corp.	42
Big Lots Inc.	46	Engelhard Corp.	39
Ashley Furniture Industries	45	Ford Motor	37
Toyota Motor Sales USA Inc.	45	Shintech Inc.	32
Ikea International	45	Exxon Mobil	30
Mattel Inc.	44	Rayonier Inc.	29
Matsushita Electric Corp. America	42	Anderson Hay & Grain	28

Source: BST Associates, "Consolidation Activities in Southern California," based on PIERS data, March 2004.

The extent to which domestic transportation (primarily consisting of trucking) has enabled the U.S. shippers and importers to reduce their total warehousing and inventory-holding costs is demonstrated by the twin trend of the declining share of transportation in GDP and the rising share of transportation in the nation's total logistics costs. As noted in Section 2-1, total logistics costs as a share of GDP have declined from about 16 percent to about 10 percent of GDP. Transportation, however, has increased its share of total

logistics costs. In 1981, transportation accounted for 45 percent of the nation's total logistics costs (i.e., expenditures on transportation, inventory holding, and logistics administration.) Today, the share of transportation of total logistics costs has grown to 60 percent. Instead, the share of inventory holding costs as a percentage of total logistics costs has declined from 51 percent to 36 percent (with the remaining 4 percent for logistics management.) Lean inventory practices and JIT supply-replenishment strategies have, in the past three decades, succeeded in reducing the level of average inventories held by manufacturers and retailers significantly. In 1970, businesses held inventories at hand equal to 1.6 times their monthly sales. In 2004, the ratio of inventory to monthly sales was 1.2. Trend data on changing logistics costs indicate that between 1981 and 2000 inventory holdings as a percentage of sales dropped from 35 percent to 25 percent.²³

2-4 Gaining Competitive Edge through Vessel and Terminal Performance Improvements

Improving terminal productivity is a key logistics strategy for shipping companies. Vessel operators strive to increase their market share and lower their operating costs by better utilizing shoreside labor, terminal lift assets, and on-dock space. Studies have indicated that poor throughput and terminal performance metrics may adversely impact the competitiveness of international ports and reduce their trade volumes, particularly for smaller and less-developed countries.²⁴ A 2005 MARAD Report to Congress on *The Performance of Ports and the Intermodal System* reported that port comparisons are not easy because consistent data and methods to construct measures that allow worldwide port comparisons are not currently available. The report concluded that the agency: “was unable to provide the requested comparison of the most congested ports in terms of operational efficiency....”²⁵

However, establishing causal connections between port competitiveness and terminal performance metrics is not easy. The difficulty of comparing port performance arises because myriad factors contribute to port efficiency, including dock facilities, connections to rail and trucking lines, harbor characteristics (e.g., channel depth and ocean/tidal movements), time to clear customs, and labor relations. In an attempt to address some of the difficulties of measuring productivity and comparing ports, a study conducted by the USACE, Navigation Economics Technology Program, was able to develop efficiency measures to allow comparisons among different ports and countries only on a commodity-by-commodity basis.²⁶

²³ *Transportation in America*, 2000, Cass Logistics, June 2001.

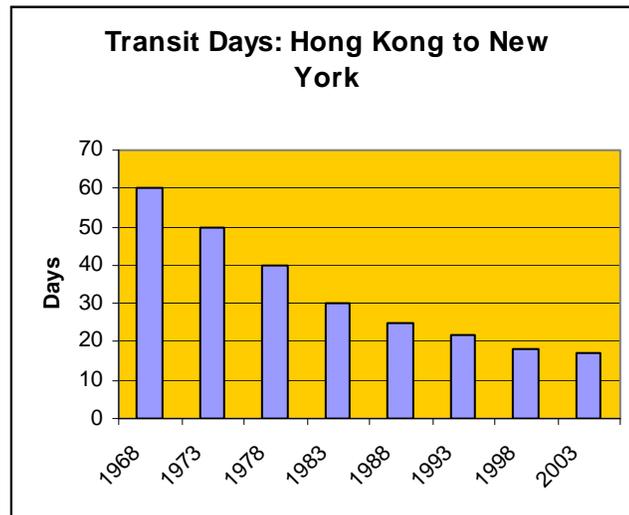
²⁴ Clark, Ximena, David Dollar, and Alejandro Micco, “Port Efficiency, Maritime Transport Costs and Bilateral Trade,” NBER working paper 10353, 2004; and John S. Wilson, Catherine L. Mann and Tsunehiro Itysyum, “Trade Facilitation and Economic Development: A New Approach to Quantifying the Impact,” *The World Bank Economic Review*, Vol. 17, 2003, 367-89.

²⁵ MARAD, *Report to Congress on the Performance of Ports and the Intermodal System*, June, 2005.

²⁶ “Port Efficiency and Trade Flows,” The Navigation Economic Technologies Program, Institute of Water Resources (IWR), USACE, IWR Report 06-NET-R-11, November 2006.

Reducing transit time by increasing vessel speed and operating efficiency is one common measure of carrier performance and competitiveness. Transit days between Hong Kong and New York (a major route for high value cargo such as garments) declined from 60 days in 1968 to 17 days in 2003 (Figure 12.) In the 1960s, much of the cargo was carried in non-container break-bulk vessels in all-water service that required a minimum of 60 days of transit time. By 1973, with new container operations introduced to achieve economies of scale and reduce handling costs, transit days for all-water service (through the Suez Canal) were reduced to 50 days. By 1978, the 60 day service had been reduced to 40 days. Beginning in 1983, development of intermodal rail service from the U.S. West Coast, with the rail mini-landbridge to the east coast, reduced the combined water-rail transit to 30 days. Introduction of doublestack rail service further reduced transit time to 25 days. In the late 1990s, the continued growth of South China convinced steamship lines to offer direct Far East Express service, bypassing ports in Korea, Taiwan or Japan. Today, the 17-day Hong-Kong to New York transit time, with about a 5-day rail service from the West Coast, has become the market standard (Figure 12).²⁷

Figure 12 - Trends in Transit Days between Hong Kong and New York



Source: *The Marine Transportation System and the Global Supply Chain*, 2006.

Terminal capacity is a function of many variables, including the berth length, vessel size mix, dwell time for containers, container stack height, percentage of wheeled containers-on chassis, and mix of cargo types (export, import, local, rail intermodal.) For instance, average container dwell time is a terminal performance measure that varies widely according to the type of terminal and shipment status. Export containers, for instance, have a terminal dwell time often twice as long as import containers, particularly if they are empty.²⁸ Table 2 shows a representative terminal dwell time for containers in Southern California:

²⁷ *The Marine Transportation System and the Global Supply Chain*, Education Team, Version 4.0, July 18, 2006., p. 53.

²⁸ The Tioga Group, "Growth in California Ports: Opportunities and Challenges", 2006.

Table 2 – Typical Terminal Dwell Times For Containers in Southern California

Type of Container	Average Dwell Time
Import – off-dock rail	1.5 days
Import – on-dock rail	2 days
Import – local delivery	4 days
Export – local pickup	6 days
Export – on-dock rail	6 days
Export - off-dock rail	6 days
Export – empty	7 days

Source: CALMITSAC, Growth in California Ports: Opportunities and Challenges, 2006.

A commonly-used metric for comparing terminal performance is TEU per gross terminal acre (gta). This metric evaluates the efficiency with which a terminal uses the scarce land. However, it does not take into account market conditions, shipping schedules, or the presence of transshipment cargo that can almost double the per acre productivity of a terminal. In the Port of Long Beach, the average TEU per gta is 5,174. By 2020, with the planned terminal capacity improvements, the port TEU per gta is projected to reach 10,980. Currently, the best U.S. West Coast ports have a TEU per gta of 6,000-8,000. Most Asian ports have a TEU per gta of 10,000-15,000 if container transshipments are not included. With transshipments included the metric reaches over 25,000 TEU per gta.

A key measure of labor productivity is tons per hour paid. At the U.S. West Coast ports, this measure rose steadily between the early 1980 and 1994 from about 3 tons per hour to almost 8 tons per hour. However, in the past eight years, this labor productivity measure has remained steady or declined slightly despite significant investment in port infrastructure and use of double-stack intermodal rail. Currently, this metric for the U.S. container-ports ranges from less than 7.5 tons per hour paid at Northern California ports to almost 10 tons per hour paid in the Puget Sound ports of Seattle and Tacoma.

Other measures of productivity include equipment cycles-per-hour and gate moves per hour. These metrics have to factor in equipment differences and type of containers handled. Table 3 summarizes some of the terminal productivity metrics based on survey data compiled by the AAPA-provided data from approximately 27 ports.²⁹

²⁹ Metrics for port capacity and productivity are suggested by survey data from 27 ports. The metrics were compiled by *The Marine Transportation System and the Global Supply Chain* Intermodal Team from AAPA-provided data, July 26, 2006, Norfolk, VA.

Table 3 – Representative Terminal Productivity Metrics

Productivity Measures	U.S. Averages West Coast Ports *	Best U.S. West Coast Ports	Asian Ports
TEU per gross terminal acre/yr	3,128 (mean) 2,993 (median)	6,000-8,000	10,000-15,000 (no allowance for Transshipment)
TEU per crane/yr	78,197 (mean) 81,534 (median)		
TEU per berth/yr	144,736 (mean) 99,660 (median)		
TEU per berth foot/yr	139 (mean) 156 (median)		
Tons per labor hour paid	3-8 tons/hr	10 tons/hr (Puget Sound/ Tacoma)	

Source: The Marine Transportation System and Global Supply Chain, July 18, 2006.

Section 3. Economic Risks: System Vulnerabilities and Consequences of Disruption in MTS Operations

This section evaluates the MTS operations based on the risk and vulnerability framework developed in Task 1 as the proof of concept for the assessment of MTS challenges. This framework allows us to identify the potential threats and system vulnerabilities, and the consequences of a disruption in maritime commerce and their attendant safety or environmental impacts and economic costs. The focus of this task report is on economic consequences. The Risk Analysis Framework is presented in Appendix A.

MTS disruptions that entail economic consequences include disrupted arrival/departure, loading/unloading, and delivery/shipment of scheduled cargo shipments resulting from capacity constraints and congestion, as described in Task 1. The factors that increase the likelihood that “something would go wrong” and result in adverse consequence are the vulnerabilities and system weaknesses that make disruptions more likely. Task 1 described and provided the evidence for the infrastructure vulnerabilities present in the MTS. This Task evaluates how these infrastructure vulnerabilities, coupled with the vulnerabilities arising from the global logistics practices, could potentially jeopardize the continued operations of the MTS for domestic and international shipping. The focus of this evaluation is the economic consequences of these vulnerabilities and the potential disruptions that may entail.

The analysis of the global supply chains and logistics in Section 2 of this report provided the context for the analysis of the economic consequences of MTS vulnerabilities. Within this context, the following drivers of the global logistics, cost outcomes, and impacts on vessel operators are identified (Table 4.)

Table 4 – Schematic Depiction of the Drivers of Global Logistics, Cost Outcomes, Impacts on Vessel Operators, and Consequences for MTS Risks

Section	Drivers of Global Logistics	Cost Outcomes	Impacts on MTS Vessel-Operators	Impacts on MTS Risk Levels
3-1	<ul style="list-style-type: none"> ◦ Desire to Reduce Costs by Outsourcing 	<ul style="list-style-type: none"> Lower Component Costs 	<ul style="list-style-type: none"> ◦Economies of Scale/ Larger vessel size 	<ul style="list-style-type: none"> ◦ Capacity Shortfall ◦ Loss of Excess Capacity ◦ Port Closures
3-2	<ul style="list-style-type: none"> ◦ Desire to Lower Prices by Increasing Imports 	<ul style="list-style-type: none"> Lower Prices of Final Goods 	<ul style="list-style-type: none"> ◦Economies of Scope 	<ul style="list-style-type: none"> ◦ Empty Container Repositioning ◦ Growing Trucking Traffic ◦ Low Value of Trade ◦ Trade Deficit ◦ Inadequate revenues for maintenance
3-3	<ul style="list-style-type: none"> ◦ Maturing of Asian Industries ◦ Shift of Manufacturing to Emerging Economies 	<ul style="list-style-type: none"> New Low-Cost Markets in Southeast Asia and S. America 	<ul style="list-style-type: none"> ◦ Shift to Suez/East Coast Ports ◦ Shift to Gulf/ Panama Canal ◦ Shift to Canadian/ Mexican Ports 	<ul style="list-style-type: none"> - Inadequate channel depth - Potentially Beneficial Effects in other areas - Traffic Diversion from Southern California Ports

Based on the above schematic outline, the consequences of MTS vulnerabilities are described in the following subsections:

- 3-1 Consequences of the growing vessel size and traffic
- 3-2 Consequences of the growing reliance on imports
- 3-3 Consequences of shifts in location of manufacturing centers

3-1 Consequences of the Growing Vessel Size and Traffic

The adverse consequences for the U.S. of the shipper logistics practices associated with the desire to reduce costs by outsourcing, as outlined in Section 2-1 include increased pressure on the existing MTS infrastructure capacity (port, rail, intermodal highway access) and congestion resulting from the growing size and volume of vessels and traffic.

Task 1 of this project described the risks associated with the infrastructure components. It described how vulnerability to operational disruption and system malfunction arising from inadequate harbor channel depth, inadequate terminal capacity, missing or overloaded intermodal connections, or structurally deficient bridges increase the likelihood that the potential threats to MTS could be realized. This section focuses on the economic consequences of the growing capacity constraints, congestion at freight rail and truck facilities, loss of excess port capacity, and labor and terminal performance issues.

Capacity Constraints

MTS capacity is being consumed at a rapid pace by increased international traffic. The report of the National Chamber Foundation on North American ports pointed out that additions to throughput capacity are being steadily absorbed by changes in traffic that use up any capacity expansion.³⁰ The Chamber report predicted that by 2010, 75 percent of the 16 ports studied will have significant capacity problems, and that most of the container capacity would be used up.

Capacity constraints arising from the escalating growth in the volume of trade traffic, size of vessels, and the number of vessel calls has been a major constraint for the U.S. container and bulk ports. The sharp increase in the number and size of the vessel calls in the past two decades has contributed to capacity constraints at the landside and waterside and increased the likelihood of disruption and delay. The number of vessel calls, for instance is projected to grow significantly from about 65,000 calls per year. As one astute observer of MTS capacity demands has observed, the implications of the growing number of vessel calls go beyond just port infrastructure: “such growth will drastically tax the capabilities of all domestic modes; age, wear & tear, and lack of maintenance are reducing the reliability – and ultimately the capacity – of an inland waterway infrastructure.”³¹

One of the reports of the National Surface Transportation Policy and Revenue Study Commission has reviewed the forecasts of container growth and concluded that capacity will expand to meet demand.³² Other evidence, however, suggest that for the most part, the U.S. ports have not been able to keep up with the growing volume of trade and demands of the modern containerships and tankers for harbor or berth depth. Forecast data provided by Freight Analysis Framework (FAF) suggest that imports will double between 2002 and 2035. Imports from Asia will quadruple and increase its share from 10 percent to 20 percent of all imports. According to the FAF forecasts, the share of imports entering U.S. through West Coast ports is projected to grow from 51 percent in 2002 to 70 percent in 2035.

³⁰ The U. S. Chamber of Commerce, “Trade and Transportation, A Study of North American Port and Intermodal Systems”, March 2003.

³¹ David Grier, “The Pace of U.S. Harbor and Channel Improvements: Will the U.S. Be Ready for a New Generation of Containerships?” USACE, undated (circa 2007).

³² Report of the National Surface Transportation Policy and Revenue Study Commission, *Transportation for Tomorrow*, January 2008.

The National Dredging Needs Study of U.S. Ports and Harbors (NDNS) has found that without the planned channel improvement projects identified by the Study, the total number of “constrained calls” by 2020 would be about 25 percent of the total vessel calls. The NDNS identified the magnitude and timing of needed harbor improvements to accommodate future vessel sizes and vessel calls projected at U.S. waterways in 2020 and beyond. It predicted that completion of the planned projects nationwide by 2020 would reduce constrained calls by half.³³ Given that many major West Coast ports are operating today at near capacity because of the rapid growth in container traffic, the economic consequences of capacity shortfalls at these congested U.S. ports could also be severe if significant volumes of traffic are diverted to alternative gateways.

Underscoring the economic consequences of inadequate funding for MTS maintenance operations is a recent report by the TRB, National Academy of Science (NAS), on challenges of infrastructure financing. The report identified inadequate maritime funding mechanisms for system maintenance an alarming trend, warned about the “downward spiral” created by lack of system preservation and rehabilitation, and cautioned that the price of short-term savings from deferred maintenance would be proportionately greater rehabilitation cost later.³⁴

Size and service requirements of the vessels used in international trade pose key threats to the viability of the nation’s container ports and bulk terminals. Inability of the ports’ berths and harbor channels to accommodate the growing size of ocean-going vessels has led to disruptions in port operations. System vulnerabilities that increase the likelihood that the threats will be realized include: a) the growing gap in the depth requirements of containerships and tankers calling at the U.S. ports, and the available harbor depth to accommodate them; b) the increasing number of vessel calls; and c) the high investment costs for purchasing container lift or bulk product handling equipment.

Loss of Excess Port Capacity

Loss of excess capacity is another adverse consequence of the rapid growth of the U.S. container trade, which can potentially have a cascading effect by further exposing the ports to threats of disruption, narrowing the port’s operational margin of error, and reducing the ports’ ability to resume normal operations. Measuring capacity constraints is not often easy since there is no single metric that captures the dynamics of productivity at ports. However, evidence presented by several international vessel analysts, including the Drewry Consults and the Howe Robinson & Co. Shipbrokers, confirms other reports, suggesting that unused capacity is dwindling.³⁵

³³ USACE, “National Dredging Needs Study of U.S. Ports and Harbors, Update 2000,” May 2003; pp. 183-185. Note that these forecasts are dated and new forecasts will be used when available.

³⁴ TRB, *Critical Issues in Transportation*, National Academy of Sciences (NAS), 2005.

³⁵ Global Insight, Inc., “Implications of International Trade and Port Capacity for Freight Transportation,” National Surface Transportation Policy and Review Study Commission Briefing Paper 4B-01, January 11, 2007, citing data from the October 2006 Howe Robinson & Co. The report also points out the additional problem of competition between different types of cargo handling facilities for available space at existing ports, causing some shifts between ports in the mix of commodities handled.

Estimates provided by Drewry Consultants suggest that terminal excess capacity at marine terminals will disappear by 2011.³⁶ The study is based on the 2005 baseline worldwide container demand of 399 million TEU, forecast to increase to 673 million TEU by 2011. The study estimated the 2006 global container capacity at 550 million TEU, and a total confirmed capacity expansion planned of 122 million for the next five years. By 2011, the total global container capacity will reach 672 million TEU. By 2011, the total global demand (based on forecast demand growth of 7.1 percent for North America, 7.6 percent for South East Asia, 10.6 percent for Far East, and a total global compound average growth rate (CAGR) of 9.1 percent) will have reached 672 million TEU. Currently, the utilization rate at the global container facilities is 78.7 percent (based on a current capacity level of about 507 million TEU.) Planned TEU capacity growth by 2011 will have reached 672 million TEU, but expected demand will have also increased to 672 million TEU, making the utilization rate 100 percent, suggesting that all excess capacity will have been used up³⁷ (See Table 5.)

Table 5 – Forecast Container Port Capacity Challenges

Container TEU	2005	2006	2007	2008	2009	2010	2011
Demand	399.2	441.8	481.4	525.7	572.8	622	672.9
Capacity	507.1	552	594	626	653	658.1	672.1
Utilization Rate	78.7	80.3	80.9	83.7	87.7	93.1	100.1

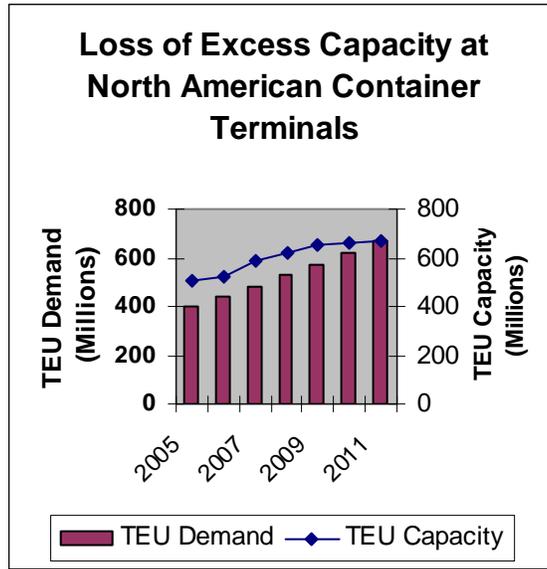
Source: Drewry Shipping Consultants, “World Container Cargo Prospects”, April 30, 2007

This projected loss of container ports’ unused capacity represents a looming vulnerability, leading to the reduced resilience of the waterway system and its diminished ability to return to normal operating conditions after disruptions in shipping operations. Figure 13 depicts the data presented in Table 5.

³⁶ Drewry Shipping Consultants, “World Container Cargo Prospects”, presentation by Neil Davidson, Research Directory, at the 25th IAPH World Ports Conference, Houston, 30 April, 2007.

³⁷ Drewry Shipping Consultants, “World Container Cargo Prospects”, presentation by Neil Davidson, Research Directory, at the 25th IAPH World Ports Conference, Houston, 30 April, 2007. Note that identical data were used in a report by John Vickerman, “Global Ports & Containerization Development: Choke Points and Opportunities,” Presented at the Fourth Annual Grain & Oilseed Transportation Conference, Memphis, Tennessee, March 26, 2007.

Figure 13 - Loss of Excess Capacity at North American Container Ports



Source: Volpe generated chart based on data reported Drewry Shipping Consultants, “World Container Cargo Prospects”, presentation by Neil Davidson, Research Directory, at the 25th IAPH World Ports Conference, Houston, 30 April, 2007

Rail and Trucking Congestion Costs

Added costs of trucking due to high rates of transloading are significant. As noted in Section 2, the practice of transloading 20’, 40’ and 45’ marine containers into 53’ domestic containers has become widespread, particularly in the Southern California region. Recent studies by the UC Berkeley professor Robert C. Leachman have shown that as much as 80 percent of the containerized goods that arrive in Los Angeles and Long Beach are taken by train or truck to retailers, manufacturers and warehouses out of state. Prior decades’ solutions for improving congestion at key bottleneck locations (e.g. the construction of the Alameda Corridor to relieve highway-rail bottlenecks at the ports of LA/LB) cannot address today’s container transloading problems. The Alameda Corridor was designed to improve the movement of intermodal marine containers on rail. The 20-mile, \$2.4 billion project succeeded in eliminating grade-level highway-rail crossings by lowering the track into a concrete trench. The Corridor, however, does not reduce the problem of highway congestion. Whereas the Alameda Corridor offered solutions for “intact” containers loaded directly on rail at the marine ports, it does not address the widespread problem of container transloading.³⁸

Land-side congestion and capacity constraints on rail and intermodal highway links, and growing highway congestion are also key measures of the adverse consequences of the gap between the transportation capacity and the MTS users’ demands. The DOT “Freight Analysis Framework” (FAF) is forecasting a 70 percent increase in freight traffic by 2020. The Federal Highway Administration (FHWA) has estimated that by 2029, 29 percent of urban NHS routes will exceed capacity (i.e., classified as congested for much of the day; while 42 percent will be congested during peak hours,) compared to only 10 percent of the

³⁸ Dan Weikel, “Cargo has L.A. Traffic at a Crawl,” *Los Angeles Times*, June 10, 2008.

National Highway System (NHS) routes that were congested in 1998. Highlighting the role of trucking in the growing highway congestion are the projections that the percentage of the segments on the urban Interstate System that carry more than 10,000 trucks per day will increase from 27 percent in 1998 to 69 percent by 2020, with over half of the segment mileage congested (compared to 20 percent today.) Furthermore, peak hour congestion on the Interstate System in metropolitan areas is projected to increase to 46 percent of the facilities by 2020 (from 29 percent in 2000.)

Labor and Terminal Performance Challenges

Vulnerabilities in the MTS relating to terminal labor and equipment performance could potentially lead to operational disruptions. In terms of terminal productivity the best Asian container ports outperform the best North American ports by more than 3 to 1. Even discounting the effect of transshipments at Asian ports, the best North American port terminals would have to double their productivity to keep pace with Asian ports. In North America, the average West coast ports are more than twice as productive as the average East coast ports, partly due to the Pacific Rim trade patterns and to the integration of modern rail intermodal technology.

There are several weaknesses inherent in the U.S. marine terminal systems that represent what the National Chamber Foundation Report refers to as “fault lines” for efficient connections between vessel operations and the terminal. These include legacy information systems that are not coordinated or integrated, and gate operations that are not conducted on a 24/7 basis. Another emerging terminal productivity problem is arising from the retailers’ practice of inventory deferral, as noted in Section 2-3. Much of inventory deferral involves “in-transit rerouting” in which shippers wait to make their routing decisions until the last possible minute in order to accommodate changing customer demands. In-transit rerouting makes the JIT delivery of goods possible, but is also makes it impossible for shippers to share the final destination of their cargo with the carriers.³⁹

Declining cargo revenues at some ports is the vulnerability of domestic ports to loss of market base or adequate capacity, either because of the type of cargo they carry or the relatively short length of haul for domestic cargo. Because port revenues from cargo handling are distance based, the increasingly short length of haul for bulk or general cargo on the waterways makes most domestic shipping operations vulnerable to facility under-maintenance. Traffic data indicate a steadily declining trend in the length of haul for domestic shipments: average length of haul for all domestic waterborne commerce has declined from approximately 800 miles in 1986 to about 500 miles in 2004. For coastwise cargo, the average miles-per-ton has declined from over 1,800 miles in 1986, to roughly 1,250 miles in 2004.⁴⁰

³⁹ This list is based on *Trade and Transportation: A Study of North American Port and Intermodal System*, National Chamber Foundation of the U.S. Chamber of Commerce, March 2003.

⁴⁰ Source: BTS http://www.bts.gov/publications/freight_in_america/html

Costs of Port Closure

Port closure, whether due to natural disasters, labor strikes, or terrorist threats has emerged as not an uncommon occurrence. Studies have suggested that loss of trade revenues arising from an actual or anticipated port closure could be manifested through economic losses to port regions or the emergence of new networks of shipping lanes and cargo handling facilities.

A study conducted for the Department of Labor in 2002 estimated that a 7-day shutdown of container traffic through the ports of LA/LB would generate losses to the economy of roughly \$75 million per day. Another study estimated the economic losses to the nation by calculating the shippers' willingness to pay to avoid a delay in import delays. The study, conducted at Purdue University, analyzed U.S. import data on a product-by-product basis. For the waterborne mode of transportation, the study estimated the shipper willingness to pay to avoid shipping delays to amount to 0.8 percent of the value of shipments.⁴¹

Another estimate of the economic costs of disruptions at marine ports is provided by a recent Congressional Budget Office (CBO) study that estimated the costs based on the scenarios similar to the 2002 West Coast labor dispute. The CBO study examined two scenarios: a 1-week shutdown and a 3-year shutdown of operations at the Ports of Los Angeles and Long Beach. The one-week shutdown was estimated to lead to losses between \$65 million to \$150 million per day, with an estimated loss of \$450 million for an average week of shutdown. The 3-year shutdown was estimated to lead to greater losses, estimated to amount between 0.35 percent and 0.55 percent of the Gross Domestic Product (GDP), equivalent of a loss of \$45 billion to \$70 billion per year. The CBO study assumed that in the aftermath of the closure, the backlog of ships waiting to enter ports would be resolved by a number of strategies, including carrier flexibility to shift port calls to alternative ports, reconfigured supply chains (albeit at higher costs), and the possibility that producers might turn to domestic sources of supply and consumers consume a different mix of goods.⁴² The CBO study attempted to correct for the previous high-end estimates of \$1.96 billion per day in losses from the 10-day 2002 shutdown of the Southern California container ports.⁴³

3-2 Consequences of the Growing Reliance on Imports

As noted previously, the U.S. imports have been exceeding the rate of exports for the past three decades, with the exception of a couple of years in the early 1970s. The economic consequences of this growing reliance on imports for MTS have been threefold:

- Declining per ton value of exports and imports
- Economic costs of trade deficits, and the

⁴¹ DRI-WEFA "The National Economic Impact of a West Coast Port Shutdown," prepared for the US Department of Labor, Office of the Assistant Secretary for Policy, may 29, 2002.

⁴² Congressional Budget Office (CBO), *The Economic Costs of Disruptions in Container Shipments*, March 29, 2006. http://www.cbo.gov/ftpdoct/71xx/doc7106/03_29_container_shipments.pdf

⁴³ The estimated losses of \$1.96 billion per day were based on Martin Associates, *An Assessment of the Impact of West Coast Container Operations and the Potential Impacts of an Interruption of Port Operations*, 2000.

- Costs of imbalance in inbound/outbound and loaded/empty containers.

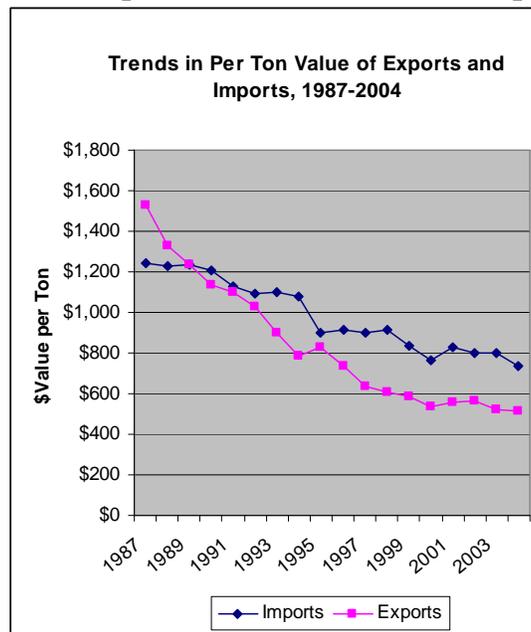
Declining Per Ton Value of Exports and Imports

While the total value of cargo trade has been rising at a rapid rate, the values have been declining per-ton of cargo shipped. The plummeting value can be attributed to a variety of factors, including a decline in the value of waterborne import cargo and a change in the composition of the U.S. exports.

One reason for the decline is that the global outsourcing trend has resulted in an overall cost decline. The other reason is that increasingly, the U.S. exports of high-value manufacturing products have been replaced with lower value commodities. Today, waste paper and scrap metal are the leading U.S. export products.

To illustrate, the U.S. maritime imports from Japan (most automobiles, parts, and electronics) are valued at \$7,000 per tone, U.S. exports to Japan (mostly agricultural products, mechanical equipments and chemicals) are valued at about \$500 per tone. The manufacturing deluge from China has held inflation at bay while lowering the value of imported goods. Figure 14 shows the trends in per-ton value of the U.S. exports and imports.

Figure 14 – Trends in per Ton Value of the U.S. Exports & Imports



Source: Volpe generated chart based on calculation of the average values per ton, using data from BEA, U.S. International Trade in Goods and Services, 1960-2004 for value of Goods Exports and Imports; and tonnage data from IWR, Waterborne Commerce of the United States, Calendar Year 2006, Table 1-6;⁴⁴

⁴⁴ Note that average values in Figure 18 are based on the Volpe Center calculations of the 2006 trade values obtained from Bureau of Economic Analysis and the tonnage data obtained from the U.S. Army Corps of Engineers Waterborne Commerce of the United States. Per-ton values may not be consistent with other sources of average-value calculation.

Economic Costs of Trade Deficits

The growing imbalance between imports and exports represents yet another potential vulnerability of the U.S. container ports. The gap between container exports and imports, reflecting an export deficit, has been growing steadily. Prior to 1998, the export deficit was less than 1 million TEU per year, but by 2005 this gap had widened to 9 million TEU per year. In 2005, containerized imports accounted for two-thirds of marine container traffic passing through our ports, compared to about one half in 1995.⁴⁵ The growing gap between the number of import and export containers has necessitated the repositioning of the empty containers to the original Asian ports. Because empty containers generate very little revenue for the ports and containerships, the growing export-import gap has exacerbated the revenue constraints (and shortage of harbor improvement funds) at some U.S. Pacific Coast ports. Figure 15 illustrates the trend in the number of container TEU and the growing gap between exports and imports, 1960-2008.

Figure 15 – International Trade in Goods and Services, 1960-2008



Source: Volpe produced chart based on BEA data reported in the *U.S. International Trade in Goods and Services*, last updated October 9, 2009

Table 6 documents the balance of goods and services in international trade between 1960 and 2008, showing the contrasting contribution of goods and services to the growing balance of U.S. trade. Until 1975, the U.S. maintained a positive trade balance. During this period the positive trade balance was in goods exports, accompanied by a negative trade balance in services. After 1975, the U.S. goods trade balance has been negative and growing, the trade in services has shown a steadily growing surplus, and the net trade deficit has been ballooning, reaching its peak in 2006 with a deficit of \$760 billion. The recession of the past two years has for the first time reduced the net trade deficit (Table 6.)

⁴⁵ BTS, *America's Container Ports: Delivering the Goods*, March 2007.

Table 6 – Balance of the U.S. International Trade in Goods and Services, 1960-2008

Year	International Trade Balance (\$Billions)		
	Total	Goods	Services
1960	\$3.5	\$4.9	-\$1.4
1965	\$4.7	\$5.0	-\$0.3
1970	\$2.2	\$2.6	-\$0.3
1975	\$5.4	\$8.9	-\$3.5
1980	-\$19.4	-\$25.5	-\$6.1
1985	-\$122.1	-\$122.2	\$0.1
1990	-\$81.2	-\$109	\$27.9
1995	-\$95.1	-\$174.2	\$79.1
2000	-\$379.8	-\$454.7	\$74.9
2004	-\$610.0	-\$671.8	\$61.8
2005	-\$715.3	-\$790.9	\$75.6
2006	-\$760.4	-\$847.3	\$86.9
2007	-\$701.4	-\$831.0	\$129.6
2008	-\$695.9	-\$840.3	\$144.3

Source: *Bureau of Economic Analysis*, U.S. DOC, for data on 1960-2004 trade balances; and for data 2004-2008, BEA, U.S. International Trade in Goods and Services, Exports, Imports, and Balances, last updated November 13, 2009.

The implications of the U.S. trade balances for the economy as a whole and for the MTS are potentially significant. In general, trade deficits are macroeconomic variables that may or many not indicate underlying problems with the competitiveness of particular industries or the nation as a whole. The reason is that overall trade flows are determined within the framework of institutional barriers to trade, as well as the macroeconomic factors in other nations such as growth in incomes, savings, and exchange rates. A recent Congressional Research Service (CRS) report on the U.S. merchandise trade deficit noted that:

“While U.S. export are highly competitive in world markets, U.S. sales abroad are overshadowed by the huge demand by Americans for imported products.....As the trade deficit rises relative to the total economy, the risk increases that the dollar will weaken, raise prices, disrupt financial markets, and reduce the economic well being of the population.....Increases in trade deficits may diminish economic growth, since net exports (exports minus imports) are a component of grow domestic product.”⁴⁶

In the late 1980s and early 1990s, export growth was an important element of an overall U.S. economic growth. In 1999, merchandize exports accounted for about 8.5 percent of GDP, compared with 5.9 percent in 1990.⁴⁷ Today, exports account for a smaller share of GDP, partly because, as the CRS report has pointed out, the rest of the world is not growing fast enough to generate a vigorous U.S. export growth. The declining export trade has not allowed the U.S. to stabilize the growth in trade deficit, let alone reduce it.

⁴⁶ Congressional Research Service (CRS), “U.S. International Trade: Trends and Forecasts”, CRS Report for Congress, Updated December 14, 2006.

⁴⁷ Some analysts have observed that rising trade deficits can also reduce total domestic demand in the economy, but that the deficits may also be offset by rising consumer, business and government demand.

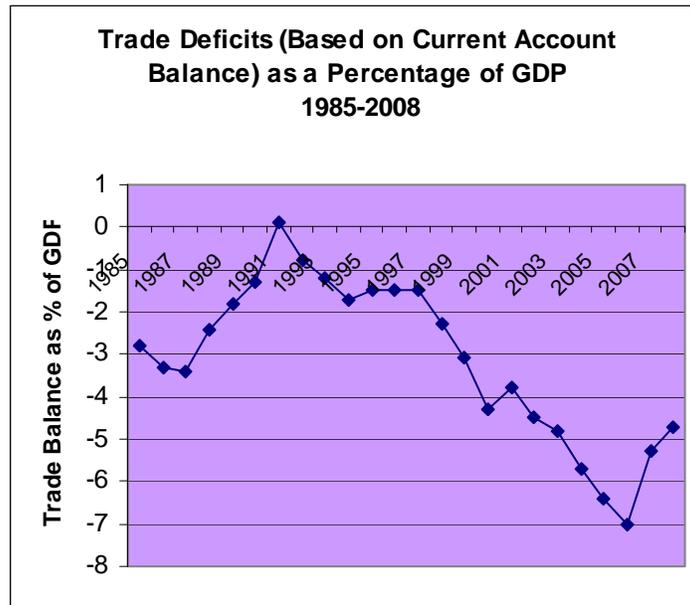
As noted in the CRS report, one risk associated with the rising U.S. trade and current account deficits is that it could lead to a larger drop in the value of the U.S. dollar. The current account deficit now exceeds 5.7 percent of GDP and is placing downward pressure on the dollar. If foreign investors stop offsetting the deficit by buying dollar-denominated assets the value of the dollar would drop precipitously. Merchandize trade (goods) is the most widely used measure of trade balance. However, “services” are important components of the total export-import balance, as measured by the BEA “Current Account Balance” since the total export-import balance provides a broader measure of U.S. trade by including services, investment income, and unilateral transfer in addition to merchandize.⁴⁸ Unlike the merchandise trade balance, the services account has been in surplus since 1975. In 2008, the U.S. surplus in services trade was \$144.3 billion. The U.S. has traditionally had a surplus in its investment income, partly because of the large value of the U.S. based multi-national investments in foreign economies.

The current account balance as a percent of GDP grew in magnitude from near zero in 1980 to -3.4 percent in 1987, was reduced to about zero in 1991, and rose to -6.4 percent in 2005. CRS points out that this rate exceeds the -5.0 percent-level, a rate the International Monetary Fund (IMF) considers to warrant caution. The U.S. trade deficit as a percent of GDP rose to its highest point in the 2005-2006 period, with the deficit rate reaching to close to -7.0 percent of GDP. In the past two years, however, with the severe economic recession and decline in consumer demand for imports, the deficit rate has begun to decline. In 2008 the Current Account Balance as a percentage of GDP was -4.72 percent, showing a declining deficit relative to the 2007 deficit level of -5.30⁴⁹ (Figure 16).

⁴⁸ The balance on services includes travel, transportation, fees, and royalties, insurance payments, and other government and private services. The balance on investment income includes incomes received on U.S. assets abroad minus income paid on foreign assets in the U.S. Unilateral transfers are international transfer of funds for which there is no quid pro quo, and include private gifts, remittances, pension payments, and government grants/foreign aid. Since the merchandise trade balance comprises the greater part of the current account, the two tend to tracks each other.

⁴⁹ http://www.economywatch.com/economic-statistics/United-States/Current_Account_Balance_Percentage_GDP/

Figure 16 - Trade Deficits as a Percentage of GDP, 1985-2008



Source: Volpe generated chart based on CRS, Issue Brief for Congress, “U.S. International Trade: Data and Forecasts”, 2008

Costs of Imbalance in Inbound/Outbound and Loaded/Empty Containers

Traffic in inbound/outbound container traffic reflects an imbalance that has created significant costs and capacity problems at the nation’s container ports.

Under normal circumstances, the cost of repositioning an empty container is a manageable operational cost, and considered a normal component of container shipment operations. However, current conditions prevailing in the West Coast, and particularly in the San Pedro Bay in Southern California, are such that the imbalance has created significant operational challenges. Over 1 million import containers transported in Southern California each year are “empties”, and virtually all of them are trucked empty back to the marine terminal. While over half a million empty containers were trucked back from the terminal to be loaded with exports, less than 2 percent of these containers are reloaded locally (a practice termed “street turned.”)⁵⁰ This practice has created two sets of problems: one is the high cost of repositioning (and the associated terminal and highway congestion problems), and the other is the shortage of export containers.

In 2005, the TEU imbalance due to the excess of the import containers had reached an estimated 7 million TEU, most of which due to the imbalance in the West Coast import trade, and the growing export deficit in US trade. The percentage of empty 40’

⁵⁰ The Tioga Group, “Empty Ocean Container Logistics Study,” Report prepared for Gateway Cities Council of Governments, Port of Long Beach, Southern California Association of Governments, May 8, 2002.

containers that are not reused for exports (Empties/Empties + Exports) has risen from about 42 percent in 2000 to 55 percent in 2004. Percentage of empty 45' containers that are not reused for exports rose from 55 percent in 2000 to about 68 percent in 2004.⁵¹

The gap between the volume of containerized exports and imports, coupled with the widespread practice of transloading marine containers has been the underlying cause of this imbalance. Because of this transloading practice, the number of intact containers handled in international ports has declined significantly. An estimated 60 percent of the 40' and 45' marine containers are transloaded into 53' domestic containers. With the growth of inventory deferral practices, more customers are transloading from marine to domestic containers on the West Coast. The findings of the Tioga Group Empty Container Study included:

- The difference between rapidly growing eastbound imports and slowly growing westbound exports since 1996 has left the US and the West Coast with a massive container imbalance.
- There has been an influx of westbound doublestack trains chiefly carrying empties diverted from their former Northern California and Pacific Northwest destinations. The ocean carriers have diverted the trains to ensure an adequate eastbound railcar supply in Southern California.
- Empty containers have a longer dwell time in marine terminals, and are using up scarce terminal capacity. This is because local ordinance often prohibit container terminal operators from increasing yard capacity by stacking the empties higher.⁵²

A longer-term consequence of the imbalance in container flow is that the decline in the number of intact containers has made infrastructure solutions such as the Alameda Corridor obsolete, because these solutions had been geared to moving intact containers. With the growing trend in transloading, intermodal rail improvements that are designed to improve the efficiency of moving the container to rail are mostly obsolete since increasingly few intact containers will be moving on rail at major import ports.

In addition to the congestion and capacity costs of the empty container imbalance there is also the growing revenue losses associated with repositioning empty containers. The high cost of repositioning has led to a buildup of empty containers that must be repositioned as 'non-revenue' moves to Asian source regions. The need to move massive quantities of empties has strained the economies gained by shifting their fleet to larger containerships. A testimony to the high cost of repositioning empty containers is the recent reports on the shortage of new containers. This shortage has arisen because exporters have begun purchasing new containers instead of paying for a repositioned container.⁵³

⁵¹ *The Marine Transportation System and the Global Supply Chain*, Education Team, Version 4.0, July 18, 2006, p. 88.

⁵² "Empty Container Logistics Study, The Tioga Group, May 2002.

⁵³ Associated Press, "Port Traffic Snarled by Container Shortage," May 12, 2008.

Section 4. MTS Resiliency: Mitigating Factors that Potentially Enhance MTS Robustness and Adaptiveness

The resiliency framework developed in Task 1 of this study identified the elements of an analysis based on the principles of system adaptiveness, fault-tolerance, redundancy, and mitigating buffers that reduce severity of consequences. Within this framework, the report identified a resilient MTS infrastructure as one that:

- is adaptive and flexible; has access to information and operational intelligence that monitor the facility boundary conditions and guard against potential threats;
- has components and attributes that make it more fault-tolerant;
- has built-in redundancies that help reduce vulnerability to single-point failures; and
- has mitigating operational conditions that work as buffers to help reduce the severity of the consequences in the event of a disruption, enabling the MTS component parts to recover a stable state and continue operations after major disruptions.

This analysis of the MTS economic resiliency will focus on three inherent elements of MTS resiliency:

- MTS adaptiveness is demonstrated by its ability to shift traffic to alternative ports;
- MTS fault-tolerance is highlighted by its capability to seek and successfully implement innovative solutions;
- Built-in redundancies in the vast inland waterway infrastructure offer the potential for expanded intermodal cargo and passenger operations for short-sea shipping operations as part of the MARAD Marine Highway program.

Note that the following descriptions are for purposes of illustration and are not designed to be comprehensive. More exhaustive treatment of the MTS resiliency attributes have either been provided in the past reports or will be offered in the future task reports.

MTS Adaptiveness: Shift of Traffic to Alternative Ports

Several shifts are underway in response to growing congestion and uncertainties at the nation's international marine ports. One strategy involves a shift of traffic away from the congested Southern California ports to better utilize the unused capacity on the East Coast, Pacific Northwest, and the Gulf ports. Diverting traffic to Canadian and Mexican ports, and greater use of the Panama Canal after the completion of the expanded 3rd Lock are also adaptive responses to the growing port congestion in Southern California.

Shippers and major retailers have already begun strategic port choices design to avoid potential disruptions. These adaptive responses have included shipper attempts to incorporate redundancy (e.g., multiple distribution center locations and additional vessel calls) in their supply chains and vessel rotation to ensure shipment reliability. The growing number of “import distribution centers” established by national retailers to handle the new container distribution and vessel routing patterns is an example of this new adaptive strategy. Wal-Mart, for instance, recently shifted its gateway and processing center to Houston, a possible sign of a new pattern of handling its imports. The rapid growth in some smaller ports, e.g., the sharp increase in ocean-borne containerized cargo volume at the Port of Savannah, demonstrates today’s shippers’ and carriers’ search for alternative ports of call as a strategic response to avoid vulnerabilities to disruption in major import ports in Southern California.⁵⁴

The potential for the diversion of some of the traffic away from congested West Coast ports to Atlantic ports through an increased use of the Suez Canal has also been entertained for some years, though the actual diversion may not be as large as expected. The changing structure of manufacturing in China is expected to lead to future shifts in location of manufacturing centers from China to the Southeast and Southern Asia (including Vietnam, Cambodia, and the Indian subcontinent), making the Suez Canal a cheaper and closer route to the Atlantic coast.

Making MTS Fault-Tolerant: Innovative Terminal and Operational Solutions

An array of innovative technologies and tools are available for improving system productivity and increasing its fault tolerance. Some of these solutions have successfully been tested for relieving truck or waterway congestion, increasing capacity, or reducing the need for dredging.

A Virtual Container Yard is one such concept, designed to relieve port area container handling congestion. A Virtual Container Yard is a truck scheduling and dispatch system, based on the underlying notion of a computerized “clearinghouse” or “bulletin board” for information on the status and availability of containers at marine terminals. The Virtual Container Yard would allow all the container yard functions to take place without moving the container to the physical location. The functions performed include: posting of container status information, communication between parties, equipment exchange, supply chain decisions about container transloading and decision on the need for value-added functions on the contents of the container.⁵⁵ Virtual Container Yard has its precedent in the port wide truck appointment system developed several years ago at the Port Authority New York/New Jersey as part of a successful initiative to deploy the Internet Portal FIRST to improve trucking efficiency and turn times.

Application of advanced technologies and decision-support tools for improving system productivity and resiliency include a water-level forecasting tool such as LoadMax that

⁵⁴ BTS, *America’s Container Ports: Delivering the Goods*, March 2007.

⁵⁵ The Tioga Group, *Empty Ocean Container Logistics Study*, May 8, 2002.

helps pilots and captains set departure times and vessel speeds to take advantage of tides and fresh water flows to allow the vessels to be loaded to the maximum depth. The successful examples also include the SmartLock navigation and communications system that establishes links between the tow and the lock, giving the pilot of the tow greater knowledge as to the position of the tow relative to the lock, and allowing a steady locking speed during periods of low-visibility and adverse conditions.

Innovative approaches to reducing congestion at the nation's container ports include expanded port operating hours, the PierPass fee system and national or national chassis pools. Other strategies include changes in container "Free Time" and terminal demurrage policies to make them more efficient and reduce the "bunching" of trucks calling a terminal. Strategies to spread out vessel sailing and arrivals in the Trans-Pacific Trade to make maximum use of terminal capacity have also been proposed and in some ports deployed.⁵⁶ Similar strategies for improving terminal efficiency and increasing container velocity have included:

- Extended gate hours
- Congestion pricing
- Trucker appointment systems
- Off-dock container yards
- High-speed rail shuttles
- Integrated maritime and rail movement
- Expanded rail connections
- Automated yard marshalling and inventory control
- Automated gate processing systems.⁵⁷

MTS Redundancy: More Efficient Use of Underutilized Infrastructure for Short-Sea Shipping

Short Sea Shipping (SSS), also called the Marine Highway initiative, has been proposed as an effective national MTS strategy with respect to shipping costs, energy efficiency, and environmental benefits. One key advantage of SSS is its greater cost-effectiveness. The American Society of Civil Engineers, in its 2005 Report Card for America's Infrastructure, gave a grade of D- to the nation's inland waterways, while pointing out the vast under-utilized resources that are offered by barge service on the inland waterway system. A single barge on the inland waterways, the report stated, can move the same amount of cargo as 58 semi-trucks at one-tenth of the costs. However, the poorly maintained locks and dams, and inadequate funding for waterway maintenance, the report cautioned, have adversely impacted the performance of the inland waterways.⁵⁸

⁵⁶ *Waterfront Coalition National Marine Container Transportation System, A Call to Action*, May 2005, <http://www.portmod.org>

⁵⁷ Thomas Ward (DMJM), "Port Congestion Relief: Attacking the Entire Chain", undated, <http://www.dmjmharris.com/media/4437.pdf>.

⁵⁸ The American Society of Civil Engineers (ASCE), *Report Card for America's Infrastructure*, March 2005.

Though SSS is not a new concept, the Marine Highway Program is a new initiative that is being implemented as part of the HR 6, Energy Independence and Security Act of 2007, signed on December 19, 2007. The MARAD Office of Marine Highways and Passenger Services has been charged with implementing Title XI, Subtitle C, Marine Transportation, of America's Marine Highway Program. The Maritime Administrative Order No. 530-1, effective May 29, 2008 includes the following procedures:

Section 5.01: Marine Highway Corridors. The purpose of this section is to designate specific routes as Marine Highway Corridors, established through an application process. The goal of this designation is to accelerate the development of multi-state and multi-jurisdictional corridors to relieve landside congestion along highway and rail corridors.

Section 5.02: Marine Highway Projects. The purpose of this section is to designate specific Marine Highway projects to mitigate landside congestion. The goal is to identify projects that, if successfully started, expanded, or otherwise enhance, would provide the greatest benefit to the public. The objectives include reduction in landside congestion, identification of services that represent the greatest public benefit as measured in congestion relief, energy savings, reduced emission and improved safety.

Section 5.03: Action by the Maritime Administration. Upon receipt of an application by the MARAD Administrator, the application will be evaluated based on the preceding criteria, including:

- (1) Marine Highway Corridor: the potential public benefit the corridor may offer;
- (2) Marine Highway Projects: Likelihood of long-term self-supporting operations, and its relationship with Marine Highway Corridors, once designated.

Section 5.04: Incentives, Impediments and Solutions. This section is aimed at increasing the use of the Marine Highways by encouraging its integration in transportation plans at the State, regional, and local levels; developing short term incentives aimed at expanding existing or starting new operation; and identifying and seeking solutions to impediments to the Marine Highway.

Section 5.05: Regional, State and Location Transportation Planning.

Section 6.0: Research on Marine Highway Transportation.

In the past several years, before the enactment of the Marine Highway Program, a number of studies have been conducted on the feasibility of SSS. These studies described several potential domestic traffic lanes and identified bulk and break-bulk commodities that could be shifted to barge with the potential to generate significant economies of scale and cost savings. One study found that SSS could be particularly competitive for heavy break-bulk shipments, hazardous cargo, and bulk chemicals that currently move over the road.

The application of SSS for deployment of small self-propelled feeder ships at the nation's coastal container ports offers one effective solution to congestion at top U.S. container ports. In the agency's 2006 *Report to Congress*, MARAD pointed out that the average size of containerships calling at U.S. ports was 17 percent larger than the size of vessels calling at ports elsewhere in the world. The report explained that one reason for the larger average size of the vessels calling at U.S. ports, and hence the growing gap between the vessel draft needs and the available channel depth, is the scarcity of small U.S. feeder vessels and SSS services. The report points out that in Europe and Asia, smaller feeder vessel and SSS services handle most of the intra-European and intra-Asian trade.⁵⁹ Given that the size of a feeder ship is between 2,000-3,000 TEU, instead of the 6,000-plus TEU vessels routinely calling on coastal ports, SSS services could potentially offer a viable solution for many corridors and underutilized ports.

Appendix 7 of this report provides an industry assessment of Short Sea Shipping in the U.S.

⁵⁹ Maritime Administration, *Annual Report to Congress*, Fiscal Year 2006.

ACRONYMS

AAPA	American Association of Port Authorities
AASHTO	American Association of State Highway and Transportation Officials
AIS	Automatic Identification System
BAP	Bridge Administration Program
CALMITSAC	California Marine and Intermodal Transportation System Advisory Council
CHL	Coastal and Hydrological Laboratory
CI/KR	Critical Infrastructure Key Resource
CMTS	Committee on the Maritime Transportation System
COB	Container on Barge
DHS	Department of Homeland Security
DOE	Department of Energy
DWT	Deadweight
ECDIS	Electronic Chart Display and Information System
EIA	Environmental Impact Analysis
ENC	Electronic Navigation Chart
EPA	Environmental Protection Agency
ERDC	Engineering Research and Development Center
FAST	Freight Action Strategy for the Everett-Seattle-Tacoma Corridor
FHWA	Federal Highway Administration
GDP	Gross Domestic Product
GPS	Global Positioning System
HMT	Harbor Maintenance Tax
HMTF	Harbor Maintenance Trust Fund
IAT	Integrated Action Team
ICMTS	Interagency Committee for the Maritime Transportation System
IRCS	Inland River Container Services
IWR	Institute for Water Resources
IWTF	Inland Waterway Trust Fund
LA/LB	Ports of Los Angeles/Long Beach

MARAD	Maritime Administration
MDA	Maritime Domain Awareness
MTSNAC	MTS National Advisory Council
MTS	Maritime Transportation System
NCHRP	National Cooperative Highway Research Program
NDNS	National Dredging Needs Study
NHS	National Highway System
NIPP	National Infrastructure Protection Plan
NOAA	National Oceanic and Atmospheric Administration
MTSA	Maritime Transportation Security Act of 2002
NED	National Economic Development
NRC	National Research Council
ORNL	Oak Ridge National Laboratory
PANY/NJ	Port Authority New York/New Jersey
RFID	Radio Frequency Identification
SCOOP	Short Sea Shipping Cooperative Program
SOW	Scope of Work
SSS	Short Sea Shipping
TEU	Twenty Foot Equivalent
TRB	Transportation Research Board
ULCC	Ultra Large Crude Carriers
USACE	United States Army Corps of Engineers
USCG	United States Coast Guard
USDA	United States Department of Agriculture
USDOD	United States Department of Defense
USDOT	United States Department of Transportation
WRDA	Water Resources Development Act
WSCS	Waterborne Commerce Statistics Center
WCUS	Waterborne Commerce of the United States

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Appendix C

Assessment of the Marine Transportation System (MTS) Challenges

Task 3: MTS Environmental Challenges

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Preface

This report is the revised Task 3 deliverable for the Volpe National Transportation Systems Center (Volpe Center) Reimbursable Agreement (RA) VH-99 with the United States Army Corpse of Engineers (USACE). The report has been prepared by Dr. Bahar Barami, the Volpe Center project manager, and revised to reflect the comments and inputs received from the project sponsors and members of the Marine Transportation System (MTS) Needs Assessment Integrated Action Team (IAT), including the comments received from: CDR Paul M. “Bo” Stocklin, USCG, on August 21, 2008; Ginny Fox-Norse, EPA, on May 8, 2009; Eric Wolfe, on June 5, 2009; and Safra Altman, NOAA, on October 15, 2009. The project manager is indebted to the Volpe Center colleague, Michael Dyer, for research support on the first draft of this report and to Rod Cook, Chief, Intermodal Infrastructure Security and Operations Division, for peer-review and quality control input.

Executive Summary

Marine vessels and cargo/passenger operations are significant sources of global air and water pollution, and their contribution to degradation of the environment has been growing relative to other modes of transportation. This study provides an assessment of the MTS environmental risks by focusing on air and water pollution hazards stemming from marine engine emissions, spills of oil and hazardous cargo in the water, and contaminations caused by dredged materials and ballast water. The focus of the study is on four categories of MTS environmental risks:

1. Risks arising from marine vessel propulsion engines, fuel, and cargo handling equipment (CHE) and the associated environmental pollution caused by the release of exhaust emissions and harmful gases into the atmosphere;
2. Risks arising from discharge of bulk cargo residues, oil spills, and hazardous materials incidents;
3. Risks arising from the disposal of contaminated dredged materials; and
4. Risks arising from the release of ballast water that can pollute the water and introduce invasive non-indigenous species in the waterways.

Risks Arising from Marine Vessel Propulsion Engines and Fuel

Engine size is a key factor in marine vessel emission levels. There are three engine sizes currently in use:

Category 1 Engines: smaller marine diesel engines of less than 5 liters per cylinder capacity used for auxiliary power or for propulsion of smaller vessels;

Category 2 Engines: marine diesel engines of less than 30 liters per cylinder capacity used for vessel propulsion or auxiliary engines;

Category 3 Engines: very large marine engines above 30 liters per cylinder capacity most commonly used to propel international container ships, tankers, bulk carriers and cruise ships, with a few found on ships in the Great Lakes.

Marine vessels operating along the U.S. coastal and inland waterways consumed 8.5 billion gallons of fuel. Over 60 percent of the fuel used by marine vessels is “residual fuel oil,” a low-grade fuel with a high degree of viscosity and high levels of sulfur oxide (SO_x) content, as well as nitrogen oxide (NO_x) and particulate matter (PM). The remaining marine vessels use distillate diesel (about 24 percent, mostly by smaller vessels or auxiliary equipment) and gasoline (about 16, mostly by recreational boats).

All diesel engines, whether used in truck, rail, or marine transportation, generate high levels of NO_x, PM, and green house gases (GHG). Main propulsion engines as well as auxiliary engines emit these pollutants. Freight transportation accounts for approximately half of the mobile-source NO_x emissions and 27 percent of all U.S. NO_x emissions (anthropogenic sources only). Heavy-duty truck vehicles today are by far the

largest contributors to freight emissions nationally, producing two-thirds of the NOx and PM from the freight sector. Marine vessels are the next largest source, accounting for 18 percent of the NOx emissions, and 24 percent of PM emissions from freight operations.¹ Heavy duty trucks also account for more than three-quarters of freight-related GHG emissions (which include NOx and CO₂, in addition to non-diesel components such as methane and Chlorofluorocarbons, or CFC), followed by marine vessels and freight railroads.

The U.S. Environmental Protection Agency (EPA) has estimated that *Category 3* marine engines are key sources of the nation's mobile source emissions. Residual fuel oil, used exclusively in *Category 3* marine engines, is the major contributor to SOx, NOx emissions and PM. The International Maritime Organization (IMO) for the past few decades has emphasized the growing contribution of marine diesel emissions to pollution and global warming. A recent study released by the IMO underscored the growing contribution of marine vessels to global air pollution and rising GHG emission by showing that CO₂ emissions from international aviation grew by 34 percent between 1990 and 2004, while emissions from international maritime transport grew by 43 percent.

Emissions Arising from *Cargo Handling Equipment* (CHE) ²

Emissions from marine cargo transportation are caused not only by the engines used to power vessels but also the engines used in the land-based equipment for moving marine cargo at ports, commonly referred to as *cargo handling equipment* (CHE), i.e., yard tractors (or yard hostlers), top and side loaders, forklifts, and cranes.

A Federal Highway Administration (FHWA) study of total marine vessel emissions at some of the nation's largest ports showed that the San Pedro Bay Region ports (consisting of the Ports of Los Angeles and Long Beach) had by far the highest emission levels in the nation, including high levels of CHE emissions (accounting for 20 percent of the ports' emissions.) The high levels of CHE emissions in these ports are due to the large volumes of containers handled in the San Pedro Bay ports that require extensive land-side CHE activity. Port of Houston had the highest level of marine vessel emissions of any single port, but relatively low levels of CHE emissions, because Houston handles a large proportion of liquid bulk freight, mostly petroleum, which requires relatively little in terms of land-side CHE.

Risks of Emission from Ports' Practice of "Hotelling"

For some engine types, pollutant emissions rise at idling speeds. Operating the engine at idling speed is associated with "hotelling" operations, i.e., the practice of running the main propulsion plant while the ship is at rest to provide power for the needs of the shipboard electrical and other auxiliary systems. NOx emissions per ton of fuel are

¹ Reported in FHWA, *Assessing the Effects of Freight Movement on Air Quality at the National and Regional Level, Final*, Report, April 2005, based on the EPA National Emission Inventory data.

² As an acronym for cargo handling equipment, CHE has been used in the Department of Defense and FHWA literature, most recently in FHWA, *Assessing the Effects of Freight Movement on Air Quality at the National and Regional Level, Final*, Report, Prepared by ICF Consulting, April 2005.

nearly twice as high for low-speed diesel engines. NOx emissions from hoteling by ocean-going vessels (OGV) at the ports in the FHWA study were highest at the Houston Region ports, accounting on average for half of the ports' emissions. At the Ports of Los Angeles and Long Beach, hoteling accounted for roughly 30 percent of the OGV emissions.

Forecasts of Future Trends in Marine Vessel Emissions

Emissions from all freight operations in the U.S. are forecast to decline by 63 percent by 2020. However, emissions from marine engines are projected to stay the same or change only slightly. Domestic truck emissions of NOx are estimated to experience the greatest decline (82 percent), followed by freight rail (43 percent). Commercial marine emissions are expected to decline only slightly by 2020 (7 percent). Total PM emissions from freight are also expected to decline 50 percent by 2020. As with the NOx emissions, the reduction is led by trucking, which is estimated to drop 71 percent in PM emissions. Freight rail PM emissions are expected to decline by 39 percent by 2020. Marine vessel emissions of PM in 2020 are predicted to stay nearly identical to 2002 levels, because growth in marine activity will offset the effect of EPA emission and fuel standards.³

EPA has predicted that by 2030, the nation's marine emissions will grow significantly in the absolute sense if no action is taken to regulate engine emissions and fuel quality.⁴ EPA projects that the relative contribution of emissions from marine vessels will also grow rapidly as emissions from other sources are subjected to increasingly stringent controls. The contribution of ship emissions is most significant in U.S. ports and coastal areas that are subject to heavy maritime traffic. Currently more than 40 U.S. ports are located in non-attainment areas for ozone or fine particulates or both. However, the problem is not limited to port areas and varies according to the wind and weather patterns that determine how much of the vessel emissions reach land and pollute the non-port inland regions.

Risks Arising from Oil Spills

The USCG data show a dramatic decline in overall spill volumes since 1990. The data reflect the impacts of the new regulatory requirements of the OPA 90, the new International Convention on the Prevention of Pollution from Ships (MARPOL) oil carriage regulations, and the emerging culture of safety among the operators and state/local port authorities. The USCG data show that oil spill events involving more than 1,000 gallons between 1973 and 2004 followed a general downward trend in the number of spills. The USCG report states that over 80 percent of the spills that occurred from 1973 - 2004 were under 100 gallons.

The Coast Guard National Pollution Funds Center (NPFC) administers the Oil Spill Liability Trust Fund (OSLTF), which pays for response and removal costs and for

³ EPA, Bryan Wood-Thomas, Associate Director, Office of Transportation and Air Quality, Testimony before the Committee on Environment and Public Works, U.S. Senate, , February 14, 2008.

⁴ The USCG has noted that the pending U.S. accession to MARPOL Annex VI could potentially impact the baseline status of vessel emissions (comments on the Draft Report by Commander Paul M. Stocklin, August 21, 2008,)

damages. The estimated removal costs and damages from incidents taking place since the enactment of the OPA 90 total approximately \$1.3 billion in 2007 dollars, according to the NPFC report for the years 2002-2006.

Risks Arising from Contaminated Dredged Material

Dredging projects are most often located in busy ports and waterways that have been home to industrial production facilities and are therefore likely to have contaminated sediments. The Army Corps of Engineers (USACE) is responsible for the proper management, placement, or disposal of all dredged materials.

The USACE is required in each dredging case to find alternatives that meet the substantive and procedural requirements of the National Environmental Policy Act (NEPA), the Clean Water Act (CWA), and the Marine Protection, Research, and Sanctuaries Act (MPRSA). These requirements address both clean and contaminated dredged materials, and evaluate the available alternatives for their disposal and beneficial use. Treatment of contaminated sediments can be expensive, estimated at up to \$50 per cubic yard. However, not all dredged materials are contaminated, with many beneficial uses of dredged materials available, as described below.

Risks Arising from Ballast Water

The rapid rate of international trade and the growing sizes of commercial marine vessels have accelerated the transport of invasive species, also called aquatic nuisance species (ANS), by marine vessels. These ANS may attach themselves as external appendages, but the vast majority of them ride in the ships' ballast tanks. Ships carry water in ballast tanks for the purpose of safe loading and the balancing of sea-going vessels. A typical modern bulk carriers and tank ships can carry as much as 200,000 metric tons of ballast water, most of which is discharged in the departure port as the ship takes on its cargo. The total amount of ballast water discharged in U.S. waters each year is about 8 million metric tons. The well publicize invasion of the zebra mussel in the Great Lakes has been estimated to have cost approximately \$5 billion in damages to water pipes, boat hulls, and other hard surfaces.

While it might appear that the U.S. would be the recipient of much of the ballast water discharged in the world, the data indicate that the U.S. is a net exporter of ballast water. This is because so many ships, particularly large tankers and containerships, return overseas with full ballast tanks for balancing the weight after discharging their cargo within the U.S. waters.

MTS Resiliency and Mitigation Measures

MTS resiliency and mitigative measures are system attributes and safeguards that reduce the probability of a single-point failure. They consist of access to information and technology solutions that make the system adaptive to environmental disruptions and reduce the severity of consequences, serve as preventive mechanisms that make the system more fault-tolerant, and facilitate access to redundant components that can mitigate the system vulnerabilities. Some of the mitigative measures present in the U.S. MTS include:

- Successfully implemented beneficial use of dredged material. Only between 5 to ten percent of all dredged materials in the U.S. are contaminated. Sediment erosion and loss of habitat are often more damaging than potential contamination. EPA has estimated that excessive sediment erosion, transport and deposition cause damages of approximately \$16 billion annually in North America. In many locations, a shortage of sediment causes coastal erosion, stream bank erosion, and wetland loss. Recent efforts at promoting beneficial uses of dredge material have proven highly effective. Dredging industry organizations have stressed the industry success in expanding the beneficial use of dredged materials. Their reports indicate that between 1998 and 2003, an average of 212.1 million cubic yards of dredge materials was excavated annually from U.S. waterways at a cost of approximately \$700 million. In the six-year period between 1998 and 2003, the beneficial use of dredged materials included 82.7 million cubic yards used for beach nourishment, 12 million cubic yards used for a combination of beach nourishment and the creation of upland sites, and 11.4 million cubic yards used to create wetlands and wildlife habitat.
- Measures to address contamination by ballast water have proven successful. In February 2004, the IMO adopted the International Convention for the Control and Management of Ships' Ballast Water and Sediments in the U.S., under the National Invasive Species Act (NISA), the Coast Guard is authorized to issue ballast water management (BWM) regulations for vessels entering the Great Lakes and Hudson River and voluntary guidelines for all vessels entering U.S. waters. As part of this process, the U.S. is working with Canadian regulatory agencies to promote a ballast water exchange (BWE) program that requires vessels in international trade entering the Great Lakes to remove organisms from a ship's ballast tanks by diluting the water and exposing freshwater organisms in the tanks to salt water, thereby killing many of them.
- To mitigate the problem of marine vessel emissions, the Ports of Los Angeles and Long Beach jointly approved an incentive program in 2008 aimed at accelerating cargo vessel operators' use of cleaner burning fuel within 40 miles of San Pedro Bay and at berth. The ports will allocate money to pay vessel operators to use cleaner-burning, low-sulfur fuel in their main propulsion engines program by reimbursing the difference between the price of bunker fuel and more costly low-sulfur distillate fuel. Similarly, the Port Authority of New York and New Jersey (PANY/NJ) has a program to offset air emissions from its dredging projects through funding the re-powering of tugboats operating in the Kill Van Kull and at the Harbor Deepening Project, and by retrofitting of the Staten Island Ferries. The Port is also trying to reduce diesel exhaust emissions by electrifying port cranes through replacement diesel-powered cranes and through infrastructure improvements enabling tenants to install new electrical cranes.
- The domestic and international regulations enforced by the IMO and EPA are promising to be effective mitigation tools for addressing the MTS environmental

challenges. In 1997, the IMO adopted Annex VI of the International Convention on the Prevention of Pollution from Ships (MARPOL) to set NO_x emissions standards for ships. MARPOL Annex VI came into force in May 2005, and required that any country that has ratified the treaty must enforce the NO_x emission standards for any ships in its waters to follow emission standards for engines on ships constructed on or after January 1, 2000. MARPOL Annex VI establishes, among other things, the following:

- Limits on NO_x emissions as a function of ships' engine speed;
- A global cap of 4.5 percent by mass on the SO_x content of fuel oil, dropping to 3.5 percent by 2012;
- Establishment of SO_x Emission Control Areas (SECA), wherein the sulfur content of fuel must not exceed 1.5 percent, dropping to 0.1 percent by 2015; alternatively, ships must fit exhaust gas cleaning systems or use other methods to limit SO_x emissions. There are now North Sea and Baltic Sea SECAs.

The U.S. Environmental Protection Agency (EPA) and the Canada and Mexico administrations are considering whether to designate one or more SECAs along the North American coastline, as provided for by MARPOL Annex VI. The U.S. Senate ratified MARPOL Annex VI in June 2008. This will allow the U.S. regulators to enforce the new regulations against any foreign-flagged ship that visits a U.S. port, whether or not the flag state of the ship has ratified the treaty. As a result, a larger share of *Category 3* marine engines in U.S. waters will be subject to the IMO emission regulations.

Introduction

This report is Task 3 of the following six Task Reports for addressing the MTS challenges:

- Task 1 – MTS Infrastructure
- Task 2 – MTS Economic and Productivity
- Task 3 – MTS and the Environment
- Task 4 – MTS and Safety
- Task 5 – MTS and National Security
- Task 6 – MTS Data, Funding, and Institutional Issues

Task 1 of this study examined the MTS physical infrastructure and conducted an assessment of the baseline MTS characteristics within a risk assessment and reliability framework. It analyzed the present and projected threats to the continued performance of the infrastructure, and identified system vulnerabilities and potential countermeasures for enhancing system resiliency.

Task 2 Report built on the risk and resiliency analysis framework developed in Task 1 and conducted an analysis of the economic impacts and risks of MTS. Within this framework, the study estimated the magnitude of the global economic impacts of a disruption in system operations, identified the vulnerabilities relating to the dependence of the nation's trade system on MTS, and assessed system resiliency with respect to the flexibility of the MTS-dependent supply chains, users and vessel operators.

Task 3 Report will address the environmental challenges arising from systemic risks and vulnerabilities inherent in MTS, including the threats to the Nation's environmental stewardship mission and the associated challenges of meeting the performance demands of a global transportation network. The report will focus of the environmental and safety risks arising from the marine vessel engine emissions, oil spills and hazardous cargo incidents, contaminated dredged materials, and invasive non-indigenous species introduced by ballast water. Task 3 will also identify measures for preventing pollution, and address issues relating to sustainable environmental practices, the resilience of the marine ecology, and the ability of MTS to return to normal conditions after an environmental disaster.

A Framework for Assessing MTS Environmental Risks

Marine vessels and cargo/passenger operations are significant sources of global air and water pollution, and their contribution to degradation of the environment in the U.S. has been growing relative to other modes of transportation. This study provides an assessment of the MTS environmental risks by focusing on air and water pollution hazards stemming from marine engine emissions, spills of oil and hazardous cargo in the water, and contaminations caused by dredged materials and ballast water.

The common approach in the first step of risk analysis is to develop scenarios that assess the risks to the operations of any complex infrastructure system by asking the following three questions:

- *What can go wrong?*
- *What is the likelihood that it would go wrong?*
- *What are the consequences?*

Answers to these questions require a systematic process of risk assessment. Appendix A provides a risk and resiliency framework created for this project, as presented in Task 1 project report. Within a standard risk assessment framework, the MTS risks are defined as the following relationship between the prevailing threats – natural, man-made, and systemic – posed by the domestic and international maritime activities, the likelihood that these threats will be realized and lead to operational disruptions, and the severity of consequences:⁵

$$R = pT \times C$$

Where:

R = *Risk* of disruption or failure in any of the MTS parts, units or subsystems

p = Probability of threat realization

T = *Threat*: probability that the condition of any of the MTS operational components/subsystems will lead to facility closure, accidents, or environmental degradation.

C = *Consequences*: criticality, severity, impacts, and resulting damages.

Threat (T) can be further broken down as a product of *exposure* to sources of threat, and the present *vulnerabilities*:

⁵ Appendix A provides a more detailed description of the Risk and Reliability Framework developed in Task 1 of this project. Descriptions in this section are adapted from Yacov Y. Haimes, *Risk Modeling, Assessment, and Management*, Wiley Series in Systems Engineering, 1998; and Yacov Y. Haimes, "Roadmap for Modeling Risks of Terrorism to the Homeland," *Journal of Infrastructure Systems*, June 2002.

$$T = E \times V$$

Where: E = exposure; V = vulnerability.

This section reviews the MTS environmental risks within the analytical framework developed in Task 1. Within this framework, the MTS environmental challenges are evaluated with respect to the following parameters:

Threats: The probability that the diminished environmental quality of waterborne transportation resources will result in disruption in MTS operations and functions in support of economic and trade activities, maritime safety, and national security.

Exposure: Probability that the magnitude of the exposure of the MTS subsystems (including the volume of traffic, hazardous cargo, ballast water, dredged materials) to external and internal threats will increase the risks involved in an adverse event or disruption.

Vulnerabilities: The probability that weaknesses inherent in the MTS facilities, vessels, cargo, waterways and terminals, and the absence of safeguards and protective mechanisms in certain MTS operational components – e.g., vessel propulsion engines, fuels used, cargo carried, dredging needs, and the discharge method of ballast water – will increase the probability that the environmental threats will be realized.

Consequences: The economic costs and safety, health, and environmental outcomes of the threats being realized.

Within this context, four categories of MTS environmental risks are evaluated:

5. Risks arising from marine vessel propulsion and auxiliary engines, fuel, and cargo handling equipment (CHE) and the associated environmental pollution caused by the release of exhaust emissions and harmful gases into the atmosphere;
6. Risks arising from discharge of bulk cargo residues, oil spills, and hazardous materials incidents;
7. Risks arising from the disposal of contaminated dredged materials; and
8. Risks arising from the release of ballast water that can pollute the water and introduce invasive non-indigenous species in the waterways.

Section 1. Risks Arising from Marine Vessel Propulsion Engines and Cargo Handling Equipment

Marine vessels and the associated cargo operations at ports and terminals are among the key sources of the MTS environmental risks. Vessel size, type of engine and fuel used, and the land-side cargo handling equipment (CHE) deployed for handling cargo within the port and terminal areas determine the magnitude of the emissions. This section reviews the vulnerabilities in the U.S. and global marine shipping operations that contribute to the MTS environmental risks stemming from:

- Large vessel engines,
- Marine vessel fuels,
- CHE, and
- Operational practices such as “Hotelling.”

1-1 Vulnerabilities Stemming from Large Marine Vessel Engines

Marine shipping vessels operating within the U.S. Exclusive Economic Zone (EEZ) include vessels transiting and shipping to and from U.S. coastal ports, the Great Lakes, and the navigable inland waterways. The size of the engines used for shipping operations – self-propelled ocean-going vessels (OGV) such as container ships, dry bulk vessels and tankers, as well as tugboats and land-based equipment – is a key determinant of the level of emissions.

When it comes to air pollution, there is a major difference in emission levels between the very large engines used for vessel propulsion and smaller engines used for auxiliary power or for propulsion of smaller vessels. The following engine types are defined as key classifications for purposes of identifying pollution levels:

Category 1 Engines: These are smaller marine diesel engines of at least 50 horsepower and a per-cylinder displacement of less than 5 liters; they are used for auxiliary power or for propulsion of smaller vessels and are similar to land-based non-road engines used in construction and farm equipment.

Category 2 Engines: These are marine diesel engines with per-cylinder displacements of between 5 and 30 liters, used for vessel propulsion or as auxiliary engines to provide on-board electricity; they are most similar to those engines found in land-based locomotives.

Category 3 Engines: These are very large engines with a displacement at or above 30 liters per cylinder, most commonly used to propel containerships, tankers, bulk carriers engaged in international trade and for cruise ships; a few of these engines are found on ships in the Great Lakes.

A key factor determining emission levels of marine engines is the fuel type they use. Most *Category 1* and *Category 2* engines burn distillate diesel fuel, which is similar to non-road diesel. *Category 3* engines burn residual fuel which has high levels of NO_x, SO_x and PM; they are the key focus of the regulatory enforcement efforts underway to reduce marine engine emissions. A new development relates to some marine vessels entering Southern California ports that are voluntarily using ultra low-sulfur diesel (ULSD) for main propulsion.

For regulation of *Category 3* marine engine emissions, the United States submitted a proposal to the IMO in February 2007 for establishing new and tighter emission standards for ships. This proposal was based on performance-based standards that reflect the use of cleaner fuels and emission control technologies, including exhaust after-treatment, as described later in this report.

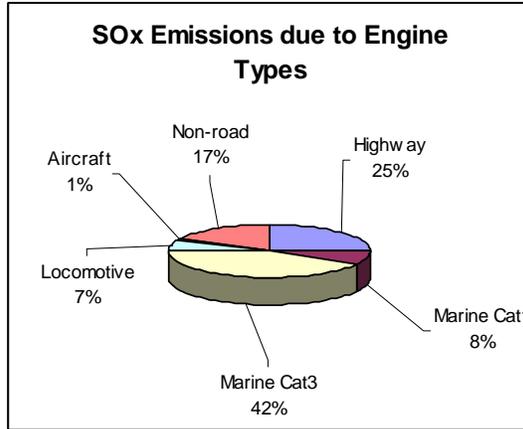
For regulation of *Category 1* and *Category 2* marine engine emissions, in 2008 the EPA finalized a rule for adoption of two new tiers of exhaust emission standards for smaller vessels that operate with high- and medium-speed engines. The proposal includes near-term emission standards (referred to as Tier 3 standards) as well as longer-term Tier 4 standards that reflect the application of high-efficiency exhaust after-treatment technology. The proposal, when implemented, would result in PM reductions of 90 percent, and NO_x reductions of about 80 percent.

EPA has developed a National Emission Inventory (NEI) that can be used to estimate mobile- and stationary-source emissions nationally and by county. The NEI is developed using a combination of national and local level activity data and input from state and local air agencies. Data from the NEI are used for air dispersion modeling, regional strategy development, regulatory enforcement, air toxics risk assessment, and tracking trends in emissions over time. Based on the NEI data, the EPA has estimated that emissions from marine vessels operating within the Exclusive Economic Zone (EEZ) of the U.S. account for approximately 13 percent of nitrogen oxides (NO_x) emissions, 17 percent of PM_{2.5} emissions, and 50 percent of sulfur oxides (SO_x) emissions.⁶

Based on the analysis of the NEI data, the EPA has estimated that *Category 3* marine engines are key sources of the nation's mobile source emissions. Figures 1, 2, and 3 show the contributions of two types of marine engines (*Category 1* and *Category 3*) to the national mobile source emissions of SO_x, NO_x, and PM_{2.5}, respectively. *Category 1* and *3* engines together accounted for 50 percent of the total SO_x, 13 percent of NO_x, and 17 percent of the PM_{2.5} emissions in 2001. Residual fuel used in *Category 3* marine engines is to a large extent responsible for the high level of SO_x originating in these engines.

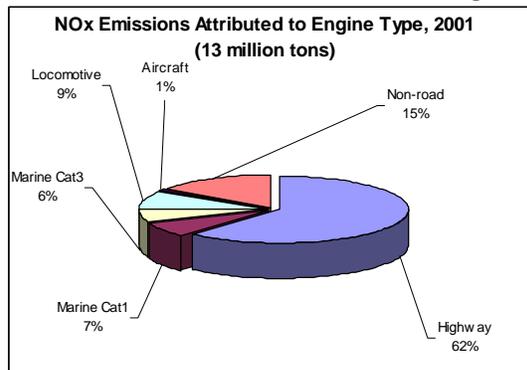
⁶ EPA, Bryan Wood-Thomas, Associate Director, Office of Transportation and Air Quality, Office of Air and Radiation, Statement before the Committee on Environment and Public Works, U.S. Senate, February 14, 2008.

Figure 1 - SOx Emissions Attributed to Engine Type



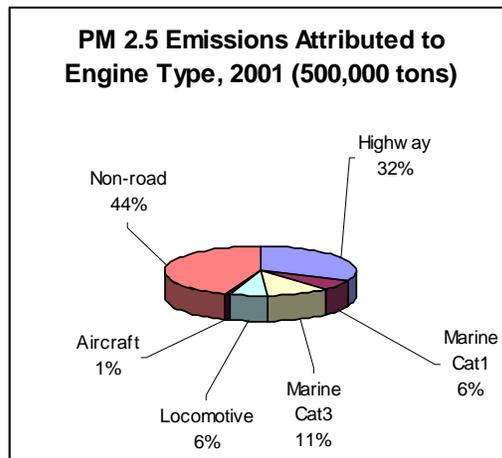
Source: Volpe generated chart based on the EPA, Bryan Wood-Thomas, February 2008

Figure 2 – NOx Emissions Attributed to Engine Type



Source: Volpe generated chart based on data from EPA, Bryan Wood-Thomas, February 2008

Figure 3 – PM_{2.5} Emissions Attributed to Engine Type



Source: Volpe generated chart based on data from the, EPA, Bryan Wood-Thomas, 2008

1-2 Vulnerabilities Stemming from Marine Vessel Fuels

In 2005, marine vessels operating the U.S. coastal and inland waterways consumed 8,500 million gallons of fuel. Sixty one percent of the fuel used was residual fuel oil (5,180 million gallons), 24 percent was distillate diesel fuel (2,000 million gallons) and the remaining 15 percent (1,260 million gallons) was gasoline. The residual diesel fuel used in marine engines is a low-grade fuel with high sulfur content. Residual fuel is a by-product of the distilling process for creating lighter petroleum products from crude oil. Though it comes in many grades and blends, residual fuel typically is of high viscosity and has a high sulfur and nitrogen content, resulting in high levels of NO_x and particulate matter (PM) emissions compared to lighter diesel products.

Estimates of the worldwide sales of marine “bunker” fuels reflect the extent to which the world marine industry relies on the highly polluting residual fuel. A 2000 study for the IMO estimated the annual world-wide marine bunker sales in 1996 at 138 million tons, including 38 million tons of distillate diesel fuel and 100 million tons of residual fuel.⁷ A more recent study found large increases in marine fuel use by 2003, including volumes of residual fuel rising to 234 million tons.⁸

Not all U.S. marine engines use residual fuel. Residual fuel is almost exclusively used by oceangoing marine vessels for international transportation. Among the U.S.-flag vessels using residual fuels are the Alaska tanker fleet, cabotage shipping vessels, and container services between Hawaii and the U.S. west coast. Some vessels serving the Great Lakes use residual fuels. Virtually all other U.S. domestic fleet – inland vessels, harbor craft,

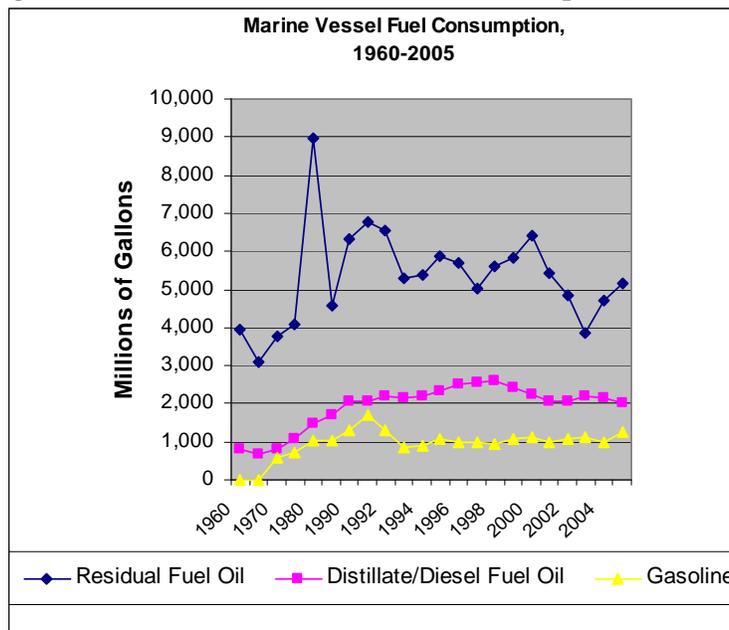
⁷ Skjølsvik et al, “Study of Greenhouse Gas Emissions from Ships”, 2000

⁸ Martin R Tallett (EnSys Energy & Systems, Inc.) and David St. Amand (Navigistics Consulting), “Potential Marine Fuels Regulations: Impacts on Global Refining, Costs & Emissions” presented at Joint IFQC & IPIECA Roundtable: Impacts of CO₂ Emissions from Refining & Shipping, London, England, 1 October 2007

small commercial workboats, ferries, excursion boats, tug boats, and other work boats – use distillate diesel fuel.⁹

The reported volumes of residual fuel oil consumed in the U.S. have fluctuated, but the fuel has remained the primary source of marine fuel. About 60 percent of the marine vessel fuel consumed in the U.S. is residual fuel, and the remaining is distillate diesel (24 percent) and gasoline (16 percent), as depicted in Figure 4. Generally, all diesel fuel engines, including the Heavy-Duty Highway Diesel (HDHD) truck engines, emit exhaust fumes composed of NOx, PM, and other harmful components that pose significant health hazards. Figure 4 shows that the use of diesel and gasoline fuels increased between 1960 and 2005, a trend that can possibly be attributed to the rise in recreational vessels and smaller engines.

Figure 4 – Trends in Marine Vessel Fuel Consumption, 1960-2005



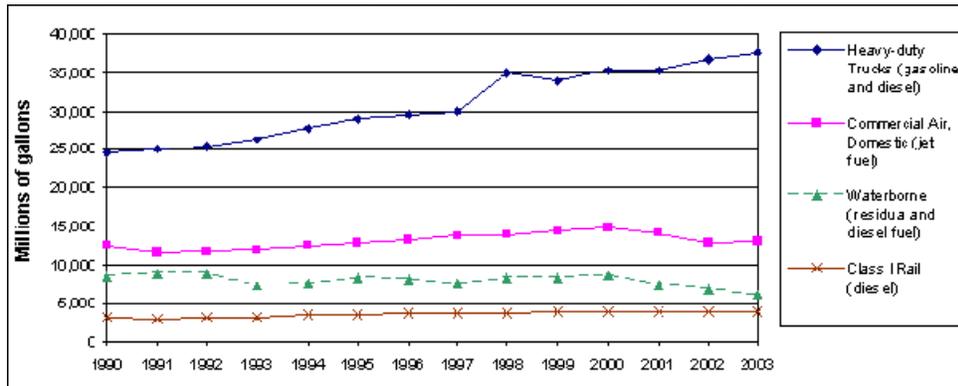
Source: Volpe generated chart based on data from BTS, Table 4-5 Fuel Consumption by Mode of Transportation

Figure 5 illustrates the trends in fuel consumption for freight movement from 1990 to 2003. It shows that heavy duty trucks are the largest users of diesel fuels used for moving freight (38 billion gallons of fuel), followed by commercial airlines (at 13 billion gallons) and waterborne freight (8.5 billion gallons.) The FHWA study that developed the trend data concluded that while freight trucks, locomotives, marine vessels, and aircraft

⁹ Tallett and St. Amand, "Global Trade and Fuels Assessment - Future Trends and Effects of Designating Requiring Clean Fuels in the Marine Sector", draft, prepared for the EPA, 2006

are becoming more fuel-efficient over time, growth in freight activity has in most cases outpaced these efficiency gains.¹⁰

Figure 5 – Fuel Consumption by Domestic Freight Mode, 1990 – 2003



Source: FHWA, *Assessing the Effects of Freight Movement on Air Quality at the National and Regional Level*, Final Report, April 2005 <http://www.fhwa.dot.gov/environment/freightaq/chapter2.htm>, based on data from Bureau of Transportation Statistics, *National Transportation Statistics 2004* (air, waterborne, rail); Federal Highway Administration, *Highway Statistics 2003* (truck).

As noted above, all diesel engines, whether used in truck, rail, or marine transportation, generate high levels of NOx and PM. Long-term exposure to diesel engine exhaust has been associated with respiratory inflammation and lung damage. The 1970 Clean Air Act established the National Ambient Air Quality Standards, identified six pollutants, and introduced basic emission standards for heavy-duty diesel engines. Since 1984, EPA has progressively implemented stringent diesel emission standards to reduce the level of allowable NOx emissions. The FHWA study cited above, based on the data derived from the EPA National Emission Inventory (NEI), developed comparisons of the U.S. NOx and PM-10 emissions for four major freight modes for 2002 (Table 1).¹¹ Note that the marine vessel emissions in Table 1 include small volumes of non-freight activity (e.g., cruise ships and ferries). Table 1 data also include some non-freight activities for rail and aviation.¹² Also note that Table 1 does not show emissions from off-road cargo terminal CHE at ports or for airport ground support equipment.

¹⁰ FHWA, *Assessing the Effects of Freight Movement on Air Quality at the National and Regional Level Final*, Report, April 2005 <http://www.fhwa.dot.gov/environment/freightaq/chapter2.htm>. Note that most commercial aircraft fuel use in this figure is due to passenger movements.

¹¹ Based on FHWA, <http://www.fhwa.dot.gov/environment/freightaq/chapter2.htm>, with data sources including: U.S. EPA, National Emission Inventory; total mobile source emissions and total emissions obtained from state air quality agencies. Freight railroad emissions estimated as 96.4 percent of total railroad NOx emissions and 96.7 percent of total railroad PM-10 emissions, based on passenger locomotive fraction in U.S. EPA, *Locomotive Emissions Standards, Regulatory Support Document*, April 1998; Air freight emissions estimated as 10.1 percent of total aircraft emissions, based on air estimated aircraft departures attributable to air freight, as described in report text.

¹² The NEI does not distinguish between freight and non-freight activity. As a result, emission estimates for air freight includes much of passenger transportation activities. FHWA estimated air freight emissions as 10.1 percent of total aircraft emissions, based on the estimated fraction of aircraft departures attributable

Table 1 – U.S. Freight Transportation NOx and PM-10 Emissions by Mode, 2002

Mode	NOx Emissions				PM-10 Emissions			
	Tons	Percent	As percent of:		Tons	Percent	As percent of:	
			All Mobile Sources	All Sources			All Mobile Sources	All Sources
Heavy-Duty Trucks	3,782,000	66.8%	33.0%	17.9%	120,000	64.7%	23.3%	0.5%
Freight Railroads	857,200	15.1%	7.5%	4.1%	21,300	11.5%	4.1%	0.1%
Marine Vessels	1,011,000	17.9%	8.8%	4.8%	44,000	23.7%	8.5%	0.2%
Air Freight	8,200	0.1%	0.1%	0.0%	300	0.2%	0.1%	0.0%
Total	5,658,400	100%	49.4%	26.8%	185,600	100%	36.0%	0.8%

Source: FHWA, *Assessing the Effects of Freight Movement on Air Quality at the National and Regional Level*, Final Report, April 2005 <http://www.fhwa.dot.gov/environment/freightaq/chapter2.htm>, Table 2-9.

Table 1 shows that freight transportation accounts for approximately half of mobile source NOx emissions and 27 percent of all U.S. NOx emissions (anthropogenic sources only). Heavy-duty truck vehicles are by far the largest contributors to freight emissions nationally, producing two-thirds of the NOx and PM-10 from the freight sector. Marine vessels are the next largest source, accounting for 18 percent of freight NOx emissions and 24 percent of freight PM-10 emissions, followed by railroads at 15 percent and 12 percent, respectively. Air freight accounts for only 0.1 to 0.2 percent of total freight emissions of NOx and PM-10. In all, freight transportation accounts for 36 percent of “mobile source” PM-10 emissions and less than 1 percent of all, mobile- and stationary-source U.S. PM-10 emissions. The vast majority of PM-10 emissions come from sources such as agricultural fields, wildfires, and fugitive dust.

Table 2 shows greenhouse gas (GHG) emissions from freight transportation sources (which include NOx, CO₂ in addition to non-diesel components such as methane and Chlorofluorocarbons, or CFC). Emissions are presented in terra grams (Tg) of CO₂ equivalents.³⁴ Freight trucks account for more than three-quarters of freight-related GHG emissions, followed by marine vessels and freight railroads. Air freight contributes about three percent of freight GHG emissions. Overall, freight transportation is responsible for 6.3 percent of all U.S. GHG emissions and one-quarter of GHG emissions from transportation.

to freight. In the case of railroads, we estimated freight railroad NOx emissions as 96.4 percent of total railroad NOx emissions and 96.7 percent of total railroad PM-10 emissions, based on the passenger locomotive fraction in EPA's *Locomotive Emissions Standards, Regulatory Support Document*.

Table 2 - Greenhouse Gas (GHG) Emissions from Freight Transportation, 2003

	GHG Emissions (Tg CO2 equivalents)			
			Percent of:	
Mode	Emissions	Percent	All Transportation Sources	All Sources
Heavy-Duty Trucks	340.7	77.8%	19.2%	4.9%
Freight Railroads	38.2	8.7%	2.2%	0.6%
Marine Vessels	46.5	10.6%	2.6%	0.7%
Air Freight	12.4	2.8%	0.7%	0.2%
Total	437.8	100%	24.7%	6.3%

Source: FHWA, *Assessing the Effects of Freight Movement on Air Quality at the National and Regional Level*, Final Report, April 2005 <http://www.fhwa.dot.gov/environment/freightaq/chapter2.htm>, Table 2-12. Based on data from U.S. EPA, *Draft Inventory Of U.S. Greenhouse Gas Emissions And Sinks: 1990-2003*, February 2005. Note: the table does not include marine and aviation bunker fuels (fuel sold in the U.S. for international transportation);

The IMO Marine Environment Protection Committee (MEPC) has for the past decades emphasized the growing contribution of marine diesel emissions to pollution and global warming. Nitrogen oxide emissions that contribute to acid rain and health problems in local areas such as harbors have grown with maritime trade. In 2002, NO_x and SO_x emissions from North American shipping alone were estimated at 2,740,000 and 1,630,000 tons, respectively.¹³ The IMO MEPC has reported that between 1990 and 2004, emissions from international aviation grew by 34 percent, while emissions from international maritime transport grew by 43 percent¹⁴ (see Figure 6). In 2000, according to MEPC, international aviation accounted for 1.5 percent of global CO₂ emissions, all aviation accounted for 2.9 percent, while maritime shipping accounted for about 3.5 percent.¹⁵ IMO has funded an updated report on GHG emissions, due to be released soon, that updates the 2000 report based on a multi-country effort. By 2050, international aviation and shipping could account for over 10 percent of the global CO₂ emissions.¹⁶

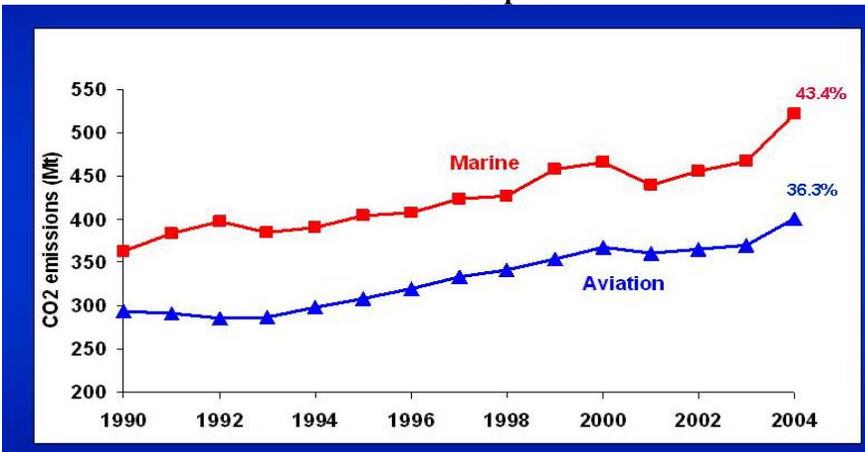
¹³ Corbett and Firestone, "Estimation, Validation, and Forecasts of Regional Commercial Marine Vessel Inventories", for the California Air Resources Board, April 2007.

¹⁴ Technical Workshop on Bunker Fuel Emissions Bulletin. International Institute for Sustainable Development. Volume 146, No. 1, 8 October 2007.

¹⁵ Faber, Jasper et al, *Aviation and Maritime Transport in a Post 2012 Climate Policy Regime*. Netherlands Programme on Scientific Assessment and Policy Analysis for Climate Change. April 2007.

¹⁶ M.G.J. den Elzen, J.G.J. Olivier, M.M. Berk. *An analysis of options for including international aviation and marine emissions in a post-2012 climate mitigation regime*. Netherlands Environmental Assessment Agency, 2007.

Figure 6 - CO2 World Emissions from International Aviation and Maritime Transport



Source: IMO, Marine Environment Protection Committee (MEPC), based on data from the International Energy Agency

1-3 Vulnerabilities Stemming from Cargo Handling Equipment (CHE)

Emissions from marine cargo transportation are caused not only by the engines used to power vessels but also the engines used in the land-based equipment for moving marine cargo at ports, commonly referred to as *cargo handling equipment* (CHE).

Land-based port emissions originate from three general sources: on-dock equipment, trucks, and locomotives. The focus of this section is on land-based port CHE emission; the scope of this study does not include emissions from on-road trucks and locomotives. On-dock CHE includes the equipment used to load and unload freight from ships, service the ships, and move freight within the port area. Estimates of emissions from this type of CHE, which includes yard tractors, top and side loaders, forklifts, and cranes, have been developed for some ports and regions in an effort to reduce their levels.

No EPA guidance or standardized methodology exists for developing estimates of port CHE emissions. A Federal Highway Administration (FHWA) study conducted to estimate CHE emissions, used data for six ports: Port of Baltimore, Port of Chicago, Port of Detroit, Houston Area ports (including ports of Houston, Galveston, Freeport and Texas City), and the San Pedro Bay ports (Port of Los Angeles, and Port of Long Beach.) To estimate the emissions for the ports of Houston, Los Angeles (POLA), and Long Beach (POLB), the study used the CHE data inventories developed by the ports. For the other ports, the study team developed a methodology that relied on the POLA and POLB CHE emission inventories and scaled emissions using appropriate cargo tonnage. Table 3 shows total marine freight vessel and port CHE emissions in the study area ports.

Table 3 – Total Marine Freight Vessel and Port CHE Emissions by Port

		Marine Freight Vessel Emissions		Port CHE Emissions		Port Total Freight Emissions	
Region	Port	NOx	PM-10	NOx	PM-10	NOx	PM-10
Baltimore	Port of Baltimore	2,399	141	916	50	3,315	190
Chicago	Port of Chicago	1,901	160	298	13	2,199	173
Detroit	Port of Detroit	247	18	221	9	468	27
Houston	Port of Houston	10,576	694	1,011	74	11,587	769
	Port of Galveston	403	21	179	9	582	30
	Port of Freeport	461	20	228	12	688	32
	Port of Texas City	1,294	73	200	10	1,494	84
	Sub-total	12,734	808	1,618	106	14,351	915
San Pedro Bay	Port of Los Angeles	8,687	614	1,892	113	10,579	728
	Port of Long Beach	9,660	647	2,371	147	12,031	794
	Sub-total	18,347	1,261	4,263	260	22,610	1,521

Source: FHWA, Assessing the Effects of Freight Movement on Air Quality at the National and Regional Level, Final Report, prepared by ICF Consulting, April 2005.

Comparisons of total marine freight emissions among the study ports show:

- The San Pedro Bay Region ports have by far the greatest emission levels - more than 22,600 tons of NOx and more than 1,500 tons of PM-10 annually.
- The Port of Houston has the greatest marine vessel emissions of any single port; the Houston metropolitan area has more than 14,000 tons of NOx and more than 900 tons of PM-10 annually from marine freight.
- Emissions in the other three regions are smaller - roughly 3,300 tons of NOx and 190 tons of PM-10 in Baltimore, 2,200 tons of NOx and 175 tons of PM-10 in Chicago, and 500 tons of NOx and 30 tons of PM-10 in Detroit.

Comparisons of port CHE emissions show:

- Port of Long Beach has the greatest emission levels, followed by the Port of Los Angeles; CHE emissions make up approximately 20 percent of the marine freight total at these ports. The high levels of CHE emissions in these ports are due to the large volumes of containers handled in POLA/POLB that require extensive land-side CHE activity.
- Port of Houston has relatively low levels of CHE emissions, about 10 percent of the marine freight total. This difference reflects the influence of the type of cargo handled at the ports: Houston handles a large proportion of liquid bulk freight (mostly petroleum), which requires relatively little in terms of land-side CHE.

Table 4 provides a comparison of NOx emissions from port CHE for the three ports that were able to provide CHE emissions by equipment type: POLA, POLB, and Houston. The table shows that yard tractors make up the largest component of port CHE emissions in all cases. This comparison shows that while yard tractor emissions are similar at the San Pedro Bay ports, emissions from handlers/loaders and from cranes are significantly higher at POLB. Again, emissions from yard tractors and handlers/loaders are relatively smaller at the Port of Houston than at the San Pedro Bay ports, reflecting the relatively small share of containerized cargo in Houston.

Table 4 - Comparison of Port CHE NOx Emissions by Port

CHE Type	Port of Los Angeles		Port of Long Beach		Port of Houston	
	NOx tons	percent	NOx tons	percent	NOx tons	percent
Yard Tractors	1,475	78%	1,409	59%	459	45%
Forklifts	92	5%	141	6%	244	24%
Handlers/Loaders	228	12%	363	15%	120	12%
Cranes	72	4%	365	15%	101	10%
Other	25	1%	93	4%	86	9%
Total	1,892	100%	2,371	100%	1,011	100%

Source: FHWA, Assessing the Effects of Freight Movement on Air Quality at the National and Regional Level, Final Report, prepared by ICF Consulting, April 2005.

1-4 Vulnerabilities Stemming from Operational Practices involving “Hotelling”

Pollutant emissions, expressed as mass per ton of fuel burned, rise for some engine types at idling speeds. This mode of operation is associated with “hotelling”, i.e., the practice of running the main propulsion plant while the ship is at rest to provide power for the needs of the shipboard electrical and other auxiliary systems. For instance, NOx emissions per ton of fuel are nearly twice as high for low-speed diesel engines.¹⁷

¹⁷ Based on the MAN B & W data provided in Corbett and Koehler, “Updated Emissions from Ocean Shipping”, Journal of Geophysical Research, Volume 108, No. D20, 2003

Table 5 compares NOx emissions from hoteling by ocean-going vessels (OGV), excluding tugs and other harbor craft operating at the study area ports. The contribution of hoteling to total OGV emissions varies significantly. It is highest at the Texas ports and at the Port of Baltimore. Hoteling accounts for roughly 30 percent of OGV emissions at the POLA and POLB. Hotelling contributes very little to OGV emissions at the Ports of Chicago and Detroit.

Table 5- Comparison of Marine Freight OGV Hotelling Emissions

	Hotelling NOx Emissions		Other OGV NOx Emissions	Total OGV NOx Emissions
	Tons	percent	tons	tons
Port of Baltimore	1,192	51%	1,161	2,353
Port of Chicago	154	9%	1,503	1,657
Port of Detroit	12	6%	192	204
Port of Houston	3,379	44%	4,238	7,618
Port of Galveston	218	75%	72	290
Port of Freeport	301	91%	31	332
Port of Texas City	607	65%	325	932
Sub-total Houston/ Galveston	4,505	49%	4,667	9,172
Port of Los Angeles	1,670	28%	4,245	5,915
Port of Long Beach	1,983	33%	4,074	6,057
Sub-total San Pedro Bay	3,653	31%	8,319	11,972

Source: FHWA, Assessing the Effects of Freight Movement on Air Quality at the National and Regional Level, Final Report, prepared by ICF Consulting, April 2005; based on specific port emission inventories and calculations by ICF Consulting.

Increasingly, emissions from ships during inshore and port operations have emerged as a major regional concern. The associated health risks of port-related operations have led to many initiatives to reduce them. These include changes in operating procedures proximate to and in ports (e.g., speed reductions), switching fuels proximate to ports, and requirements to shut down engines and take shore power provided by the port for all shipboard needs. Some of these initiatives are examined in the upcoming section on port resiliency and mitigation measures.

1-5 Forecasts of Future Trends in Vessel Emissions

As noted, marine diesel engines constitute significant sources of the U.S. mobile-source pollution. The previously cited FHWA report on freight transportation-related emission used data from the EPA National Emission Inventory (NEI) has developed emission forecasts based on a number of assumptions about the implementation and effectiveness of the EPA emission regulations. Table 6 shows current and future NOx emissions from freight and the percent change from 2002 levels. These estimates show total freight NOx emissions declining 63 percent by 2020. Truck emissions are estimated to experience the greatest decline (82 percent), followed by freight rail (43 percent). Commercial marine emissions are expected to decline only slightly by 2020 (7 percent), while air freight emissions are expected to increase 51 percent. Whereas air freight emissions are estimated to increase, they represent only 0.6 percent of the total projected 2020 freight transportation NOx emissions. Note that these figures do not show emissions from off-road CHE at ports or airport ground support equipment.

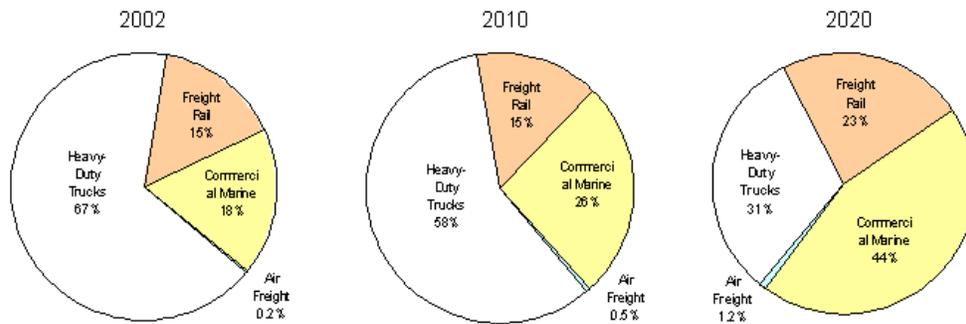
Table 6 - Current and Future Freight Transportation NOx Emissions by Mode

Year	Heavy-Duty Trucks		Freight Rail		Commercial Marine		Air Freight		Freight Total	
	tons	change	tons	change	tons	change	tons	change	tons	change
2002	3,782,000		857,200		1,011,000		8,200		5,658,400	
2010	2,186,900	-42%	563,200	-34%	987,200	-2%	10,000	22%	3,747,299	-34%
2020	662,600	-82%	486,400	-43%	938,600	-7%	12,400	51%	2,099,999	-63%

Source: FHWA, Assessing the Effects of Freight Movement on Air Quality at the National and Regional Level, Final Report, prepared by ICF Consulting, April 2005, with data from U.S. EPA, National Emission Inventory, adjusted by ICF Consulting to reflect freight as described in report text; 2010 and 2020 estimates calculated by ICF Consulting based primarily on EPA regulatory support documents.

Figure 7 compares the relative contribution of the U.S. freight transportation modes to total freight NOx emission in 2002, 2010, and 2020. Currently, trucking dominates freight NOx emissions (67 percent of the total), but the trucking share is expected to decline rapidly by 2020 (31 percent of the total). In contrast, commercial marine emissions currently account for only 18 percent of the freight sector total, but are expected to account for 44 percent by 2020. Freight rail NOx emissions are expected to also grow in significance, from 15 percent today to 23 percent by 2020. The share of total freight NOx emissions for air freight is expected to increase 1.0 percentage point by 2020.

Figure 7 - Freight Transportation NOx Emissions in 2002, 2010, and 2020



Source: FHWA, Assessing the Effects of Freight Movement on Air Quality at the National and Regional Level, Final Report, prepared by ICF Consulting, April 2005. 2002 data from U.S. EPA, National Emission Inventory, reflecting adjustments by ICF Consulting; 2010 and 2020 estimates calculated by ICF Consulting based primarily on EPA regulatory support documents.

Table 7 shows current and future PM-10 emissions from freight transportation sources and the percentage change from 2002 levels, based on the assumptions and methodology outlined above.³³ Total PM-10 emissions from freight are expected to decline 50 percent by 2020. As with freight NOx emissions, the reduction is led by trucking, which is estimated to drop 71 percent in PM-10 emissions. Freight rail PM-10 emissions are expected to decline by 39 percent by 2020. Commercial marine emissions of PM-10 in 2020 are nearly identical to 2002 levels, because growth in marine activity will offset the effect of EPA emission and fuel standards. Air freight emissions of PM-10 are expected to decline by 10 percent. Again, these figures do not show emissions from off-road cargo handling equipment at ports or airport ground support equipment.

Table 7 - Current and Future Freight Transportation PM-10 Emissions by Mode

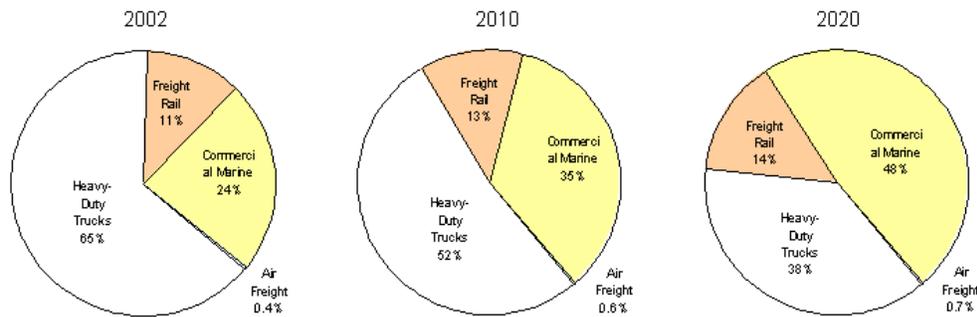
Year	Heavy-Duty Trucks		Freight Rail		Commercial Marine		Air Freight		Freight Total	
	tons	change	tons	change	tons	change	tons	change	tons	change
2002	120,000		21,300		44,000		300		185,600	
2010	65,380	-46%	15,730	-26%	42,930	-2%	290	-3%	124,329	-33%
2020	34,760	-71%	12,990	-39%	44,080	0%	270	-10%	92,099	-50%

Source: 2002 data from U.S. EPA, National Emission Inventory, adjusted by ICF Consulting to reflect freight as described in report text; 2010 and 2020 estimates calculated by ICF Consulting based primarily on EPA regulatory support documents as described in report text.

Figure 8 compares the relative contribution of the modes to total freight PM-10 emission in 2002, 2010, and 2020. The trend is similar to NOx emissions - the trucking share of the PM-10 total from freight declines from 65 percent today to 38 percent by 2020. During this period, the commercial marine share doubles from 24 percent to 48 of all PM-10

emissions from freight. Little percentage change is seen for PM-10 emissions attributable to the freight rail and air freight sectors.

Figure 8 - Freight Transportation PM-10 Emissions in 2002, 2010, and 2020



Source: FHWA, Assessing the Effects of Freight Movement on Air Quality at the National and Regional Level, Final Report, prepared by ICF Consulting, April 2005. 2002 data from U.S. EPA, National Emission Inventory, adjusted by ICF Consulting to reflect freight as described in report text; 2010 and 2020 estimates calculated by ICF Consulting based primarily on EPA regulatory support documents.

By 2030, EPA projects significant growth in marine emission if no action is taken to regulate engine emissions and fuel quality. EPA expects that the relative contribution of emissions from marine vessels will grow rapidly as emissions from other sources are subjected to increasingly stringent controls. The contribution of ship emissions is most significant in U.S. ports and coastal areas that are subject to heavy maritime traffic. Currently, more than 40 U.S. ports are located in non-attainment areas for ozone or fine particulates or both. However, the problem is not limited to port areas and varies according to the wind and weather patterns that determine how much of the vessel emissions reach land. For instance, the Santa Barbara County, which has no commercial ports, has estimated that by 2020, 67 percent of its NO_x inventory will come from marine shipping traffic transiting the California coast.¹⁸ By 2030, EPA projects that engines on commercial vessels will contribute to 49 percent of mobile source emissions of NO_x, 95 percent of mobile source emissions of Sox, and 52 percent of mobile source emissions of PM_{2.5} in the U.S. (Figures 9, 10, 11.)

¹⁸ Based on data provided in EPA, Bryan Wood-Thomas,

Figure 9 – Forecast NOx Emissions, 2030

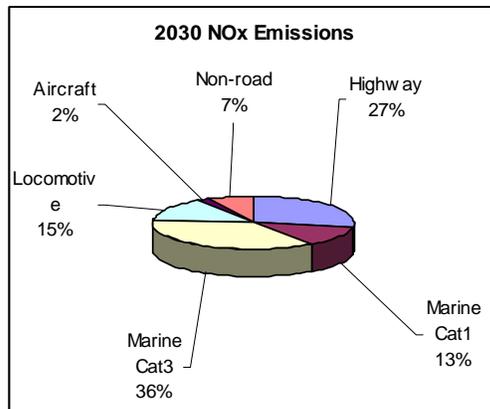


Figure 10 - Forecast SOx Emissions, 2030

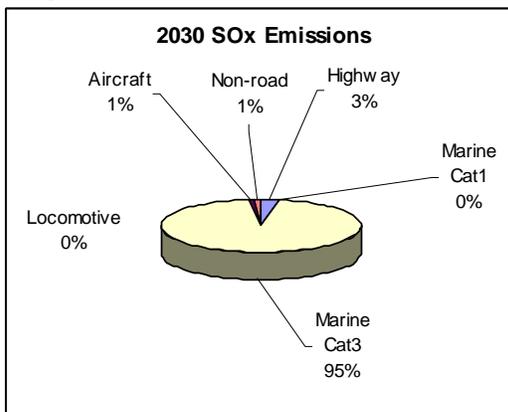
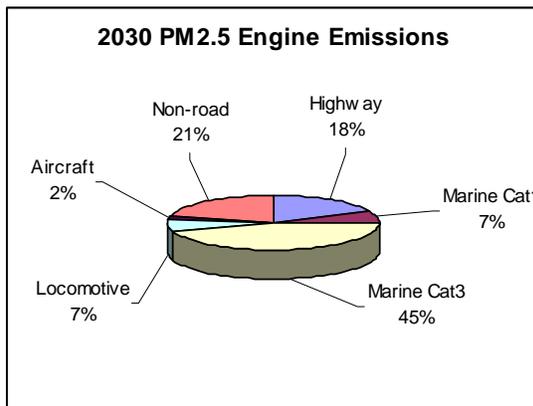


Figure 11 - Forecast PM_{2.5} Emissions, 2030



Section 2. Risks Arising from Marine Oil Spills and Hazardous Cargo Incidents

The second major component of risk in marine operations consists of the threat of disruption arising from the MTS vulnerability to oil spills and hazardous materials incidents and their associated adverse consequences. It should be noted that while this report focuses on maritime sources of spills, while noting that the majority of hydrocarbon inputs to the sea come from natural seeps and run-off from land sources.¹⁹

2-1 Trends in Incidents Involving Oil Spills

There has been an overall downward trend in incidents involving marine oil spills and hazardous materials incidents. The 1989 *Exxon Valdez* spill in Prince William Sound, Alaska was the largest ever U.S. oil spill, involving 37,000 metric tons of oil. In the global perspective, the *Exxon Valdez* has been only the 35th largest tanker spill worldwide since 1967. The largest documented spill has been the *Atlantic Empress* in 1979, off Tobago, West Indies, a spill of 287,000 metric tons.

The *Exxon Valdez* incident directly led to the enactment of the Oil Pollution Act of 1990 (OPA 90). OPA 90 spawned many major new Coast Guard regulations on ship design, seafarers' standards, insurance and indemnity provisions, the Oil Spill Liability Trust Fund, certificates of financial responsibility (COFR) for vessel and facility owners, spill response planning and equipment, and marine salvage services, among others.

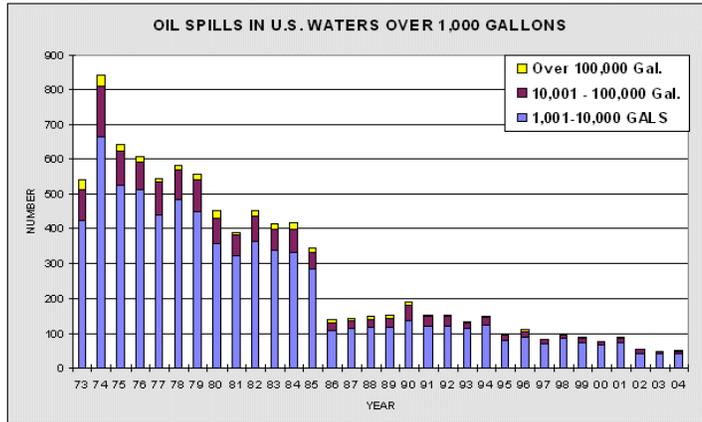
Since the *Exxon Valdez* spill and OPA 90, there has been a general and significant trend downward in the number and volume of oil spills relating to international commerce in the U.S. In the aftermath of the events, there has been a major shift in the safety culture among oil carriers, particularly U.S.-based entities, where concern for safety and avoidance of oil spills has become a primary objective because of the severe financial and public relations consequences of major spills.

The U.S. owned oil carriers represent a significant portion of the overall national bulk oil trade, though by far less than oil imports via foreign flag vessels. The U.S.-flag oil carriers are engaged primarily in the Trans-Alaska Pipeline Service (TAPS) trade to the U.S. west coast and the movement of refined oil products along the coasts and on the rivers.

The United States Coast Guard (USCG) has data describing these long term trends, as well as data on sources, locations, and types of oil involved in the spills. Figure 12 shows the USCG depiction of the oil spill events involving more than 1,000 gallons between 1973 and 2004. The figure shows a general downward trend in the number of spills over 1,000 gallons. The USCG report states that over 80 percent of the spills that occurred from 1973 - 2004 were between 1 and 100 gallons. In total, there were 81,310 marine oil spills between 1994 and 2004, including 935 of over 1,000 gallons.

¹⁹ USCG comments (Commander Paul M. Stocklin, August 21, 2008) on the Draft Report, based on the findings of "Oil in the Sea III: Inputs, Fates and Effects", National Academy of Sciences, page 69, table 3-2, 2003.

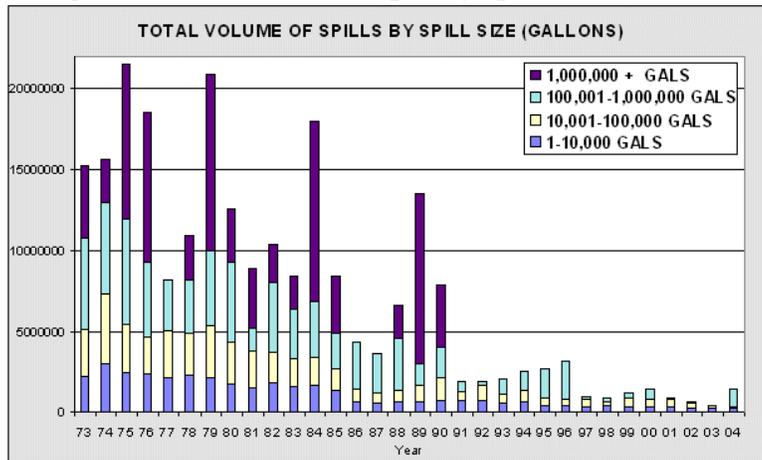
Figure 12 - Oil Spills Over 1,000 gallons, 1973 – 2004



Source: USCG Source: USCOG, Polluting Incident Compendium, Cumulative Data and Graphics for Oil Spills 1973-2004"; <http://www.uscg.mil/hq/g-m/nmc/response/stats/Summary.htm>

Figure 13 shows a dramatic decline in overall spill volumes since 1990. The data reflect the impacts of the new regulatory requirements of OPA 90, the new international oil carriage regulations in MARPOL, and the emerging culture of safety and vigilance among the operators and state/local port authorities.

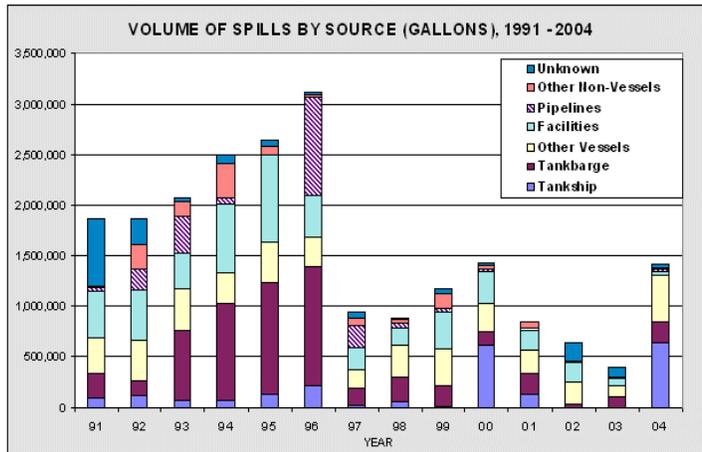
Figure 13 - Total Volume of Spills by Spill Size, 1973 – 2004



Source: USCG Source: USCOG, Polluting Incident Compendium, Cumulative Data and Graphics for Oil Spills 1973-2004"; <http://www.uscg.mil/hq/g-m/nmc/response/stats/Summary.htm>

Figure 14 shows the source of oil spills between 1991 and 2004. According to the USCG report, 35.7 percent of the volume of oil spilled during the period came from tank vessels (ships or barges); 27.6 percent from facilities and other non-vessels; 19.9 percent from non-tank vessels; 9.3 percent from pipelines; and 7.4 percent from unknown (“mystery”) spill sources.

Figure 14 - Oil Spills by Source, 1991 – 2004



Source: USCG Source: USCOG, Polluting Incident Compendium, Cumulative Data and Graphics for Oil Spills 1973-2004”; <http://www.uscg.mil/hq/g-m/nmc/response/stats/Summary.htm>

The figures above do not include data from 2005. In that year, there was a major spike in spills as a result of Hurricanes Katrina and Rita, which caused six major, five medium, and over 5000 minor oil and hazardous material (hazmat) responses. It is estimated that over 9 million gallons of oil were released from the major and medium sized spills alone; it should be noted that the vast majority of this volume was from facilities on land²⁰.

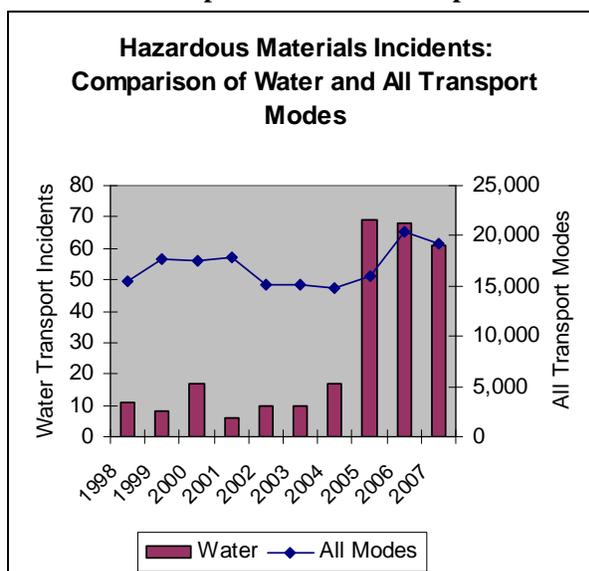
2-2 Trends in Incidents Involving Domestic Hazardous Materials Spills

Whereas spills related to incidents in international maritime transportation have been significant in the past three decades, marine hazmat incidents involving domestic water transport appear to be insignificant compared to hazmat spills in other transport modes. The U.S. Department of Transportation’s Hazardous Materials Information System (HMIS) reports that there were 277 spills associated with water transportation out of a total of 169,000 transportation-related hazmat spills in the period 1998-2007 (Figure 15).²¹

²⁰ U.S. Coast Guard, “Report to Congress: Oil Spill Liability Trust Fund Hurricane Impact”, May 2006

²¹ <http://hazmat.dot.gov/pubs/inc/data/tenyr.pdf>

Figure 15 – Domestic Hazmat Spills in Marine Transportation and Other Modes



Source: Volpe generated chart based on data from Hazardous Materials Information System (HMIS), U.S. DOT, <http://hazmat.dot.gov/pubs/inc/data/tenyr.pdf>

2-3 Cost and Consequences of Oil Spills

The Coast Guard National Pollution Funds Center (NPFC) administers the Oil Spill Liability Trust Fund (OSLTF), which pays for response and removal costs, natural resource damages, property and boat damages, loss of profits and earning capacity, loss of subsistence, use of natural resources, and costs to government agencies including revenue losses. These payments are made only when spill costs are above the responsible parties' liability limits, as established by OPA 90 regulation.

The estimated removal costs and damages from incidents taking place since the enactment of OPA 90 total approximately \$1.3 billion in 2007 dollars, according to the NPFC report for the years 2002-2006. Since none of these have been for payments to spills from facilities (i.e., for damages exceeding the liability limits), it is clear that most (if not all) major spills are from vessels. A substantial portion of these costs are for damages from oil discharges where the responsible parties could not be identified or were unable to pay.²²

Spill response and cleanup costs have risen with improved awareness and techniques. The OSLTF could pay for up to \$1 billion in emergency clean-up costs. Yet, given the potential for extremely costly major spills, a future major spill like the *Exxon Valdez*

²² U.S. Coast Guard, "Report on Oil Pollution Act Liability Limits", to the Committee on Commerce, Science and Transportation of the Senate and the Committee on Transportation and Infrastructure of the House of Representatives, October 2007.

disaster could easily lead to liquidation of the available Fund balance. The November 2004 spill from the single-hull tanker *Athos I* of 265,000 gallons (only about 1,000 metric tons) into the Delaware River, caused by submerged obstacles on the bottom,²³ has been estimated to have cost \$291 million²⁴. The cost of the November 2007 *Cosco Busan* spill in San Francisco Bay (53,000 gallons, or 200 metric tons) will not be known for some time, but is likely to be very high as well. Biologists have found that the oil affected 50 miles of rocky intertidal habitat, 41 miles of sandy beach habitat, and 7.5 miles of salt marsh habitat around the Bay Area. A restoration plan may take two years to complete and the restoration effort itself may be five years off and last many years once begun.²⁵

Finally, there is the prospect of spills resulting from natural disasters. The Coast Guard reported in 2007 that there had been no impact on the OSLTF from Hurricanes Katrina and Rita, the damages so far having been paid from the Stafford Act Disaster Relief Fund (DRF) or by responsible parties²⁶. DRF payments to Coast Guard and EPA for spill response efforts were approximately \$350 million, and NOAA estimated that natural resource damage assessment and restoration claims could be as high as \$250 million²⁷. Potentially, a final reckoning of the full costs could reveal much higher costs, particularly for environmental restoration.

2-4 Costs and Consequences of Hazardous Materials Incidents

The consequences of hazardous materials spills in the marine environment have been small relative to other transportation modes, as the data in Table 5 show. These marine spills are also a very small proportion of total transportation related hazmat spills by any of five measures: total number of incidents, serious incidents, deaths, injuries, and total costs. Table 8 shows the total incidents and costs for the ten year period from 1998-2007.

Table 8 - Hazardous Materials Spills Associated with Transportation, 1998-2007

Mode	Incidents	Serious Incidents	Deaths	Injuries	Costs
Water	277	20	0	20	\$3,862,000
All Modes	169,000	5,057	141	2,823	\$631,000,000
Water as a Percentage of All Modes	0.17%	0.40%	0.00%	0.71%	0.61%

Source: U.S. Department of Transportation Hazardous Materials Information System

²³ University of Delaware Sea Grant Program website, <http://www.ocean.udel.edu/oilspill/>

²⁴ U.S. Coast Guard, October 2007.

²⁵ Prado, Mark "Oil spill's environmental impact studied six months later", Marin Independent Journal, May 3, 2008.

²⁶ Mark Prado, "Oil spill's environmental impact studied six months later", Marin Independent Journal, May 3, 2008.

²⁷ Coast Guard, May 2006

Section 3. Risks Arising from Contaminated Dredged Materials

Dredged sediments in rivers, lakes, and oceans have often been mingled with residues of contaminants that have been released years ago or continue to be introduced in the waterways. These contaminants can be discharged directly from industrial and municipal waste disposal facilities, flow as polluted runoffs in urban and agricultural areas, or get carried through the air and precipitated into lakes and streams far from their original sources²⁸. EPA has identified five major types of pollutants found in sediments:

- Nutrients, including phosphorous and nitrogen compounds such as ammonia, which can lead to algal blooms, hypoxic conditions in the water, and toxically high concentrations of ammonia;
- Bulk organics, that is, hydrocarbons including oil and grease;
- Halogenated hydrocarbons (“persistent organics”) that are chemicals highly resistant to decay;
- Polycyclic aromatic hydrocarbons, organic chemicals including petroleum products and byproducts; and
- Metals, such as iron, manganese, lead, cadmium, zinc, and mercury, and metalloids such as arsenic and selenium.

3-1 Challenges of Balancing the Nation’s Trade Needs and Environmental Priorities

Dredging projects are most often located in busy ports and waterways that have been home to industrial production facilities and are therefore likely to have contaminated sediments. The U.S. Army Corps of Engineers (USACE) is responsible for the proper management and placement of all dredged materials and has developed a Technical Framework to provide a consistent approach for that purpose. The Corps is required in each case to find alternatives that meet the substantive and procedural requirements of the National Environmental Policy Act (NEPA), the Clean Water Act (CWA), and the Marine Protection, Research, and Sanctuaries Act (MPRSA). These requirements address both clean and contaminated dredged materials, and three kinds of management alternatives: open-water disposal, confined (“diked”) disposal, and beneficial use, all of which must be carefully evaluated from the standpoint of environmental acceptability, technical feasibility, and economic efficiency.²⁹

MPRSA prohibits the dumping of many substances other than trace contaminants unless they are rapidly rendered harmless. Trace contaminants in this context are defined as

²⁸ EPA Office of Water website: <http://www.epa.gov/waterscience/cs/>

²⁹ U.S. EPA & U.S. Army Corps of Engineers, “Framework for Dredged Material Management”, May 2004.

substances that will not cause unacceptable adverse impacts after dumping in terms of persistence, toxicity, and bioaccumulation.³⁰

Treatment of contaminated sediments can be extremely expensive, estimated at up to \$50 per cubic yard.³¹ However, not all dredged materials are contaminated. By one estimate, only 5 to 10 percent of the dredged materials are contaminated. The USACE balances its national waterways growth and maintenance and environmental protection missions through a risk-based methodology and an assessment of project alternatives. While the days of indiscriminate dumping at ocean sites are over, and seeking “beneficial uses” for dredged materials has emerged as the goal, the conflict between facilitating trade and protecting the environment is often played out through the NEPA environmental review process today.

Disposal of contaminated sediments has also created significant challenges. Identifying beneficial uses of dredged material has been proposed as a solution to the large volume of sediments dredged each year. The need for more efficient tools and information systems for management of sediment risks has been recognized. One innovative approach is the development of tools for tracking the volume of dredged material to increase their beneficial use. (These issues are addressed in the following section on MTS Resiliency and Mitigation Measures.)

Another problem associated with dredging projects has been proliferation of law suites and project-completion delays. The conflict among government agencies, industry and environmental advocates that delayed a New York Harbor dredging project for many years is a typical example. Another example is the conflict between fishing and tourism interests and the proponents of protecting the ecosystem from contamination by sediments containing dioxin and heavy metals, leading to extensive project delays and disruption in marine operations.³²

3-2 Vulnerabilities Stemming from the Scale of the USACE Dredging Projects

As noted in the Risk and Resiliency Framework created in Appendix A, MTS environmental risks can be assessed as a function of the probability of the threats being realized, existing vulnerabilities and exposure levels, and the consequences of the threats if they materialize.

Size of the exposure to potential contaminants determines the vulnerability of the MTS components to channel dredging. This exposure is in part a function of the size and extent of the dredging projects underway. The USACE reports on dredge contracts and dredge volumes in some detail, but does not include data on contaminated dredge materials. The national contracting data for 2002 through 2007 appear in Table 9,

³⁰ US Environmental Protection Agency, “Evaluation of Dredged Material Proposed for Ocean Disposal, Testing Manual”, EPA 503/8-91/001, February 1991.

³¹ Personal conversation, Michael Dyer (Volpe Center) and Dr. Todd Bridges, Director, Center for Contaminated Sediments, Army Corps of Engineers, May 6, 2008.

³² Sullivan, Joseph, “Burial of Tainted Sludge Wins Broad Endorsement”, New York Times, Feb 2, 1995.

followed by Table 10 on the location and geographical distribution of dredging projects by Corps district. The tables reflect the values for contracted dredging, including operations and maintenance (O&M) and new work. Note that the data do not include dredging operations performed by the USACE, and that some 80 percent of the USACE-sponsored dredging is performed by private contractors.³³

Table 9 - National Dredge Contracting Data, 2002 through 2007

YEAR	2002	2003	2004	2005	2006	2007
Total Contracts	167	178	168	130	135	114
Total Bid (Millions of Cubic Yards)	230	182	151	140	122	124

Source: U.S. Army Corps of Engineers

Table 10 – Location of National Dredge Project Contracts, 2002 through 2007

Cubic Yards by Corps of Engineers District and Fiscal Year							
DISTNAME	2,002	2,003	2,004	2,005	2,006	2,007	Total
ALASKA		1,412,500	900,000	1,938,000	2,095,000	2,142,500	8,488,000
BALTIMORE	7,019,953	1,978,500	2,623,011	2,967,600	3,497,782	925,031	19,011,877
BUFFALO	1,130,000	660,000	1,438,193	1,009,000	1,070,000	940,000	6,247,193
CHARLESTON	10,741,400	3,578,000	3,802,800	6,001,810	3,353,000	6,927,400	34,404,410
CHICAGO						431,500	431,500
DETROIT	1,232,500	709,900	912,500	882,500	903,050	1,245,500	5,885,950
GALVESTON	34,459,082	33,966,900	15,670,600	11,945,100	22,801,072	8,878,300	127,721,054
HONOLULU			17,700		24,649	30,000	72,349
HUNTINGTON	200,000	254,550	283,500	215,000	215,000		1,168,050
JACKSONVILLE	14,082,000	2,996,200	5,403,000	14,976,000	5,646,300	3,753,000	46,856,500
LITTLE ROCK	1,667,000					1,667,000	3,334,000
LOS ANGELES	8,790,000	700,000	3,592,000	654,000	2,116,527	315,000	16,167,527
LOUISVILLE	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	6,000,000
MEMPHIS	3,000,000						3,000,000
MOBILE	13,300,734	18,774,000	14,661,908	9,257,723			55,994,365
NEW ENGLAND	549,000	6,521,500			677,129	183,000	7,930,629
NEW ORLEANS	70,235,000	66,276,430	53,290,000	57,570,000	44,275,000	62,735,900	354,382,330
NEW YORK	4,326,940	4,614,169	4,285,475	1,200,000	267,015	483,640	15,177,239
NORFOLK	3,038,100	5,435,984	5,919,790	2,394,600	2,133,950	3,510,000	22,432,424
PHILADELPHIA	8,836,651	7,983,367	9,695,000	8,156,006	5,682,297	3,532,000	43,885,321
PORTLAND	2,943,000	2,419,000	2,842,000	3,918,300	6,875,000	12,409,750	31,407,050
SACRAMENTO	36,000	199,040	503,830	169,716	603,879		1,512,465
SAN FRANCISCO					700,000	542,000	1,242,000
SAVANNAH	20,800,000	1,766,000	7,000,000	8,000,000	7,457,000		45,023,000
SEATTLE	2,050,000	2,400,000	1,705,000			293,000	6,448,000
ST. LOUIS			750,000		2,000,000		2,750,000
ST. PAUL	1,917,000	1,495,000	110,000	2,327,000		460,000	6,309,000
VICKSBURG		8,000,000	5,000,000			4,500,000	17,500,000
WILMINGTON	18,800,000	9,123,096	10,365,000	5,936,000	9,159,100	7,216,000	60,599,196

Source: U.S. Army Corps of Engineers

³³ Comments of Virginia R. Pankow, IWR, USACE, email correspondence to David Grier, dated October 1, 2008.

The U.S. maritime industry has accommodated the trend towards introduction of increasingly larger ships coupled with the growing import trade volumes, with extensive channel deepening projects, as noted in the previous MTS Assessment Task 1 and 2 Reports on MTS infrastructure and economic challenges.

These changes in vessel size and traffic volumes have brought larger ships into the historically shallow Atlantic and Gulf coast ports at a growing rate. Plans have been drawn to deepen channels approaching the ports of New York/New Jersey, Savannah, Charleston, and Virginia to depths of 50 to 55 feet to accommodate post-Panamax container ships. The Delaware River Channel-Deepening Project, now in the planning and approval stages, would deepen the approaches to Philadelphia from 40 to 45 feet.³⁴ To illustrate the magnitude of a typical channel deepening project, the Port of New York/New Jersey Harbor Deepening Project will generate more than 49 million cubic yards of dredged material, nearly all of which is slated for beneficial reuse, either for ocean placement to cap the Historic Area Remediation Site (HARS) or for use in brownfield remediation, mine reclamation, or landfill closure.³⁵

³⁴Port of Philadelphia website,
http://www.philaport.com/news_releases.htm#SENATOR%20SPECTER%20VISITS%20THE%20WORKIN%20PORT

³⁵ Port of New York/New Jersey website

Section 4. Water Pollution Risks from Marine Vessels

The growth of international trade, growing sizes of commercial marine vessels, and the proliferation of vessel types have accelerated the centuries-long phenomenon of transport of invasive species, also called aquatic nuisance species (ANS), by marine vessels. These ANS may attach themselves as external hull-fouling appendages, but the vast majority of them ride in the ships' ballast tanks. Ships carry water in ballast tanks for the purpose of safe loading and balancing of sea-going vessels. It is estimated that more than 10,000 marine species each day hitch rides around the globe in the ballast water of cargo ships, and the rate of successful new invasions via ballast water has accelerated dramatically in recent years.

The total amount of ballast water discharged in U.S. waters each year is about 8 million metric tons, equivalent of 2 billion gallons. While it might appear that the U.S. would be the recipient of much of the ballast water discharged in the world, the data indicate that the U.S. is a net exporter of ballast water. This is because so many ships, particularly large tankers and containerships, discharge cargo within the U.S. waters and return overseas in with full ballast tanks. An example of the ANS invasion emanating from the U.S. to overseas countries is the American jack-knife clam that has spread rapidly over the North Sea coast, where it has become one of the most common bivalves, replacing many native species.

New trade routes have also created new “donor regions” of potentially invasive species. Furthermore, the risks of the introduction of ANS have risen with faster modern ships with shorter voyages, as these modern vessels have increased the likelihood of survival of the invasive organisms to points of discharge into the coastal waters of the receiving regions.³⁶ The threat of water pollution represents not only an environmental risk for MTS, but also an economic risk.³⁷

Contamination risks arising from hull-fouling species represent another facet of the MTS water pollution risks. Hull-fouling species make up the majority of non-native species in U.S. coastal systems. Over 50 percent of the non native species are hull-fouling species that could have come from either ballast water or hulls. It has been pointed out that while the risks of contamination from ANS is high in terms of volume of organisms, the potential threat from invasive species is not necessarily greater in ballast compared to contamination arising from hull fouling. Hull fouling in general has been historically overlooked as a vector until recently, though there is a growing body of literature on hull fouling as a vector. The risks arising from this vector are different from the ballast water risks and vary according to types of vessels, shipping routes, or operating domains). The

³⁶ U.S. Environmental Protection Agency Office of Water, “Issues and Options”, September 10, 2001.

³⁷ The National Ballast Water Information Clearinghouse Database contains information on these risks, as noted by Safra Altman, NOAA, in comments sent on October 15, 2009.

invasive species vector has also created a problem when dealing with ship decommissioning and in reference to MARAD's "ghost vessel fleet."³⁸

4-1 Vulnerabilities to Risks of Aquatic Nuisance Species (ANS) Stemming from Growing MTS Trade

The growing volumes of international trade have contributed to the rising levels of ballast water carriage. Ballast water discharge volumes are expected to double in the next 20 years. Modern bulk carriers and tank ships can carry as much as 200,000 metric tons of ballast water, most of which is discharged in the departure port as the ship takes on its cargo. Container ships, cruise ships, car carriers, and other types typically carry smaller though still significant volumes of ballast water.

The growing trade lanes along the coastal as well as inland navigable waterway and the Great Lakes in the recent decades have contributed to the rapid spread of the ANS. The problem encountered in the St. Lawrence Seaway provides an example of the rapid pace of the invasion. Shortly after the opening of the St. Lawrence Seaway locks and dams in 1959 for deep draft shipping between the Atlantic Ocean nations and North America, a European zebra mussel labeled as an aquatic invasive species (AIS) was discovered in Lake St. Clair in 1988, introduced in ballast water tanks of the ships serving the Great Lakes. These invasive zebra mussels have caused enormous problems for city water supplies and electric utilities' water intakes, and have since spread by "secondary invasions" to waterways and lakes all over the northeastern and mid western U.S. According to recent studies, the total number of ANS, including algae, fish, invertebrates, and plants in the Great Lakes are estimated at 180. Since the discovery of these species, the Canadian and U.S. maritime officials have concentrated on devising technologies for replacing the ballast water, as discussed below in [Section](#) on MTS Resiliency.³⁹

Comment [NG1]: What Section?

The International Convention for the Control and Management of Ships' Ballast Water and Sediments has released a report on the devastating effects of the ANS introduction in many areas of the world. Quantitative data show the rate of bio-invasions is continuing to increase at a high rate, with new areas being invaded each year. As volumes of seaborne trade continue overall to increase, the magnitude of the discharge volume is expected to rise further.

4-2 Economic Costs and Environmental Consequences of Contaminated Ballast Water

There are no precise estimates of the ecological and monetary consequences of ANS biotic invasions available at this point. It has been difficult to quantify the economic, social, recreational, and ecological losses and costs attributable to ANS. Data on damages to water pipes, boat hulls, and other hard surfaces by zebra mussels in the Great

³⁸ References to hull-fouling species were made by Safra Altman, NOAA, in comments sent on October 15, 2009.

³⁹ Transportation Research Board (TRB), *Great Lakes Shipping, Trade and Aquatic Invasive Species*, Special Report 291, July 2008

Lakes have estimated the costs at approximately \$5 billion. However, the estimates of the costs involving losses of native species and environment restoration to pre-invasion quality are not available.⁴⁰

Attempts have been made to assess the ecological scope of the widespread dominance of native habitats by the invaders, displacement of native species, and the disruption of commercial fisheries and shell-fisheries. Invasive species are thought to have been involved in 70 percent of the last century's extinctions of native aquatic species.⁴¹ The San Francisco Delta ecosystem is considered to be one of the worst disrupted aquatic ecosystems in the United States, with colonization by more than 230 non-native species. In the Gulf of Mexico, it is suspected that ANS from ballast water have caused contamination of commercial oyster beds.

4-3 Risks Associated with Marine Debris

Marine debris poses a threat to marine environment, wildlife, and sensitive habitat. Marine debris is also a costly threat to vessel navigation, as the debris can endanger vessels and mariners. Many forms of debris are found in our coastal and ocean waters. Plastics are a persistent form of debris, with a dramatic increase in the variety of plastic items found in the marine environment. Glass, metal, and rubber are similar to plastic in that they are long-lasting, ubiquitous and commonly used in a wide range of products. While these materials can be worn away and broken into smaller and smaller fragments, generally they do not completely biodegrade. This causes major problems in coastal watersheds and oceans as these materials come into contact with wildlife, people, boats, and fishing nets. Thousands of aquatic animals are injured, killed or have their habitat impacted by marine debris each year. Coastal communities spend substantial resources removing marine debris from their shorelines.

One of the most biologically harmful forms of marine debris is derelict fishing gear (DFG), defined as nets, lines, pots, and other recreational or commercial fishing equipment that has been lost, abandoned, or discarded in the marine environment. DFG is an extremely dangerous form of debris worldwide. In Hawaii, DFG has been identified as the most serious human-related threat to the fragile coral reefs of the Northwestern Hawaiian Islands, where it abrades and enshrouds corals. Because much of today's fishing gear is made of plastic, it can persist for decades in the ocean, and continue to catch and entangle marine animals long after its original fishing purpose has expired. Entanglement of marine animals in these nets can kill, injure, and impair the mobility of marine animals. Between 1982 and 2000, over 200 endangered Hawaiian monk seals have been entangled in DFG.

Commercial and recreational boaters also encounter DFG. This gear can become entangled in and potentially damage boat propellers, which can become a safety issue

⁴⁰ Buck, Eugene H., "Ballast Water Management to Combat Invasive Species", Updated June 20, 2007

⁴¹ H. R. 5030 the "Prevention of Aquatic Invasive Species Act of 2006."

when vessels are disabled. Derelict fishing gear has also created problems for naval vessels and submarines.⁴²

⁴² Testimony of Timothy Keeney, Deputy Secretary for Ocean and Atmosphere, NOAA, before congressional committee on Natural Resources, September 29, 2005.
<http://www.ogc.doc.gov/ogc/legreg/testimon/109f/Keeney0929.htm>

Section 5. MTS Resiliency: Mitigating Measures for Addressing the Environmental Challenges

Based on the framework developed in Appendix A, the MTS has the potential to strengthen certain system attributes and safeguards that reduce the probability of a single-point failure. These attributes involve adaptive problem solving focused on maximizing system strengths, mitigating system weaknesses, and deploying effective countermeasures. As noted in Appendix A, resiliency engineering has four major components:

- a) Access to information and intelligence that make the system adaptive to disruption;
- b) System conditions that serve as preventive measures, make the system more fault tolerant, and reduce the totality of the events that can go wrong;
- c) Availability of redundant system components that can mitigate the vulnerabilities;
- d) Presence of factors that can reduce severity of the consequences.

This section reviews several of these attributes, including promotion of beneficial uses of dredged materials, promotion of effective ballast water management strategies, and regulatory and mitigative measures promoted by the IMO, EPE, and state and local MTS stakeholders.

5-1 Promoting the Beneficial Uses of Dredged Materials

Available data indicate that only 5 to 10 percent of all dredged materials in the U.S. are contaminated, and that sediment erosion and loss of habitat are often more damaging than potential contamination. Subject matter experts are of the opinion that contaminated materials, that is, those requiring special handling, probably make up less than ten percent of the total of dredged materials.⁴³ EPA has estimated that excessive sediment erosion, transport and deposition cause damages of approximately \$16 billion annually in North America. The U.S. spends about \$800 million annually on dredging sediments from locations where too much has been deposited. Sediment overloading has been known to cause many problems. Excessive sedimentation in rivers, reservoirs, and estuaries may contribute to high turbidity, loss of flood carrying capacity and sediment deposition in navigable waterways. Yet in other locations, a shortage of sediment causes coastal erosion, stream bank erosion, and wetland loss. Many water resource projects are designed to remedy local sediment problems, and sometimes create even larger problems some distance away. Sediment management planning is often done outside the context of watershed management plans, and often adversely affects navigation, flood and storm damage reduction efforts, and environmental quality.⁴⁴

⁴³ Personal conversation, Dyer and Bridges, May 6, 2008.

⁴⁴ EPA, "Dredged Material Management: Action Agenda for the Next Decade," EPA842-B-04-002, July 2003, based on a workshop sponsored by the National Dredging Team, January 23-25, 2001, Jacksonville, Florida.

Recent efforts at promoting beneficial uses of dredge material have proven highly effective. Dredging industry organizations have stressed the industry success in expanding the beneficial use of dredged materials. Their reports indicate that between 1998 and 2003, an average of 212.1 million cubic yards of dredge materials was excavated, annually, from U.S. waterways at a cost of approximately \$700 million. In the six-year period between 1998 and 2003, the beneficial use of dredged materials included 82.7 million cubic yards used for beach nourishment, 12 million cubic yards used for a combination of beach nourishment and the creation of upland sites, and 11.4 million cubic yards used to create wetlands and wildlife habitat. During this period, a total of 1.2 billion cubic yards of dredged material were excavated from ports, harbors and inland waterways, with almost all of the dredged material used beneficially.⁴⁵

5-2 Preventing Marine Water Pollution

Section 402 of the 1972 Clean Water Act (CWA), the National Pollutant Discharge Elimination System (NPDES), requires permits for discharge of pollutants into the nation's surface waters. The NPDES controls water pollution by regulating point sources that discharge pollutants into waters of the United States.⁴⁶ Until February 2009, marine vessel discharges incidental to normal operations of the vessels, e.g., grey water and ballast water, were exempt from permit requirements. On March 30, 2005, the U.S. District Court for the Northern District of California (in *Northwest Environmental Advocates et al. v. EPA*) ruled that the EPA regulation excluding discharges incidental to the normal operation of a vessel from NPDES permitting exceeded the Agency's authority under the CWA. On September 18, 2006, the Court issued an order revoking this regulation (40 C.F.R. 122.3(a)) as of September 30, 2008. EPA signed the final VGP on December 18, 2008, with an effective date of December 19, 2008. Subsequently, the U.S. District Court for the Northern District of California signed an order providing that "the exemption for discharges incidental to the normal operation of a vessel, contained in 40 C.F.R. § 122.3(a), is vacated as of February 6, 2009." Therefore, the regulated community needed to comply with the terms of the VGP as of February 6, 2009.⁴⁷

The Vessel General Permit (VGP) regulates discharges incidental to the normal operation of vessels larger than 79 feet in length operating in a capacity as a means of transportation. The VGP includes general effluent limits applicable to all discharges, setting general effluent limits applicable to 26 specific discharge streams. Not included in the VGP requirements are recreational vessels, as defined in section 502(25) of the Clean Water Act. Also exempted from the VGP requirements are non-recreational vessels less than 79 feet in length, and all commercial fishing vessels, regardless of length, as described below.

The Clean Boating Act of 2008 (S.2766), signed on July 29, 2008, amends the Clean Water Act (CWA) to provide that no NPDES Permit will be required for the discharge

⁴⁵ Patella, Lawrence (Executive Director, Western Dredging Association), "Dredging Creates a Strong Economy, Cleaner Environment", *Sea Technology*, March 2005.

⁴⁶ <http://cfpub.epa.gov/NPDES/>

⁴⁷ EPA, Vessel Discharges, Final Vessel General Permit, http://cfpub.epa.gov/npdes/home.cfm?program_id=350

from a recreational vessel of: graywater, bilge water, cooling water, weather deck runoff, oil water separator effluent, or effluent from properly functioning marine engines or for any other discharge incidental to the normal operation of such vessel. The Act defines “recreational vessel” as any vessel that is leased, rented or chartered to a person for a person’s pleasure or that is manufactured or used primarily for pleasure. Excluded are vessels that are subject to Coast Guard inspection and that are engaged in commercial uses or that carry paying passengers.

Under the new Clean Boating Act, the EPA Administrator is required to: (1) develop best management practices (BMP) for recreational vessels to mitigate the effect of vessel discharges; and (2) promulgate federal standards of performance for each discharge for which a BMP is developed. An additional bill (S.3298), signed by the President in July 2008, provides for a two-year moratorium on NPDES permits for all commercial fishing vessels of any size and for all other commercial vessels under 79 feet, during which time the EPA and the Coast Guard will conduct a 15-month study to evaluate the impacts of these discharges and report their findings to Congress.

5-3 Promoting Treatment of Ballast Water

The IMO adopted International Convention for the Control and Management of Ships' Ballast Water and Sediments in February 2004. While ratification by member states has not yet achieved the numbers required to bring the Convention into force, there are several significant provisions that serve as models for national regulations and scientific programs in many countries, including:

- Promotion and facilitation of scientific and technical research on ballast water management
- Ballast water record keeping
- Ballast water management requiring ballast water exchange at sea for ships constructed before 2009.
- Ballast water management starting for ships constructed after 2009 meeting the ballast water discharge standard for maximum allowable concentrations of several types and sizes of organisms
- Development and deployment of prototype ballast water treatment technologies

In the United States, Congress has responded to concerns about ANS through a series of legislative actions. The objective of the Non-indigenous Aquatic Nuisance Prevention and Control Act (NANPCA) (passed in 1990) was to prevent and control ANS infestations of the coastal and inland waters. The National Invasive Species Act (NISA) of 1996 authorized the Coast Guard to issue ballast water management (BWM) regulations for vessels entering the Great Lakes and Hudson River and voluntary guidelines for all vessels entering U.S. waters. In 2004, the Coast guard finalized mandatory BWM requirements, for all ships operating in or entering U.S. waters, including maintenance of ballast water records (volumes, sources, and discharge points) and ballast water management activities. The latter includes mandatory mid-ocean

ballast water exchange (BWE), with exceptions for coastwise shipping and for ships to which BWE poses a stability safety threat. The intent of BWE is to flush coastal water and mechanisms from the tanks and replace it with organically poorer water containing ocean species in smaller numbers and less likely to invade coastal ecosystems. New USCG ballast water standards rulings are also measures to address the risks of MTS water pollution.

The Canadian and U.S. strategies for mitigating the introduction of ANS and aquatic invasive species have focused on steps that shipping companies can take to reduce the risk by replacing (exchanging) their freshwater ballast with ocean water before entering the Great Lakes. BWE removes organisms from a ship's ballast tanks by diluting the water and exposing freshwater organisms in the tanks to salt water, thereby killing many of them. Canadian and U.S. regulations require vessels in international trade entering the Great Lakes to manage their ballast water through effective strategies, including BWE.⁴⁸ New strategies for ship development and construction including ships without ballast are also among potential measures to reduce MTS water pollution.

The effectiveness of BWE is questioned by many experts and it is viewed as an interim control measure in advance of the adoption of mandatory ballast water discharge standards. The Coast Guard is developing such standards with the IMO standard in mind and, per authorization of NISA, is also encouraging the development and testing of ballast water treatment technologies to better determine their effectiveness and their operational limits in the shipboard environment.

The Shipboard Technology Evaluation Program (STEP) is a technology initiative designed as a vehicle for testing of chemical and physical treatment processes on a variety of ships. STEP and several other Government testing programs are increasing the knowledge of treatment technology and effectiveness and will inform the development of treatment standards and regulations. In coordination with this initiative, MARAD is participating in the Great Ships Initiative with many other state agencies and industry entities, which operates the Research, Development and Technology Evaluation (RDTE) facility in Superior, Wisconsin. To promote more efficient treatment of ballast water, NOAA disperses grants annually through its Ballast Water Technology Demonstration Program. There are other shore-side testing facilities operated by the University of Washington at Marrowstone, Washington and by the Naval Research Laboratory in Key West, Florida.⁴⁹

⁴⁸ Transportation Research Board (TRB), *Great Lakes Shipping, Trade and Aquatic Invasive Species*, Special Report 291, July 2008

⁴⁹ Integrated Portfolio Risk Management Framework has been defined as a tool for providing detailed information that allows makers to manage risk. This allows investment decisions to be made about "buying down consequences" i.e., risks, and "buying up service, security, and safety" i.e., reliability. Condition assessment and risk analysis are assessment tools and processes for evaluating the baseline condition of the infrastructure, setting targets for improvements and evaluating alternative candidates for investment.

5-4 NOAA Marine Debris Program

To address the growing risks of marine debris, the Marine Debris Research, Prevention, and Reduction Act, signed on December 22, 2006, legally establishes the NOAA Marine Debris Program. The Act sets a \$10 million authorization for NOAA for implementation of the program, including mapping, identification, and impact assessments, removal and prevention activities, research and development of alternatives to gear posing threats to the marine environment, and outreach activities. The Act also re-establishes the Interagency Marine Debris Coordinating Committee which NOAA co-chairs. This committee reports to the Subcommittee on Integrated Management of Ocean Resources (SIMOR) within the new ocean governance structure.⁵⁰ One of Marine Debris Program's projects, for instance, has involved training exercises for Navy divers on a mission to identify, map, and remove derelict fishing gear (DFG) in various regions of the country. In addition, NOAA is working with the U.S. Coast Guard and the Department of Interior on a major effort in debris assessment and removal in the Northwestern Hawaiian Islands. The agency is also using satellite and aerial remote sensing to locate and track oceanographic features likely to accumulate floating marine debris, and support external partners in the development and testing of protocols for the safe removal of derelict fishing gear from coastal waters.

5-5 International and Domestic Regulatory Measures to Improve Marine Vessel Emissions

IMO Measures for Addressing Emissions

The International Maritime Organization (IMO) leads the development of international regulations for ships. The IMO adopted Annex VI of the International Convention on the Prevention of Pollution from Ships (MARPOL) in 1997 to set NO_x emissions standards for ships. MARPOL Annex VI came into force in May 2005, and required that any country that has ratified the treaty can enforce the NO_x emission standards for any ships in its waters to follow emission standards for engines on ships constructed on or after January 1, 2000. The MARPOL Annex VI was ratified in 2008 and allows enforcement of the rules against any foreign-flagged ship that visits a U.S. port, whether or not the flag state of the ship has ratified the treaty. This would allow a larger fraction of *Category 3* marine engines in U.S. waters to be subject to the IMO emission regulations. MARPOL Annex VI establishes, among other things, the following:

- Limits on nitrogen oxides (NO_x) emissions as a function of ships' engine speed
- A global cap of 4.5 percent by mass on the sulfur content of fuel oil, dropping to 3.5 percent by 2012
- Establishment of SO_x Emission Control Areas (SECA), wherein the sulfur content of fuel must not exceed 1.5 percent, dropping to 0.1 percent by

⁵⁰ NOAA, National Ocean Service, Office of Response and Restoration, <http://marinedebris.noaa.gov/about/act.html>

2015; alternatively, ships must fit exhaust gas cleaning systems or use other methods to limit SO_x emissions. There are now North Sea and Baltic Sea SECAs. The U.S. EPA and the Canada and Mexico administrations are considering whether to designate one or more SECAs along the North American coastline, as provided for by MARPOL Annex VI. EPA is currently examining potential responses by the petroleum-refining and ocean-transport industries to such a designation, along with any resulting economic impacts.⁵¹

- IMO'S Marine Environment Protection Committee has agreed to further revise MARPOL Annex VI, by banning the burning of residual fuel oil after 2020, by specifying fuels of such low sulfur content (below 0.5 percent) that residual fuels will not be able to comply⁵². The shipping industry has expressed support for the IMO's actions. Both the World Shipping Council and the International Chamber of Shipping have agreed that development of a new environmentally effective regime is important and that a consistent international regulatory regime will avoid the confusion likely to result from different nations or local governments trying to regulate maritime commerce.⁵³

With respect to the goal of reducing greenhouse gas emissions in international shipping, the IMO has recognized that many potential operational, technical and policy options exist. However, they have taken aim at serious emissions limits and new fuel standards.⁵⁴

EPA Measures for Addressing Diesel Emissions

EPA established the first emission standards for the marine engines in 2000 to take effect between 2004 and 2007. The standards require relatively modest reductions in NO_x, CO₂, and PM. By 2020, these standards are expected to reduce commercial marine NO_x emissions by 21 percent, relative to uncontrolled levels, and reduce PM-10 emissions by 11 percent.

In May 2004, EPA announced its intent to propose more stringent emission standards for all new commercial, recreational, and auxiliary marine diesel engines, except *Category 3* engines. Like the new standards planned for locomotives, the new marine standards are expected to be modeled after the 2007/2010 highway and Tier 4 non-road diesel engine programs and will result in the use of advanced emission control technology. It is important to note that EPA standards apply only to U.S.-flagged vessels. While the vast majority of *Category 1* and *Category 2* engines in U.S. waters are U.S.-flagged, most *Category 3* vessels are foreign-flagged and thus not subject to EPA regulations.

⁵¹ Tallett and St. Amand, "Global Trade and Fuels Assessment - Future Trends and Effects of Designating Requiring Clean Fuels in the Marine Sector", prepared for the EPA, April 2006.

⁵² Safety at Sea International, "Bunker revolution as residuals banned", <http://www.safetvatsea.net>, April 4, 2008.

⁵³ Fairplay Shipping News, "Industry applauds air emission decision", <http://www.fairplay.co.uk>, 4 April 4, 2008.

⁵⁴ International Maritime Organization, "Study of Greenhouse Gas Emissions from Ships", Issue no. 2, March 2000.

U.S. regulations promulgated by the EPA apply to domestic vessels only, the vast majority of which use marine distillate fuel. Although engines produced today must meet emissions requirements, the EPA states that “current standards are relatively modest and these engines continue to emit significant amounts of nitrogen oxides (NOx) and particulate matter (PM), both of which contribute to serious public health problems.”

EPA now addresses emissions from marine engines through regulation of both fuel content and engine emission limits. In May 2004, EPA finalized new requirements for non-road diesel fuel that will decrease the allowable levels of sulfur in fuel used in marine vessels by 99 percent. These fuel improvements began to take effect in 2007, with significant expected environmental and public health benefits due to particulate matter reductions from new and existing engines.

In March 2008, EPA finalized a three part program that will dramatically reduce emissions from marine diesel engines below 30 liters per cylinder displacement (*Category 1* and *Category 2*.) These include marine propulsion engines used on vessels from recreational and small fishing boats to towboats, tugboats and Great Lake freighters, and marine auxiliary engines ranging from small generator sets to large generator sets on ocean-going vessels. The rule will cut PM emission from these engines by as much as 90 percent and NOx emissions by as much as 80 percent when fully implemented. The final rule includes the first-ever national emission standards for existing marine diesel engines, applying to engines larger than 600kW when they are remanufactured -- to take effect as soon as certified systems are available, as early as 2008. The rule also sets Tier 3 emissions standards for newly-built engines that will phase in beginning in 2009. Finally, the rule establishes Tier 4 standards for newly-built commercial marine diesel engines above 600kW, based on the application of high-efficiency catalytic after-treatment technology, phasing in beginning in 2014.⁵⁵

The National Clean Diesel Campaign is another EPA initiative with the goal of deploying verified or certified clean diesel technologies to modernize the legacy diesel fleet of 11 million diesel engines that predate the new emissions standards. The grant program awards \$49.2 million in grants nationwide to help build diesel emissions reduction programs across the country. The grant competition targets all mobile engines, including marine diesels, and grant recipients can use a variety of cost effective emissions reduction strategies, such as EPA-verified retrofit and idle-reduction technologies, EPA-certified engine upgrades, vehicle or equipment replacements, cleaner fuels, and creation of innovative clean diesel financing programs.⁵⁶

State/Local/Industry Measures Addressing Emissions

Many state and local agencies and port authorities have begun taking action ahead of regulatory changes to improve local air quality. Many ports have directly addressed shipboard emission sources, while others have focused on shore-side pollutant sources.

⁵⁵ <http://www.epa.gov/otaq/marine.htm>

⁵⁶ <http://yosemite.epa.gov/opa>, “U.S. EPA putting its money to work, to clean up diesel engines”, April 9, 2008.

In 2008, the Ports of Los Angeles and Long Beach jointly approved an incentive program aimed at accelerating cargo vessel operators' use of cleaner burning fuel within 40 miles of San Pedro Bay and at berth. The ports will allocate money to pay vessel operators to use cleaner-burning, low-sulfur fuel (0.2 percent or less) in their main propulsion engines program. This means that the ports will pay the difference between the price of bunker fuel and more costly low-sulfur distillate fuel. The Ports of Long Beach and Los Angeles have committed up to \$10 million and \$9 million, respectively, for the one-year incentive program.

The program has additional operational requirements: 1) the low-sulfur fuel must also be used in ships' auxiliary engines while at berth; and 2) ships must participate in the ports' voluntary Vessel Speed Reduction Program, limiting speeds and reducing emissions to 12 knots in the same approach/departure areas. The Port of Long Beach has committed as much as \$2.2 million a year to encourage participation in the speed reduction program. Its Green Flag Incentives reward vessel operators with environmental recognition and a 15 percent reduction in dockage fees in the following year. Long Beach is also preparing to provide electrical power for ships at berth so that main and auxiliary engines can be shut down (a practice known as "cold ironing"). Shore-side power sources and cold ironing can significantly reduce auxiliary engine emission of OGV while at berth.

The Port Authority of New York and New Jersey (PANY/NJ) is offsetting air emissions from an ongoing dredging project through funding the re-powering of tugboats and the retrofitting of the Staten Island Ferries. The repowering of two tugs operating in the Kill Van Kull is expected to reduce emissions of NOx by 50 tons per year for the next 10 years and the Port Authority plans to repower 6 to 8 more tugs to offset the emissions from the Harbor Deepening Project. The Port has aimed to reduce diesel exhaust emissions by electrifying port cranes through replacement diesel-powered cranes (\$12 million) and through infrastructure improvements enabling tenants to install new electrical cranes (\$100 million).

The PANY/NJ tenants have also installed electronic gates and extended gate hours to reduce truck delays and congestion, thus reducing air emissions, have replaced their diesel-powered forklifts with propane or electric units, and modernized their cargo handling equipment fleet to meet the more stringent EPA 2004 on-road standards. The Port Authority's 2004 Cargo Handling Equipment (CHE) Emissions Inventory Report indicated a 30 percent air emissions reduction, aggregated for all pollutants, compared to 2002, despite a 5 percent increase in operating hours and a 25 percent increase in the total number of containers handled.

The South Carolina State Ports Authority has committed to 100 percent use of ultra-low sulfur diesel (ULSD) fuel for all equipment at their public facilities by the fall of 2008, aiming for cleaner air and particulate matter emissions cuts by 10 percent. The Port Authority has also reduced truck idling on its facilities and decreased truck trips on local roads, lessened construction impacts, retired dirty equipment, and purchased cleaner engines.

The Port of Oakland in March 2008 adopted a “Maritime Air Quality Policy Statement” to reduce air pollutant emissions and their related health risks, with funding commitments to encourage retrofit or replace older polluting trucks at the seaport and to reduce ship idling emissions while the vessels are docked at the Port. It is projected that even as cargo business grows, the Port will cut PM pollution 85 percent by 2020, relative to the 2005 seaport emissions inventory baseline. The Port Policy Statement provides funding mechanisms, including container fees, to generate \$520 million over several years for maritime air pollution reduction initiatives and infrastructure improvements.

Industry measures to mitigate the adverse environmental impacts of marine vessels have also proven effective. Estimates of the growth of marine vessel emissions indicate that cargo growth has been more rapid than emission.⁵⁷ Improvements in ship engineering and propulsion design (engines, transmissions, and propellers), hull form innovations to reduce friction and drag, increasing ship size (larger hulls have relatively less wave-making and frictional resistance and higher proportions of volume available for cargo), and hull coatings. Vessel operators are also pursuing operational efficiencies such as weather routing to avoid storms, minimizing congestion and wait times, and efficient plant operation while in port.

⁵⁷ These claims need to be verified. According to the American Association of Port Authorities website, the 2006, cargo grew a total of 64.5 percent (to 6.54 billion metric tons), at an average annual growth rate Shipping Statistics Yearbook of 3.9 percent.

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ACRONYMS

AAPA	American Association of Port Authorities
AASHTO	American Association of State Highway and Transportation Officials
AIS	Automatic Identification System
AIS	Aquatic Invasive Species
ANS	Aquatic Nuisance Species
BAP	Bridge Administration Program
BWM	Ballast Water Management
BWE	Ballast Water Exchange
CFC	Chlorofluorocarbons
CHE	Cargo Handling Equipment
CHL	Coastal and Hydrological Laboratory
CI/KR	Critical Infrastructure Key Resource
CMTS	Committee on the Maritime Transportation System
COB	Container on Barged
CO ₂	Carbon Dioxide
CWA	Clean Water Act
DFG	Derelict Fishing Gear
DHS	Department of Homeland Security
DOE	Department of Energy
DWT	Deadweight
EEZ	Exclusive Economic Zone
EIA	Environmental Impact Analysis
EPA	Environmental Protection Agency
ERDC	Engineering Research and Development Center
FHWA	Federal Highway Administration
GDP	Gross Domestic Product
GHG	Green House Gases
GPS	Global Positioning System
HARS	Historic Area Remediation Site
HMIS	Hazardous Materials Information System
HMT	Harbor Maintenance Tax
HMTF	Harbor Maintenance Trust Fund
IAT	Integrated Action Team
ICMTS	Interagency Committee for the Maritime Transportation System
IRCS	Inland River Container Services
IWR	Institute for Water Resources
IWTF	Inland Waterway Trust Fund
LA/LB	Ports of Los Angeles/Long Beach
LOOP	Louisiana Offshore Oil Port
LRD	Lakes and Rivers Division
MARAD	Maritime Administration
MARPOL	International Convention on Prevention of Pollution from Ships
MDA	Maritime Domain Awareness

MEPC	Marine Environment Protection Committee
MPRSA	Marine Protection, Restoration, and Sanctuaries Act
MTSNAC	MTS National Advisory Council
MTS	Maritime Transportation System
NANPCA	Non-indigenous Aquatic Nuisance Prevention and Control Act
NDNS	National Dredging Needs Study
NEI	National Emission Inventory
NEPA	National Environmental Policy Act
NHS	National Highway System
NIPP	National Infrastructure Protection Plan
NISA	National Invasive Species Act
NOAA	National Oceanic and Atmospheric Administration
NPDES	National Pollutant Discharge Elimination System
MTS	Marine Transportation System
MTSA	Maritime Transportation Security Act of 2002
NED	National Economic Development
NRC	National Research Council
OGV	Ocean-Going Vessels
ORNL	Oak Ridge National Laboratory
OSV	Offshore Supply Vessel
PANY/NJ	Port Authority New York/New Jersey
RITA	Research and Innovative Technology Administration
RFID	Radio Frequency Identification
SCOOP	Short Sea Shipping Cooperative Program
SECA	SOx Emission Control Area
SIMOR	Subcommittee on Integrated Management of Ocean Resources
STEP	Shipboard Technology Evaluation Program
SOW	Scope of Work
SSS	Short Sea Shipping
TAPS	Trans Alaska Pipeline System
TEU	Twenty Foot Equivalent
Tg	Terra gram
TRB	Transportation Research Board
ULCC	Ultra Large Crude Carriers
USACE	United States Army Corps of Engineers
USCG	United States Coast Guard
USDA	United States Department of Agriculture
USDOD	United States Department of Defense
USDOT	United States Department of Transportation
VDR	Voyage Data Recorder
VLCC	Very Large Crude Carriers
VTS	Vessel Traffic Services
WRDA	Water Resources Development Act
WSCS	Waterborne Commerce Statistics Center
WCUS	Waterborne Commerce of the United States



Appendix D

Assessment of the Marine Transportation System (MTS) Challenges

Task 4: MTS Safety Challenges

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Preface

This Report is the Revised Task 4 deliverable for the Volpe Center Reimbursable Agreement (RA) VH-99 with the United States Army Corps of Engineers (USACE). The report has been prepared by Dr. Bahar Barami, the Volpe Center project manager, and revised to reflect the comments and inputs received from the project sponsors and members of the Marine Transportation System (MTS) Needs Assessment Integrated Action Team (IAT), including: CDR Paul M “Bo” Stocklin, USCG, CG-541; Jeff Hoedt, CG-5422; CDR Erin MacDonald, CG-5341, Office of Research and Rescue; LCDR Chuck Bright, CG-541; Richard Schaefer, CG-5341; David Edwards, CG-5341; Todd Steiner, CG-5241; Joy Liang, USDOT; staff from Transportation Security Administration (TSA); and Eric Wolfe, NOAA. At the Volpe Center, Rod Cook, Chief, Intermodal Infrastructure Security and Operations Division, provided peer-review and quality control input.

Introduction

This MTS Needs Assessment report is the fourth of six task reports for addressing the MTS challenge. Task 1 of this study examined the MTS physical infrastructure and conducted an assessment of the baseline MTS characteristics within a risk and reliability assessment framework. It analyzed the present and projected threats to the continued performance of the infrastructure, and identified system vulnerabilities and potential countermeasures for enhancing system resiliency.

Task 2 Report built on the risk and resiliency analysis framework developed in Task 1 and conducted an analysis of the economic impacts and risks of MTS. Within this framework, the study estimated the magnitude of the global economic impacts of a disruption in system operations, identified the vulnerabilities relating to the dependence of the nation's trade system on MTS, and assessed system resiliency with respect to the flexibility of the MTS-dependent supply chains, users and vessel operators.

Task 3 Report addressed the environmental challenges arising from systemic risks and vulnerabilities inherent in MTS, including the threats to the Nation's environmental stewardship mission and the associated challenges of meeting the performance demands of a global transportation network. The report focused on the environmental and safety risks arising from the marine vessel engine emissions, oil spills and hazardous cargo incidents, contaminated dredged materials, and invasive non-indigenous species introduced by ballast water. Task 3 also identified measures for preventing pollution and addressed issues relating to sustainable environmental practices, the resilience of the marine ecology, and the ability of MTS to return to normal conditions after an environmental disaster.

Task 4 will evaluate the MTS safety challenges within the risk and resiliency framework created and used in other three task reports. Within this framework, the threats, vulnerabilities and exposure levels that contribute to vessel and navigational risks will be identified and the factors that enhance system resiliency will be evaluated. The report will evaluate the trends in marine accidents and safety threats and the adequacy of the existing safeguards, as outlined in the project scope of work (SOW):

“This task will evaluate the adequacy of MTS operational safety capabilities, including systems and processes in place for waterways monitoring, pilots' duties, aids to navigation, vessel control and communications systems, and terminal interface with vessels and waterways. The task will also address system resiliency issues relating to MTS fault tolerance, available backup devices and early warning systems, frequency of dissemination of updated channel survey data, and the ability of the system to “degrade gracefully” by allowing the safety system to continue to operate with a reduced level of service rather than fail completely. There will be coordination with the CMTS integrated action team regarding “Navigation Safety Integration and Coordination” to encourage complementary efforts and eliminate duplication.”

For this purpose, the following sections will evaluate the components of maritime safety risks – threats, vulnerabilities, and consequences – and assess the extent to which MTS safety challenges have changed or evolved in the past decades, the system conditions that have led to new developments, new technology and information systems that have helped improve the safety of the system, the unmet challenges, and prospects for future improvements. The following sections will address these issues:

- Section 1 revises the risk and resiliency framework developed in previous task reports to adapt it to the assessment of the MTS safety threats, vulnerabilities, and consequences;
- Section 2 provides an overview of historical trends in MTS accidents and casualties and creates a typology of vessel types characterized as: steadily declining casualty rates, fluctuating rates, or rising casualty rates;
- Section 3 reviews the safety profile of the international tanker safety market that has demonstrated steadily declining trends in casualty and spill rates;
- Section 4 reviews trends in accident rates for freight ships, offshore service vessels (OSV), and the barge/tow industry that have demonstrated fluctuating accident rates;
- Section 5 review trends in rising casualty rates in passenger vessels, fishing vessels, and recreational boating;
- Section 6 provides an assessment of the safety risks at the interface of the infrastructure/terminals with vessels, with emphasis on safety risks to the inland waterways, navigation channels, and intermodal connectors.
- Section 7 concludes the assessment of MTS safety risks by addressing risk management priorities, risk mitigation alternatives, and system resiliency.

Section 1.0 A Risk and Resiliency Framework for Assessing MTS Safety Threats, Vulnerabilities, and Consequences

This section adapts the framework created for the Assessment of MTS Infrastructure Challenges in Task 1 to the analysis of MTS safety risks.

1-1 A Risk Analytic Process for Identifying the MTS Safety Challenges

Safety is defined as a measure of freedom from risks that threaten a complex transportation system. In this context, marine safety can be viewed as freedom from those conditions that can cause death, injury, degradation of the marine ecology and the environment, and damage to assets and property.

Risk analysis is an approach to risk control that allows potential risks to an organizational entity or a complex infrastructure system to be systematically assessed, managed, and communicated for informed decision-making. The common approach to a systematic risk analysis consists of a sequential 3-phase study consisting of risk assessment, risk management, and risk communication phases.

The first step, *risk assessment*, consists of finding answers for three critical questions about threats to the system, the vulnerabilities that would make the threats more likely to happen, and the events' consequences, asking: *What can go wrong? What is the likelihood that it would go wrong? What are the consequences?*

Answers to the questions posed above are found in a systematic process of *risk assessment*, where the MTS risks are defined as the following relationship between the prevailing threats – natural, man-made, mechanical failure, and systemic – confronting the domestic and international maritime activities, the likelihood that these threats will be realized and lead to operational disruptions, and the severity of consequences:¹

$$R = pT \times C$$

Where:

R = Risk of disruption or failure in any of the MTS parts, units or subsystems

p = Probability of threat realization

T = *Threat*: probability that the condition of any of the MTS operational components/subsystems will lead to facility closure, accidents, or environmental degradation

¹ Descriptions in this section are adapted from Yacov Y. Haimes, *Risk Modeling, Assessment, and Management*, Wiley Series in Systems Engineering, 1998; and Yacov Y. Haimes, "Roadmap for Modeling Risks of Terrorism to the Homeland," *Journal of Infrastructure Systems*, June 2002.

C = *Consequences*: criticality, severity, impacts, and resulting damages.

Threat (T) can be further broken down as a product of *exposure* to sources of threat, and the present *vulnerabilities*:

$$T = E \times V$$

Where: E = exposure; V = vulnerability.

Within such a framework, MTS safety challenges are evaluated with respect to the following parameters:

Threats: The probability that incidents involving vessel collisions, grounding, spills and allisions² will diminish the safety of waterborne transportation resources – vessels, people, infrastructure – and could potentially disrupt MTS operations and jeopardize its functions in support of economic and trade activities, environmental stewardship, and national security.³

Exposure: The probability that the magnitude of the exposure of the MTS subsystems (including the volume of vessel traffic and movement of hazardous cargo) to external and internal factors will increase the probability that the threat of an adverse event will be realized.

Vulnerabilities: The probability that weaknesses inherent in the MTS facilities, vessels, waterways and terminals, and the methods used for securing cargo, coupled with an absence of safeguards and protective mechanisms in certain MTS operational components, will increase the likelihood that the safety threats will be realized.⁴

Consequences: The economic costs (property damage and loss of assets), safety outcomes (fatalities, injuries), and environmental losses (contamination of waterways and marine ecology) resulting from realization of threats.

The *Risk Assessment* process culminates in estimating the potential safety impacts of marine safety threats by calculating the magnitude of the consequences of vessel collisions and groundings in terms of loss of life and injuries, economic losses, and potential for adverse environmental impacts of cascading chain effects. The process, in addition to producing an assessment of each component or risk – threat, exposure, vulnerability, and criticality/consequences – could produce a document integrating the

² Allision is defined as a vessel colliding with a fixed object.

³ Other terms referring to marine accidents include “ramming”, i.e., the intentional diversion of a vessel to collide with another object to avoid grounding; and “foundering,” referring to a vessel sinking beneath the water and becoming disabled. At the suggestion of the USCG Office of Investigations and Analysis, CG-5452, these terms have not been used in this report.

⁴ A reviewer commented that a facility on the waterfront can be regarded as “inherently vulnerable” to waterborne attacks, but that some other vulnerabilities could be procedural weaknesses.

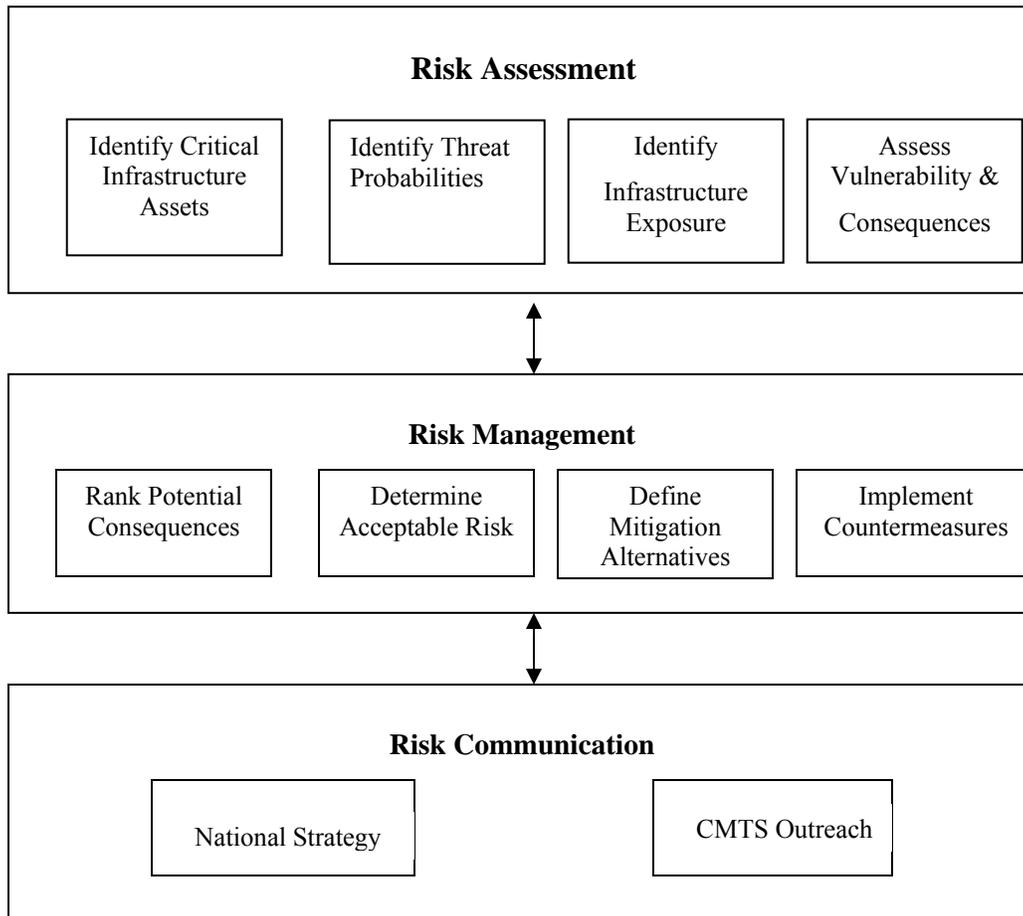
results in a decision-support matrix, juxtaposing the elements in the order of criticality. This matrix could be used for the next stage of risk analysis for risk management.

The *Risk Management* process involves:

- Identification and characterization of alternative countermeasures
- Development of decision processes and criteria
- Selection of countermeasures to be implemented
- Implementation of selected countermeasures.

Finally, risk analysis culminates with the *Risk Communication* process as the implementation of the countermeasures continues with communication and outreach with governmental agencies (MTS and other), the transportation community, policy makers and legislative bodies, and other affected parties and the public.

Figure 1– Risk Analysis Processes



Source: Adapted from National Research Council (NRC), *Minding the Helm: Marine Navigation and Piloting*, 1994.

The three stages of risk analysis are fully linked. The overall value of the process depends on achieving a high degree of iteration and integration among them, even though the

depiction of the three phases suggests independence among the elements of risk analysis. For example, the threat, in terms of the likelihood and nature of a potential failure of a specific transportation asset will be shaped largely by the vulnerability of the asset, the likely consequences of the chain events, the countermeasures in place, and the effectiveness of related communications with relevant transportation safety and search and rescue (SAR) agencies.

1-2 Identifying Accident Causes and Triggering Events

Marine accidents often occur not as a consequence of a single failure, but as part of a causal chain of events, errors, and hazards confronting the voyage. The risk assessment framework created above defined a *threat* as anything that can go wrong and lead to vessel collision, grounding, or allision. These events are called *accidents* or *incidents*, depending on the chain of events involved. What causes these events? Determining the causes of a vessel grounding or collision is part of a complex process of risk assessment which should be closely linked to risk management strategies that would avert future risks. The chain of events involved in this process links the *basic (root) causes* to *immediate causes* and *triggering incidents* that may or may not lead to an accident:⁵

Basic causes: These are the root causes of accidents, and include factors such as inadequate staffing, training or supervision, and poor preventive equipment maintenance or inspection of critical systems.

Immediate causes: There are the direct causes of accidents, and include human error (incompetence, inattention, fatigue, drug/alcohol use, lack of navigational skill), component failure, mechanical/equipment failure, and hazardous situations that may or many not lead to an accident.

Triggering incidents: These are undesirable events related to system failure or lapses in operational controls that may be detected or corrected in time to prevent accidents.⁶ Examples include loss of propulsion, steering failure, electrical power failure, navigation chart error, or human error. Some of these incidents can be prevented from developing into accidents by presence of redundancy or backup systems, as layers of redundant safeguards can compensate for some of the inherent mechanical and operator system vulnerabilities.

Accidents: These are occurrences that cause damage to vessels, facilities, or personnel, e.g., pollution incidents, collision, allision, grounding, fires, explosions, etc.

Consequences: These are the effects of accidents on personnel, equipment, and environment, and include fatalities, injuries, spills, and property damage.

⁵ This passage is based on John R. Harrald and Martha Grabowski, "Risk Mitigation in Passenger Vessel Operation," an undated article originally appearing in Disaster Recovery Journal (Vol.7, No.3).

⁶ A USCG reviewer commented that not all "reportable" incidents are considered "reportable marine casualties", so many "incidents" that do not involve marine casualties are not included in the accident databases.

Impacts: These are the broader results of accident consequences on individuals, organizations, and systems.

Within the analytical framework created to identify each of the MTS safety challenges, this report will address these risks by identifying the root causes and triggering events that contribute to MTS accidents, as depicted in Figure 2.

Figure 2 – Causal Chain of Accidents

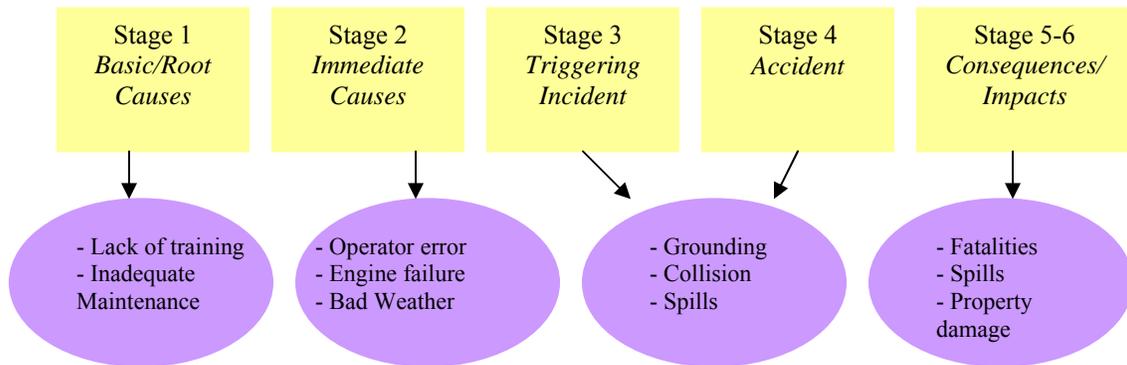
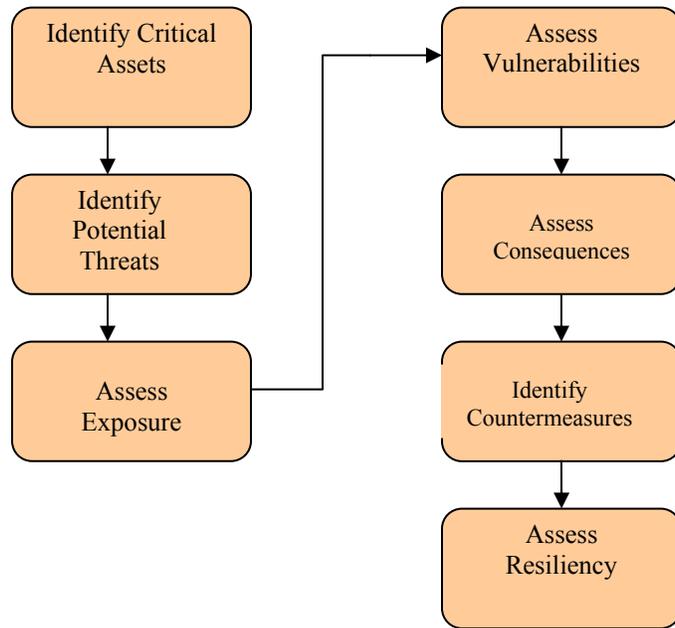


Figure 3 depicts the sequential processes involved in *risk assessment* and *risk management*. Sections 2 through 6 will assess the threats and vulnerabilities in critical segments of the MTS and the alternatives for reducing the consequences. The findings will be reflected in Section 7 with a review of the countermeasures available for mitigation of the adverse consequences. As defined in previous task reports, a resilient MTS is one that:

- Prevents and prepares for the worst to make the worst less likely to happen;
- Has built-in layers of operational capability for system redundancy;
- Has design-base fault tolerance and structural hardiness;
- Has response capability for mitigating the consequences of safety failures and accidents if they occur; and
- Is adaptive and will bounce back after a disruption rather than fall apart.

Figure 3 - MTS Infrastructure Risks and Resiliency Assessment Process



Section 2.0 Historical Trends in MTS Accidents and Existing Approaches to Risk Assessment

This section provides an overview of historical trends in MTS safety and accident rates. Overall, the trends suggest improvements in MTS safety and generally declining vessel accident risks. The trends provide a testimony to the success of the policies and practices of the commercial marine industry and the federal safety agencies to reduce marine accident risks in general, and certain vessel-based hazards in particular.⁷

2-1 Overview of Marine Accident Trends and Vessel Casualties

To understand the relative magnitude of marine transportation safety risks, we need to put in perspective the magnitude of maritime accidents and casualties with comparable statistics for other modes of transportation. Table 1 shows the 2006 rates for accidents, fatalities and injuries for all transportation modes in the U.S., showing that marine vessels and recreational boats account for 2 percent of all transportation fatalities and 0.2 percent of all accidents and injuries. The table shows that waterborne transportation had the next highest number of accidents and fatalities after highway transportation, and the third highest injury rate, after highway and transit (Table 1.)

Table 1 – Waterborne Transport Accidents and Casualties Compared to Other Modes

Mode of Transportation (2006 Data)	Accidents		Fatalities		Injuries	
	Frequency	% of Total	Frequency	% of Total	Frequency	% of Total
Air (General Aviation)	1,603 (1,515)	0.03%	766 (688)	1.7%	287 (261)	0.011%
Highway	5,973,000	99.5%	42,653	95.0%	2,575,000	98.8%
Pipeline	386	0.06%	19	0.04%	32	0.001%
Railroad	5,823	0.1%	603	1.3%	8,324	0.32%
Transit/Light rail	8,851	0.15%	74	0.16%	18,327	0.70%
Waterborne * (Vessel-Based/Commercial) (Recreational Boats)	10,367 (5,400) (4,967)	0.17% (52%) (48%)	797 (87) (710)	1.8% (11%) (89%)	5,245 (771) (4,474)	0.20% (15%) (85%)
All Transportation Modes	6, 000,030	100.0	44,912	100.0	2,607,215	100.0

Source: *Bureau of Transportation Statistics*.

* Statistics on waterborne accidents refer to all reportable accidents involving vessels in U.S. waters, and not just U.S. vessels.

⁷ A recent study conducted by IHS/Global Insight for the Maritime Administration (MARAD) has maintained that the U.S. maritime policy is constrained by legislative authority and enforcement of safety regulations and remains narrowly focused on vessels. IHS Global Insight, “An Evaluation of Maritime Policy in Meeting the Commercial and Security needs of the United States,” January 7, 2009 [http://www.marad.dot.gov/documents/Final_Reoprt_-_MARAD_Policy_Study_\(2\).pdf](http://www.marad.dot.gov/documents/Final_Reoprt_-_MARAD_Policy_Study_(2).pdf)

A dominant theme emerging from comparing the risk factors for marine and other transport modes is the similarity in risk between two key components of the aviation and marine transportation sectors: commercial and non-commercial. Recreational boating accidents account for 48 percent of the waterborne transport accidents, 89 percent of its fatalities, and 85% of its injuries. This suggests at least one parallel risk factor implicit in Table 1: the fact that General Aviation, similarly, accounts for about 95 percent of all aviation accidents (1515 out of 1603); 91 percent of the fatalities (698 out of 766 fatalities); and 91 percent of the injuries (261 out of 287 injuries). The high accident rates for the two non-commercial transportation modes suggest that organizational factors and regulatory safeguards that guide commercial transportation safety and operator training and skill are key factors that influence variation in transportation safety, whether in aviation or marine transportation, as addressed in Section 5.0.

Focusing on the risk factors present in the marine transportation, Table 2 shows trend data on vessel-specific fatalities and injuries reported for 1970 through 2006. With respect to fatalities, the table shows that freight ships, tankers and offshore service vessels (OSV)/mobile offshore drilling units (MODU) have had declining though fluctuating rates of fatality, with the average annual rates declining significantly in the recent years. Other vessel types – including passenger ferry/cruise vessels, fishing vessels, tug/towboats, barges, and recreational boats – on the other hand, have been showing high, rising, and fluctuating annual fatalities. The injury rates in Table 2 are consistently higher with greater fluctuation, suggesting that the combined rates of fatality and injury are better metrics for characterizing the risk profile of the U.S. marine transportation sector.

Table 2 - Vessel-Specific Casualties by Vessel Type

Vessel Type	Average Annual Fatalities		
	1970-1990	1991-1999	2000-2006
Freight ship	13	1	3
Tanker	4	1	0
Passenger	3	6	8
Tug/Towboat	16	2	4
OSV + MODU+ Platform	NA	3	1
Fishing Vessel	61	31	17
Recreational	1,256	804	703
Barges (Tank and Freight)	0	6	8
Average Annual Injuries			
Freight ship	11	4	9
Tanker	14	6	3
Passenger	24	63	80 *
Tug/Towboat	19	17	18
OSV + MODU+ Platform	NA	10	9
Fishing Vessel	24	35	30
Recreational	2,309	4,151	3,838
Barges (Tank and Freight)	6	22	10

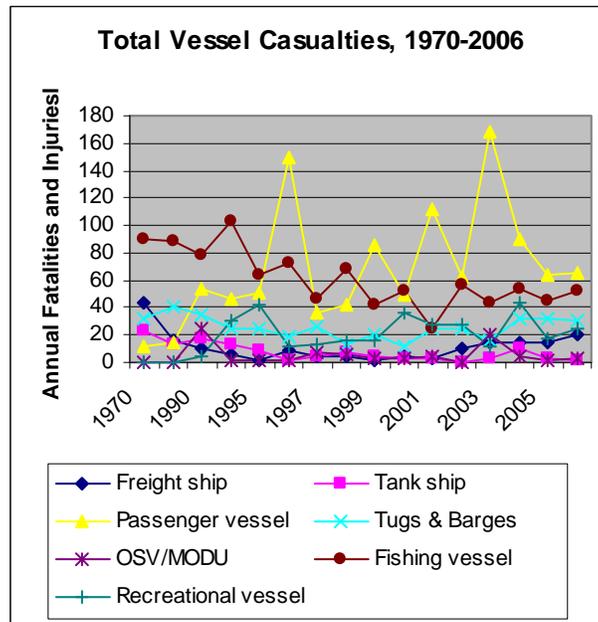
Sources: 1)USCG Vessel Accident data reported in BTS, *National Transportation Statistics, Water Transportation Profile, 2007*; and 2) USCG *Recreational Boating Statistics* annual publications. Note that the available statistics on waterborne accidents refer to all reportable accidents involving vessels in U.S. waters, and not just U.S. vessels.

* As several reviewers of the report have pointed out, a single catastrophic event may have caused such a significant rise in the average number of casualties. Such events represent outliers that influence trends in casualty. The study scope and time constraints do not allow further analysis of the high-consequence events that have led to such jumps in the casualties.

When the combined casualty rates (i.e., fatalities plus injuries) are plotted (Figure 4), a fairly consistent trend is demonstrated for each vessel type:

1. *Declining Casualty Trends:* Tanker vessels exhibit a relatively steady declining trend, with minor fluctuations in casualty rate.
2. *Fluctuating Casualty Trends:* Freight ships, Tugs/Tows, Barges, and OSV/MODU vessels show fluctuating though generally declining trends.
3. *Rising Casualty Trends:* Passenger Ships, Commercial Fishing vessels and Recreational Boats demonstrate generally rising casualty trends, to a large extent consistent with rising exposure rates.

Figure 4 – Trends in Total Vessel Casualties (Fatalities and Injuries), 1970-2006



Source: USCG Vessel Accident data reported in BTS, *National Transportation Statistics, Water Transportation Profile, 2007*. Note that the data relate to “Vessel-related” accidents and casualties, and not all accidents related to waterborne transportation. To this extent, the casualty data underreport the recreational boating casualties, not all of which can be “vessel related.”

These three trends will serve as the basis for the vessel risk typology created in Section 2-3. The following two findings summarize the analysis of marine accident trends in this section.

Finding 2-1 Waterborne Transportation accounts for less than 2 percent of all transportation casualties, with the dominant share of it attributed to non-commercial recreational boating.

Finding 2-2 Vessel type is a key predictor of marine fatality and injury rates, with three distinct patterns emerging: declining, fluctuating, or rising rates.

2-2 Current Models for Addressing Maritime Risks

The standard framework for analyzing maritime vessel accident risks is the Port and Waterway Safety Assessment (PAWSA), a qualitative risk assessment tool developed by the USCG. The PAWSA process grew out of the enactment of the Port and Waterway Safety Act in 1990 and the Vessel Traffic Service (VTS) acquisition program that led to the development of the congressionally required Port and Waterway Safety System

(PAWSS) to address waterway user needs to reduce navigational risks.⁸ The model is designed to identify major waterway safety hazards, estimate risk levels and consequences, evaluate potential mitigation measures, and set the stage for implementation of selected measures to reduce risk.

The PAWSS risk model defines maritime risk as a function of the probability of a casualty and its consequences, and incorporates the variables associated with both the causes and the effects of vessel casualty.⁹ The factors influencing the likelihood of incidents relate to vessel and waterway design, fleet composition, traffic conditions, navigation conditions, voyage frequency, waterway configuration, personnel training, availability of AtoN, and operational/organizational issues and regulatory enforcement. The model emphasizes the human factor issues not only in reference to crew training, but also in the context of automation, manning levels, and the human integration into the ship bridge system. The model identifies consequences as the immediate and subsequent outcomes of a casualty accident. In general, the PAWSS waterway risk model incorporates six variables dealing with the causes and consequences of risk:

1. Vessel conditions: the quality of vessels and their crew that operates on a waterway;
2. Traffic conditions: the number of vessels that use the waterways and their interaction;
3. Navigational conditions: the environmental conditions that vessels must deal with in a waterway relating to wind, water tide/currents, and weather;
4. Waterway condition: the physical properties of the waterway that affect how easy it is to maneuver a vessel;
5. Immediate consequences: impacts on the number of people killed, injured, spills, property damage;
6. Subsequent consequences: economic impacts of shutdowns, destruction of fishing habitat and extinction of species, water contamination, etc.

The six risk elements of the PAWSS risk model, together with the system attributes that characterize each operational component of marine transportation create a 26-cell matrix of contributing factors. The PAWSS model uses the matrix to estimate the probability of maritime accidents and their consequences for use in vessel traffic control systems such as VTS.

⁸ As part of the PAWSS, the USCG convened a national dialogue group (NDG) comprised of maritime and waterway community stakeholders to identify the needs of waterway users with respect to Vessel Traffic Management (VTM) and VTS systems.

⁹ USCG defines casualty broadly, as “accident outcomes, including fatalities and injuries.”

Table 3 – The PAWSS Risk Matrix

Fleet Composition	Traffic Conditions	Navigations Conditions	Waterway Configuration	Immediate Consequences	Subsequent Consequences
% of High-Risk Deep Draft	Volume of deep draft vessels	Wind Conditions	Visibility Obstruction	Number of people on Waterway at risk	Economic Impacts
% of high-Risk Shallow-Draft	Volume of Shallow Draft Vessels	Visibility Conditions	Channel Width	Volume of Petroleum Cargo spills	Environmental Impacts
	Volume of Fishing and Pleasure Craft	Tide and River Currents	Bottom Type	Volume of Hazardous Chemical Cargo Accidents	Health and Safety Impacts
	Traffic Density	Ice Conditions	Waterway Composition		

Source: Ports and Waterways Safety Assessment (PAWSA), *Final Report*, USCG, http://www.navcen.uscg.gov/mwv/projects/pawsa/PAWSA_FinalReports.htm

Variations on the PAWSS risk model are used in several other navigation risk models. The model used in the International Association of Marine Aids to Navigation and Lighthouse Authorities (IALA), for instance, has developed a risk management tool for Ports and Restricted Waterways which builds on the PAWSS 26-cell matrix, and adding 4 new elements to develop a 5x6 matrix of 30 cells. The elements that the IALA model adds to the PAWSS matrix are “commercial fishing vessel” and “small craft quality” (two cells added to the Fleet Composition column), “mobility” (a cell added to the “Immediate Consequences” column), and “aquatic resources” (a cell added to the “Subsequent Consequences” column). The elements of the 26- or 30-cell matrix will be incorporated in the safety risk assessment framework used in the following section.

2-3 A Proposed Framework for Analysis of MTS Risks

The framework proposed to present the findings of this study builds on the component factors identified in the PAWSA risk model. It incorporates the multitude of factors that influence exposure to hazard, the system’s inherent vulnerabilities, and accident consequences. The study will attempt to explain the causes of MTS safety risks with reference to the four underlying causes used in current risk models:

1. Vessel Design, Size, Cargo Attributes. These risks relate to engineering and mechanical failures relating to vessel operations and cargo type. (They are most applicable to risk factors present in oil tanker and tow & barge vessel operations and spill risks.)

2. Vessel Operations, Operator Error, and Human Factors. These relate to voyage frequency, usage, complexity of bridge operations, exposure levels, and crew size, manning, training and skill levels. (They are addressed most prominently in relation to risk factors present in freight ships, passenger and fishing vessels and recreational boating.)
3. Terminal and Infrastructure Capacity. These risks stem from an array of infrastructure-related factors relating to the waterway fleet composition, traffic density, waterway configuration, visibility obstruction, channel width, bottom type, and terminal-ship interface. (These issues are addressed in Section 6.)
4. External/Weather/Environmental Factors. These risks stem from weather and the ocean environment, and navigational conditions, including diminished visibility, winds, tides and currents and ice conditions that contribute to waterway accident risks. (These risk factors relate most prominently to OSV/MODU vessels, commercial fishing vessels, and recreational boating.)

The analysis presented in the following section builds on a risk typology that assigns marine vessels to three vessel-based risk categories – vessels with declining, fluctuating, and rising accident profiles – with an added section on vessel-infrastructure interface. Within this framework, the following sections will assess the nature of the threats, the existing vulnerabilities, exposure factors and their attendant consequences, and assess the risks with respect to the underlying causes of the accidents:

- *Threats* relating to the probability of vessel collision, grounding, allision, and spills;
- *Exposure* factors arising from traffic conditions and intensity;
- *Vulnerabilities* that cause vessel malfunction, operator error, infrastructure failure, and weather-related incidents;
- *Consequences* in terms of fatalities, injuries, environmental damage, and property damage; and
- *Mitigation* tools and system resiliency.

Table 4 shows the average annual vessel combined fatality and injury casualties for 1970-2006, highlighting the three trends that characterize transformations in vessel accident risks in the U.S. in the past three and half decades:

1. Tanker vessels exhibit a relatively steady *declining* trend in casualty rates, from 23 in 1970 to 2 in 2006 (with a minor spike in 2004 with 10 casualties).¹⁰
2. Freight ships, tugs/tows, barges, and OSV/MODU vessels show *fluctuating* though generally declining trends.
3. Passenger vessels, commercial fishing vessels and recreational boats demonstrate *generally rising* (or consistently high, as in fishing vessels) casualty

¹⁰ As noted earlier, spikes in accident rates are often due to a high-consequence outlier event. Time constraints do not allow further examination of these outlier events.

trends, to a large extent consistent with rising exposure rates and vulnerability to operational weaknesses.

Table 4 – Average Annual Vessel-Based Casualty Rates, 1970-2006

Vessel Type	Average Annual Casualties (Fatalities and Injuries)		
	1970-1990	1991-1999	2000-2006
Freight ship	24	5	12
Tanker	18	7	3
Passenger	27	69	88
Tug/Towboat/Barge	41	47	40
OSV + MODU+ Platform	NA	13	10
Fishing Vessel	65	66	47
Recreational	3,565	4,955	4,540

The analysis of trends in marine accidents in the following sections is based on the available USCG accident statistics available from several sources, including the USCG Marine Information for Safety and Law Enforcement System (MISLE); Recreational Boating Statistics; the USCG Search and Rescue (SAR) Management Information System Incident Reports; and Marine Safety Management Information System.

To determine the number of vessels affected by MTS safety conditions, the USCG target population of the eligible vessels for carriage of Automatic Identification System (AIS) was used. The AIS eligible population encompasses the vessels covered under the International Maritime Organizations (IMO) Safety of Life at Sea (SOLAS) Convention regulations and the Marine Transportation Security Act (MTSA) safety regulations. Section 7.0 addresses the AIS implementation and the benefits generated as a risk mitigation strategy.

Table 5 – Population of Vessels Eligible under Current U.S. Safety and Security Regulations ¹¹

Eligible Vessels	AIS Vessel Population (Commercial Self-Propelled (1))	MTSA Vessels (SOLAS + Vessels ≥ 65' + Tugs/Tows) (2)	US Flag SOLAS Vessels
Tankers	122	155	120
Freight Ships (Container, Dry-bulk, RoRo, General Cargo)	298	389	245
Offshore Supply Vessels (OSV)	553	770	55
Mobile Offshore Drilling Units	210	65 *	2
Industrial Vessels	748	2	21
Research Vessels	97		
School Ships	19		
Passenger Cruise/Ferries (≥ 65 ft or ≥ 50 Passengers; or > 30kts)	3,235	2,744	89
Fishing Vessels ≥ 65 ft	5,520	3,804	4
Towboats/Tugs	4,560	6,440	13
Dredges	35		
Unclassified/Unknown	926		
Total U.S.-Flag Vessels	16,323		
Foreign Flag ≥ 65 ft	1,119		
Total	17,442	14,369	549

(1) Source: Federal Register, Vol. 70, No. 209, October 31, 2005, DHS/USCG, Vessel requirements for Notices of Arrival and Departure, and Carriage of Automatic Identification System (USCG –2005–21869); Chart entitled “Estimated Expanded AIS Population” for self-propelled vessels of ≥ 65 ft in length, or vessels meeting other regulatory requirements.

(2) Source: Mr. Jorge Arroyo, Project Manager G-MWV, Department of Homeland Security, U.S.CG, e-mail correspondence, December 20, 2007USCG, MTSA vessels

Note: The world population of commercial vessels of all flags is 15,819; population of vessels of U.S. Flag Registry is 295; population of U.S. Flag Vessel Country of Ownership is 739 (Source: (MARAD, Maritime Trade and Transportation, 2007, Table 7-3.)

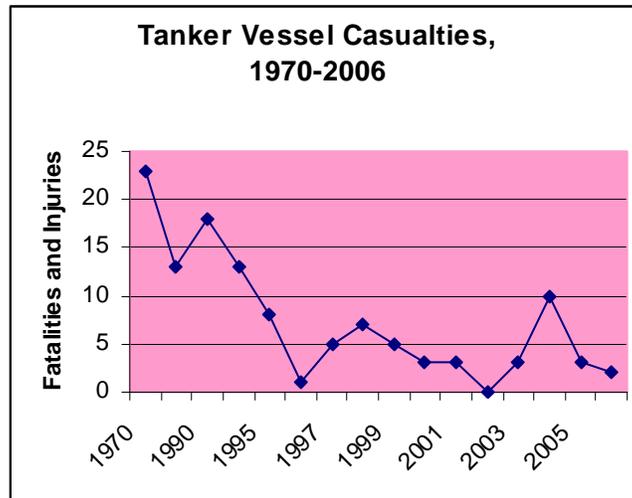
* MTSA vessel population for MODU includes 36 Oil Recovery vessels

¹¹ Table 5 omits recreational vessels since the scope of the data in the table is limited to vessel eligible under the MTSA, SOLAS, and AIS regulations. Safety risks relating to recreational vessels, however, are addressed at length in Section 5.0.

Section 3.0 Vessels with Steadily Declining Casualties

Tankers represent the only vessel type demonstrating low and steadily-declining casualty levels. Figure 5 shows average annual casualties from tanker accidents between 1970 and 2006.

Figure 5 – Tanker Vessel Casualties, 1970-2006



Source: U.S. DOT, *Water Transportation Profile*

Threats

Grounding and collision incidents are initial events that are likely to lead to spills. Worldwide, there were 325 tanker accidents in 2007. Between 2000 and 2004, there were 67 reported tanker spills (Table 6.)

Exposure

Under the AIS compliance requirements, there are 122 eligible tankers. These represent the lower bound of the population of tanker vessels in the U.S. (compared to the MTSA tanker vessel population of 155 and U.S. flag vessels of 329.)¹² The population of tanker vessels also includes gas and liquefied natural gas (LNG) vessels. The exposure parameters for measuring tanker accident risk also include the number of tanker port calls (21,230 calls per year in 2006) and transits (42,460 per year). Tankers disproportionately contribute to the volume of oil spilled, even though both the number of tanker accidents and frequency of oil spills have declined significantly in the past decade. There has been a sharp decline in average volume of oil spilled from vessels in U.S. waters. Trends suggest that between 1973 and 2000, the average spill volume has declined by a factor of

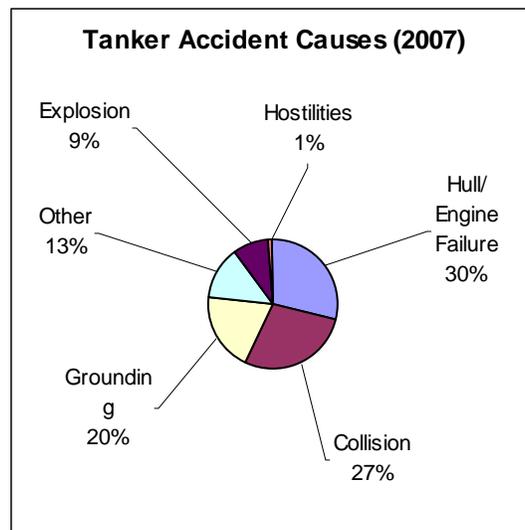
¹² MARAD, *U.S. Water Transportation Statistical Snapshots*, May 2007.

15, from an average of 7.7 million gallons to 515,000 gallons, a 93 percent decline.¹³ The average volume of tanker spill has been 276,000 gallons, representing 41% of all spills (Table 6.)

Vulnerabilities

The primary causes of the 325 worldwide tanker accidents in 2007 were mechanical failure related to hull damage or engine-failure, collision, grounding and fire¹⁴ (Figure 6.)

Figure 6 – Causes of Tanker Accidents in 2007



INTERTANKO, Peter Swift, “Tanker Business Today,” May 1, 2008

Another key vulnerability for oil tankers is that they are responsible for the largest volumes of spills, even though they have relatively few spill events. The USCG spill statistics indicate that in spill volume, tank vessels contribute disproportionately to the tonnage of oil spilled, though they account for only 2 percent of average number of spill incidents. Between 2000 and 2004, 41 percent of the volume of oil spilled in the U.S. came from tanker vessels; 21 percent from barges, and 38 percent from other vessels, including general freight, OSV/MODU, and fishing vessels. The average spill volume for tank vessels in this period was 4,130 gallons. Table 6 summarizes the USCG data on tanker spill volumes and frequency. (Contribution of barge vessels to the frequency of spills and the magnitude of property loss and environmental damage is discussed in Section 4.)

¹³ USCG Oil Spill Data, reported by Leschine, Tom, “Environmental Impacts of Vessel Operations from a Risk Perspective,” University of Washington, School of Marine Affairs, Presentation at the Marine Board Fall Meeting, November 19-21, 2008.

¹⁴ INTERTANKO, Peter Swift, “Tanker Business Today,” May 1, 2008.

Table 6 – Oil Spill Events by Vessel Type

Vessels involved in Oil Spills: 2000-2004	Average # of Spills	Average Annual Volume Spilled (Gallons)	Average Size of Spill per Incident (Gallons)	Average Cleanup Costs per Spill (based on \$37 per Gallon)
Tankers (% of total)	67 (2%)	275,886 (41%)	4,130	\$153,000
Tanker barges (% of total)	180 (6%)	138,951 (21%)	772	\$28,600
Other Vessels (% of total)	2,917 (92%)	258,812 (38%)	89	\$3,300
All Vessels	3,163 (100%)	673,649 (100%)	213	\$7,900

Source: USCG, Oil Spill Compendium 2004, <http://www.uscg.mil/hq/>
 Reported in BTS National Transportation Statistics, Table 4-50,
 Petroleum Oil Spills Impacting Navigable U.S. Waterways

Consequences

In 2006, there were zero tanker fatalities (down from 4 per year in 1970 and 1980), and 2 injuries (down from 19 in 1970.) Table 7 shows that in the past three and half decades, tanker accident injuries and fatalities have declined to an average of 3 casualties for the period between 2000 and 2006.

Table 7 – Tanker Accident Trends

Tank Ship Accident Rates	Average # of Fatalities/ Yr	Average # of Injuries/ Yr	Average Casualties (Fatalities + Injuries)/Yr
1970-1990	4	14	18
1991-1999	1	6	7
2000-2006	0	3	3

Source: U.S. DOT, *Water Transportation Profile*

As for the consequences of oil spills, consistent data on cleanup costs are not available, though the total costs may have declined given the sharp decline in average volume of oil spilled from vessels in U.S. waters. Trends suggest that between 1973 and 2000, the average spill volume has declined by a factor of 15, from an average of 7.7 million gallons to 515,000 gallons, a 93 percent decline (Table 8.)

Table 8 - Average Oil Spill Volumes, 1973-2000

USCG Data Reports	Average Spill Volume (Gallons/yr)
1973-1979	7,713,753
1980-1989	4,988,000
1990-1999	1,674,430
1995-2000	515,110

Source: USCG Oil Spill Data, reported by Tom Leschine, “Environmental Impacts of Vessel Operations from a Risk Perspective,” University of Washington, School of Marine Affairs, Presentation at the Marine Board Fall Meeting, November 19-21, 2008

To illustrate with historical examples, the cleanup cost of the 1989 Exxon Valdez accident, which spilled 37,000 metric tons of oil was \$93,568 per ton, given the spill

location, the quality of oil spilled, and the complexity of cleanup operations. The Athos I tanker accident in the Delaware Bay in 2004 spilled 265,000 gallons of oil at a cost of \$65 million (or \$254 per gallon). Another study on the costs of cleaning up oil spills estimated the cost to cleanup a generic gallon of oil at \$3,100 per ton, \$1,540 per barrel, and \$37 per gallon of oil spilled.¹⁵

Mitigation Measures

Modern double-hull tank bottoms and advanced navigation and communications technologies have been effective in addressing the high risks inherent in transportation of oil in tanker vessels:

- Double-hull tankers have reduced the probability of vessel damage and spills;
- Vessel Traffic Service (VTS) directly addresses collision and grounding risks;
- Radar technologies and Automatic Radar Plotting Aid (ARPA) directly address collision and grounding risks associated with spill probability and the attendant consequences;
- Electronic Chart Display Information System (ECDIS) and the NOAA Physical Oceanographic Real-Time System (PORTS[®]) mitigate tanker grounding and spill risks arising from changing water level and changing ocean bottom and channel terrain.

Illustrating the benefits from the mitigation measures currently deployed is a recent Formal Safety Assessment (FSA) study conducted in accordance with the IMO guidelines for risk assessment to estimate the benefits of using ECDIS for grounding avoidance. The study was based on three types and routes of test oil tankers: an 80,000 deadweight (DWT) oil tanker trading between Kuwait and France; a product tanker of 4,000 DWT trading between ports in Norway and Sweden; and a bulk carrier of 75,000 DWT carrying coal between Australia and Japan. ECDIS, compared to paper chart, showed a net effectiveness rate of 36 percent in reducing grounding accidents and grounding-related casualties and spill cleanup costs. The ratios of costs to benefits for the three vessel types were: 1:5; 1:2; and 1:4 respectively; indicating that using ECDIS is 2 to 5 times more cost effective than staying with paper charts.¹⁶

Finding 3-1 Tankers casualties have declined significantly in the past three decades and spill volumes and frequencies have also declined, though tankers remain key sources of spill risks.

¹⁵ Washington State, “Study of Tug Escort in the Puget Sound,” December 2004.

¹⁶ “Formal Safety Assessment – ECDIS”, presentation of Rolf Skjong, Chief Scientist, Stananger, 8 January 2006. The model assumed ECDIS costs of \$75,000 (including the net present value (NPV) of purchase, maintenance, and training) compared to the NPV of benefits that ranged between \$175,000 for the product tanker to \$396,000 for the oil tanker.

Section 4.0 Vessels with Generally Declining but Fluctuating Rates of Accident

Three vessel types – freight ships, tugs/tows and their barges, and OSV/MODU – have demonstrated generally declining though highly fluctuating rates of accident and casualty. The risk parameters for each vessel type are examined in this section.

Freight Ships

Threats

Grounding and collisions are key events that can go wrong with freight ships.

Exposure

The population of AIS-eligible vessels serving the U.S. maritime commerce encompasses 298 freight ships. Of these, 83 are containerships and the remaining 215 are dry bulk, general freight, and Roll-on-Roll-off (RoRo) vessels operating in the U.S. maritime trade. The containerships make a total of 19,600 port calls per year, involving 39,200 transits. The remaining vessels together make 23,214 port calls per year, involving 46,400 transits.¹⁷ Containerships have been among the fastest growing commercial marine vessels, and have been steadily growing in size. In the five years between 2002 and 2007, port calls for containerships of all sizes increased by 15.9 percent, while port calls by containerships of $\geq 5,000$ TEU grew by 251 percent. In 2007, freightships of all types and size made about 44,000 port calls at U.S. ports, with some 88,000 vessel transits.¹⁸

Consequences

Freightship fatalities and injuries have generally declined in the past three decades, but have shown fluctuating spikes. Before 1990, these vessels had, on average, 13 fatalities and 11 injuries per year. Between 1991 and 1999, the average casualties declined to 1 fatality and 4 injuries per year. Between 2000 and 2006, the average casualties for all freight ships rose again to 3 fatalities and 9 injuries per year (Table 9, Figure 7.) Consistent transit data are not available to normalize freight ship accident rates, though the spikes may be attributed to rising size and exposure (traffic volumes.)

¹⁷ Note: Excluded from the user population of commercial vessels are approximately 28,000 dry barges and 4,200 tank/liquid barges. The decision to exclude this vessel population was based on the fact that barges have no propulsion capability. Based on data from US Department of Transportation, Maritime Administration, *US Merchant Marine Data Sheet* (various years).

¹⁸ MARAD, U.S. Water Transportation Statistical Snapshot, May 2008.

Table 9 – Freight Ship Accidents, 1970-2006

Freight Ship Accident Rates	Average # of Fatalities per Year	Average # of Injuries per Year	Total Average Annual Casualties
1970-1990	13	11	24
1991-1999	1	4	5
2000-2006	3	9	12

Source: BTS, Water Transportation Profile, based on USCG data,

Figure 7 - Freight Ship Casualty Trends, 1970-2006



Source: U.S. DOT, *Water Transportation Profile*

Vulnerabilities

Human factors and operator error account for 70-80 percent of the root causes of many vessel accidents. Accident reports have attributed primary basic causes of freight vessel accidents to lack of skill and training of the ship bridge crew, bridge manning levels, operator fatigue, and the effectiveness of the master/pilot exchange are critical to reducing vessel accidents. Among these operational factors are the lack of operator access to updated charts and communication devices and information on real-time tide and water levels, and lack of awareness of other vessels and their intentions in close proximity.

Reduced crew size in commercial freight vessels is emerging as a key human factor vulnerability. A 1996 USCG analysis of 279 incidents identified fatigue as a factor in 33 percent of injuries and in 16 percent of vessel accidents. The National Transportation Safety Board (NTSB) has on several occasions suggested that the USCG should implement more stringent regulations to enforce crew rest periods to reduce fatigue. In its investigation of vessel accidents, the NTSB has maintained that the voluntary USCG program (known as Crew Endurance Management System), which requires 8 hours of

crew sleep, is unacceptable because it is not enforced.¹⁹ Another report conducted by the United Kingdom Marine Accident Investigation Board (MAIB) has the following conclusions about Marine Watchkeeping:

“Watchkeeping and manning levels, fatigue, and a master’s ability to discharge his duties are major causal factors in collision and groundings, and poor lookout is a major factor in collision. The hours of work and lookout requirements contained in STCW-95, along with the principles of safe manning, are having insufficient impact in their respective areas....[The MAIB recommended] addressing causal factors of fatigue, inadequate manning, and poor lookout.”²⁰

Mitigation Measures

Advanced navigation, surveillance, location, and communications technologies, VTS, electronic charts and real-time tides & currents information, and other AtoN technologies have been effective in mitigating navigation risks by reducing the root causes of vessel collisions and grounding and the chain of events. Containerships are most likely to use advanced navigation and surveillance technologies because they tend to carry high value cargo and are often draft constrained because of the increasingly larger vessels deployed.

Finding 4-1 - For freight ships, fatality and injury accidents been generally declining, with fluctuations in rates largely precipitated by the operational and scheduling constraints on vessel operators and reduced crew size.

Tows and Barges

Threat

Collisions, groundings and barge breakaway, and the associated risks of oil spills and casualty, remain at relatively high levels for the towing sector.

Exposure

An estimated 4,560 tugs/tow vessels operate in the U.S., per the AIS eligibility requirements. There are also 28,000 dry bulk barges and 4,200 liquid tank barges in domestic use.

Vulnerabilities

Organizational factors relating to the small size of firms operating in the industry and low cargo value, hazardous nature of the liquid bulk products transported, and constant exposure to severe weather and changing channel configurations are among vulnerabilities that make tow/barge accidents more likely. Oil spill from tank barges accounts for 21 percent of the average volume of oil spilled and 6 percent of the average number of spills, as previously shown in Table 6.

¹⁹ Professional Mariner, “NTSB Labels Coast Guard Effort to Address Mariner Fatigue as ‘Unacceptable’”, Issue 3 112, April 2005, <http://professionalmariner.com/ME/Sgments/Publications/Pring.asp>

²⁰ Marine Accident Investigation Branch (MAIB), *Bridge Watchkeeping Safety Study*, Safety Study prepared by MAIB, United Kingdom, July 2004.

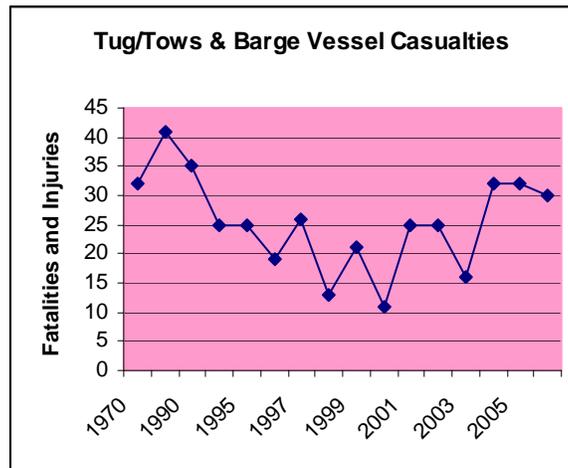
Consequences

Between 2000 and 2004, the USCG reported 180 spills involving tanker barges, each with an average spill volume of 139,000 gallons. With respect to the number of fatalities and injuries, the safety of the tug/tow and barge industry has in general improved in the past three decades. Between 1970 and 1990, there were, on average, 16 tug/towboat fatalities and 19 injuries per year. Between 1991 and 1999, fatalities declined to 2, and injuries to 17 per year. Between 2000 and 2006, the averages rose again to 4 fatalities and 18 injuries per year (Table 10, Figure 8.)

Table 10 - Tugs/Towboat Fatalities and Injuries, 1970-2006

Tugs/Towboats Accident Rates	Average # Fatalities per Year	Average # Injuries per Year	Combined Annual Average Casualties
1970-1990	16	19	35
1991-1999	2	17	19
2000-2006	4	18	22

Figure 8 – Tugs/Tows & Barge Vessel Casualties, 1970-2006



Source: U.S. DOT, *Water Transportation Profile*

Regulatory Safeguards

The evolution of marine industry safety followed the growing rates of accidents in the 1970s and 1980s that led to enactment of the International Safety Management code (ISM) and SOLAS convention regulations, but applied only to vessels over 500 gt on international voyage. Domestic regulation did not require that towing vessels comply with the ISM codes. The wake up call came with a tug incident on September 1993: A tug boat hit a rail bridge leading to derailment of an Amtrak Sunset Limited train crossing the bridge, killing 47 passengers and crews. The accident led to a new Safety Management System requirement for the members of the American Waterways Operators (AWO) called the Responsible Carrier Program (RCP) to ensure a minimal level of

navigation equipment. In the late 1990s, the AWO/RCP compliance began, with the compliance program mirroring many aspects of the ISM Code. Major differences have remained in standards relating to risks arising from the firm operating practices – as opposed to industry-wide practices and internal auditing requirements. Changes in the RCP programs are gradually moving RCP to more closely resemble the ISM. Before the recent changes in safety approach in towing industry, the predominant response to accidents was to investigate accidents. Increasingly, a preventive safety management system is adopted that includes internal audits, training, and reporting incidents and observations for vessels or ports.²¹

Another potential safeguard is the implementation of new marine towing and salvage services provided by the nation’s Marine Assistance Towing industry. The industry operates under the regulation of the USCG with properly licensed operators. The USCG is in the process of implementing a new inspection program for towing vessels, which until now were exempt from safety inspection. The industry grew in the 1980s, with the growth in privatization of many segments of maritime vessel response industry. The industry has created the Conference for Professional Operators of Response Towing (C-PORT) as its collective representation. C-PORT provides service to the USCG by adding a non-emergency addendum to the SAR policy known as the Maritime SAR Assistance Policy (MSAP).²² Today the Maritime Assistance industry is comprised of two major networks of TowboatUS/VesselAssist and SeaTow in addition to 40-plus independent operators.²³

Mitigation Measures

The USCG has promulgated laws pursuant to the OPA 1990, as published in 33 CFR 168, for escort for tankers and for specific segments of the waterways such as the Puget Sound. Accordingly, tug escort is required for all laden U.S. and foreign flag single hull tankers in excess of 5,000 gt operating in the U.S. waters. Tug escort is also required for tankers carrying petroleum oils, pursuant to 46 CFR regulations of pollution category I cargoes. Included in this study are the 4,560 tug/towboats covered under the USCG AIS regulations. Tugs/towboats are also required to have documentation for a voyage plan, per USCG regulations.

Finding 4-2. Tugs/tows and barge vessels remain at relatively high risk of grounding, ramming, and allision.

²¹ American Institute of Marine Underwriters, “Vessel Casualty Investigation and Its Role in Improving Safety: Moran Towing Corporation,” May 2007

²² Captain Terry Hill, “A New Era in Commercial Assistance,” *On Scene, the Journal of U.S. Coast Guard Search And Rescue*, Summer 2007.

²³ Mr. David Edwards, USCG, CG-5341, has pointed out that the towing industry has two distinct services offered to commercial vessels and recreational boaters. Mr. Edwards emphasizes that the non-commercial/recreational boating sector should be clearly differentiated from the commercial sector since the two sectors have different exposures, consequences, and regulatory safeguards,

Offshore Service Vessels (OSV) and Mobile Offshore Drilling Units (MODU)

Threat

Offshore vessels are at risk of collisions due to their high exposure to hazards associated with deep sea navigation. Severe weather events, hurricanes, equipment malfunction, and lack of access to adequate safety information pose constant threats to life and property for offshore oil and gas operations.

Exposure

A total of 763 offshore supply vessels (OSV) and mobile offshore drilling units (MODU) vessels for eligible under the AIS implementation requirements (553 OSV and 210 MODU vessels.) These vessels are among the Special Use vessels for which the Coast Guard has inspection responsibility, which also include what the oceanographic research vessels and oil spill response vessel. OSV/MODU vessels have grown at more rapid rates than most other marine vessels. Driving the growth of these vessels has been the growing demand for oil exploration and production capacity in the industrialized world, and the emergence of new industrial markets in Asia and elsewhere. Clarkson Research Service has reported a 36 percent growth rate for the privately-owned US OSV fleet between 2002 and 2007, increasing from 479 vessels in 2002 to 652.²⁴

Vulnerabilities

Several emerging trends in the oil industry have contributed to the rising risks of collision and accidents for these vessels. A study conducted for the United Kingdom Health and Safety Executive (HSE) on the benefits of new navigation and surveillance technologies for managing the risks of offshore vessels found that the proliferation of permanently manned installations with satellite stations, or multiple installations served by a central control and emergency response center, has heightened the risks of accidents at offshore drilling sites.²⁵

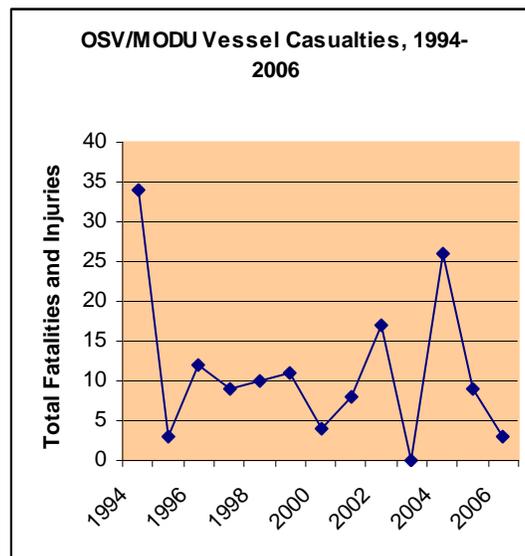
Offshore drilling facilities are vulnerable to the hazards associated with deep sea navigation. As offshore explorations move further out from shore bases, threats from severe weather events, equipment malfunction, and lack of access to adequate safety information also rise. The facilities face high casualties if they fail to anticipate a hurricane, as accurate forecasting of these storms and their expected tracks will prevent severe casualties the platforms. The Louisiana Offshore Oil Port (Loop) installations, for instance, are at risk of current eddies, i.e., powerful and deep localized currents that can damage drill strings deployed below drilling vessels in the Gulf of Mexico since they

²⁴ Clarkson Research Service, www.clarkson.net, reported in MARAD, U.S. Water Transportation Statistical Snapshot, May 2008

²⁵ Anatec UK Limited, "Assessment of the benefits to the offshore industry from new technology and operating practices used in the shipping industry for managing collision risks," prepared for the Health and Safety Executive (HSE), Research Report RR592, 2007

cause disruption in exploratory drilling. LOOP operators use forecasts of tides and currents and PORTS® data on the current eddies to set more efficient drilling schedules. Other offshore vessels sensitive to weather and surface/subsurface ocean conditions include heavy lifts, pipe-laying and pipe-trenching vessels, remotely operated vehicle (ROV) operations, and deep-water pile driving operations. These ROVs are fitted with hydraulic power tools and are used for deep water oil and gas operations for laying pipes are exposed in the water and are highly sensitive to sub-surface currents, current vacillations and wind-wave forces on surface support vessels.

Figure 9 – OSV/MODU Vessel Casualties, 1970-2006



Source: U.S. DOT, *Water Transportation Profile*

Aging vessels also pose a safety problem for the industry. A tally of the vessel age for the 652 privately-owned OSV suggests that 60 percent of the vessels are more than ten years in age, built before 1998, with nearly half of them more than 25 years old.²⁶

Consequences

In the past two decades, there have been significant safety gains in the U.S. offshore oil exploration industry. Casualties from accidents involving OSV, MODU, and platform vessels have declined from an average of 13 fatalities and injuries per year between 1994 and 1999, to an average of 10 fatalities and injuries per year in the past 6 years (Figure 9.)

Regulatory Safeguards

46 CFR, Part 130 on OSV require all OSV to carry up-to-date navigation charts, Coast Guard Light List, Tide and Currents Tables, Local Notice or Notices to Mariners, and Current Tables. In addition, OSVs are required to carry radar and an electronic position fixing device to ensure safe navigation.

²⁶ MARAD data on OSV age profile indicates that 48% of the vessels were built before 1983; 12% between 1983 and 1997; 25% between 1998 and 2002; and 15% after 2002.

Mitigation Measures

The industry is technology-intensive and highly reliant on advanced surveillance and navigation technologies. The LOOP facilities, for instance, rely heavily on data on tides and currents to schedule drilling operations. The ROV equipment operating with long cables and power lines use navigation forecasts to schedule pipe-laying operations to avoid risks to equipment and expensive interruptions of operations.²⁷

The HSE study cited above documented the strong reliance of the offshore drilling industry on real-time tides and currents and electronic navigation charts such as ECDIS and other AtoN. In the straits of Malacca and Singapore, for instance, the study found that ECDIS is capable of linking a shore-based marine information and communications infrastructure with the corresponding navigational and communication facilities onboard transiting ships. The offshore oil and gas industry, the study found, has already achieved significant progress in e-navigation by deploying a navigation system that is built on a network of electronic charts/ECDIS that integrates AIS, real-time tidal and current and meteorological data and surveillance technologies on a platform that covers the entire operating region. By having access to situational data available to vessels in real-time, the emergency response and rescue officials have succeeded in reducing the operational and environmental risks involved in the OSV and MODU vessels.²⁸

A recent report by the Norwegian classification society DNV that has warned about the rising risks of human error due to staffing reductions and crew fatigue on commercial vessels has noted the significant safety gains in the offshore drilling industry and has recommended that the marine industry should “learn more from practices in offshore and aviation industry with intense focus on human and organizational factors for more 25 years.”²⁹

²⁷ Rich Adams, Martin Brown, Charlie Colgan, Nic Flemming, Hauke Kite-Powell, Bruce McCarl, Jim Mjelde, Andy Solow, Tom Teisberg, Rodney Weiher, “The Economics of Sustained Ocean Observations: Benefits and Rationale for Public Funding, A Joint Publication of NOAA, and Office of Naval Research, August 2000.

²⁸ Anatec UK Limited, “Assessment of the benefits to the offshore industry from new technology and operating practices used in the shipping industry for managing collision risks,” prepared for the Health and Safety Executive (HSE), Research Report RR592, 2007.

²⁹ DNV, “Increasing incidence of serious accidents”, Stamford, Connecticut, October 9, 2007.
<http://www.dnv.com/industry/maritime/publicationsanddownloads>

Section 5.0 Vessels Exhibiting Rising Risks of Accidents

Fishing Vessels

Threat

Fishing vessels are at risk of groundings, allisions and collisions, given their size and precarious operating conditions.

Exposure

The population of fishing vessels subject to AIS regulations is 5,520 vessels of ≥ 65 foot in length operating in the U.S. waters. This population encompasses a portion of the fishing vessels subject to the MTSA regulations (3,800 vessels of ≥ 65 feet in length, four of which are SOLAS vessels.)³⁰

Vulnerabilities

The size of fishing vessels, their operating practices, weather conditions, and the competitive pressures that are driving the vessels further out in the ocean represent vulnerability to accidents in this sector.

Consequences

The USCG accident database of vessel-based navigation accidents for the past three decades has shown that accidents and casualties for commercial fishing vessels in all years have been above the average rate for all other vessel types (with the possible exception of recreational boating accidents as discussed separately below.) Between 1970 and 2006, fishing vessel fatalities declined from an average of 61 deaths per year to 17, (as 72 percent decline.) Injuries have not only been high but also on the rise, with the annual average injuries rising from 24 to 30 (an increase of 88 percent.) Both trends – declining fatality rates and rising injury rates – are indicative of the improved efficacy of SAR operations, as discussed in Section 7 (Table 11 and Figure 10.)

Table 11 – Fishing Vessel Accidents, 1970-2006

Analysis Period	Average Fatalities/yr	Average Injuries/yr	Combined Casualties
Average Annual 1970-1990	61	24	85
Average Annual 1991-1999	31	35	66
Average Annual 2000-2006	17	30	47

Source: USCG data reported in BTS, *Water Transportation Profile*

³⁰ Listing of the MTSA population, in a document prepared by the Office of Coast Survey, 2007

Figure 10 – Fishing Vessel Casualties, 1970-2006



Source: U.S. DOT, *Water Transportation Profile*

Regulatory Safeguards

The USCG regulations for carriage of AIS devices apply to 5,500 fishing vessels operating in the U.S. waters.

Mitigation Measures

Fishing vessel operators use electronic chart, GPS, and National Weather Service (NWS) weather and the NOAA and PORTS[®]/tides and currents data to determine the fishing route and location, plan their route in conjunction with electronic tools for locating fish. For example, the commercial product Fish Finder is bundled in a single package with GPS and a chart plotter along with information on tides, currents, shaded depth contours, navigation aids, spot soundings, etc.³¹ User surveys have indicated that the usage rate for electronic charts and tide and current data for the fishing fleets operating in the U.S. waters are relatively low.

Passenger Vessels

Threat

Passenger vessels and cruise ships are at risk of grounding, allisions and collisions, as well as terrorist attacks, given the high-consequence nature of incidents involving loss of life for a large group of passengers.

Exposure

³¹ <http://www.westmarine.com/1/1/12009-a65-gps-chartplotter-fishfinder-system-pack.html>

There are some 3,235 AIS-eligible commercial passenger vessel population of ≥ 65 feet (or those carrying ≥ 50 passengers; or high-speed ferries of > 30 knots in speed) regulated by the USCG AIS requirements. This population is comparable to the MTSAs population of 2,744 commercial passenger and cruise vessels (about 90 of which are SOLAS vessels) when added to it are the 690 domestic passenger ferries that carry passengers within the United States.³² In 2007, 10.3 million passengers departed from the 27 U.S. ports with passenger cruise service.

Regulatory Safeguards

Passenger cruise ships and ferries are governed by a number of national and international regulations regarding the carriage of electronic charts and aids to navigation. International passenger ships on international voyage are required to comply with all relevant IMO regulations, including those for SOLAS and Load Line Conventions. Since 2001, eight IMO Subcommittees have worked on promoting passenger vessel safety and operational efficiency. These subcommittees – Radio communications and Search and Rescue (COMSAR), Ship Design and Equipment, Fire Protection, Safety of Navigation (NAV), Stability, Load Lines, and Standards of Training, Certification, and Watch-keeping for Seafarers (STCW) – are actively promoting the five pillars of passenger ship safety: Prevention, Survivability, Regulatory Flexibility, Operations in areas Remote from SAR Facilities, and Health/Safety/Medical Care.

Passenger vessels are also subject to the International Safety Management (ISM) safety code. The ISM applies to vessels inspected under the 46 CFR Subchapter H, K and T that carry more than 12 passengers on an international voyage. The 33 CFR Part 96 Rules set guidelines for the safe operation of vessels and safety management systems.) Passenger Vessels on a domestic voyage are encouraged to participate in the program. Domestic passenger vessels and ferries are subject to the Voluntary ISM program. The Coast Guard has established an equivalent to the ISM Code for small passenger vessels certificated under subchapter T of Title 46 CFR that must comply with the requirements of the ISM Code. In addition to passenger vessels, the ISM applies to oil and chemical tankers, bulk carriers, gas carriers, and cargo high-speed craft of over 500 gross tons (gt), and other cargo ships and MODU over 500 gt.

Consequences

Passenger vessels have shown rising levels of fatality and injury in the past three decades. The high annual accident rates reflect the growing volume of cruise passenger traffic (i.e., rising exposure.) However, consistent data for normalizing the passenger vessel fatalities and injuries by traffic volume are not available to correct for the rising incidents of vessel casualty.³³

³² Source: MARAD, U.S. *Water Transportation Snapshot*, May 2008.

³³ Mr. David Edwards, USCG, CG-5341 has correctly pointed out that the primary focus of the passenger vessel risks in this report has been on the cruise ships and not the domestic passenger vessel casualties. Mr. Edwards has pointed out that cruise ships have fewer sailings than domestic passenger ships and ferries, and are subject to more demanding international standards (which may be voluntary for domestic passenger ships.) Referring to the available NTSB reports on ferry incidents, Mr. Edwards emphasizes that the high

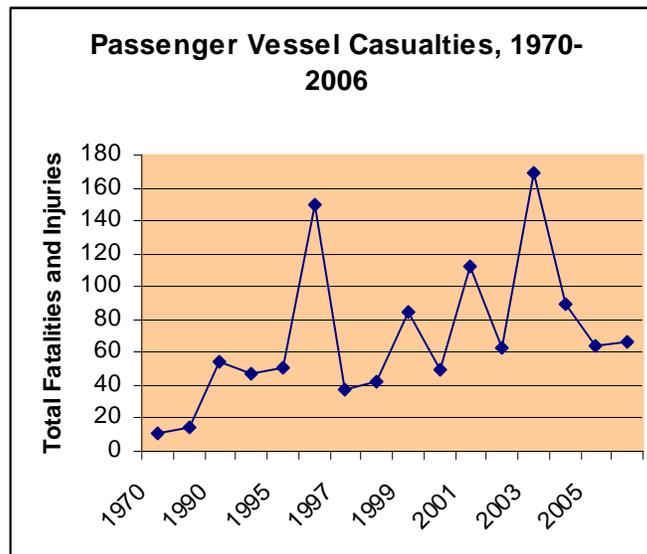
In-vessel passenger fatalities have increased from an average of 3 deaths between 1970 and 1990, to an average of 8 deaths between 2000 and 2006. As a percentage of total water-transportation fatalities for this period, passenger vessel fatalities have grown from 2 percent in the 1970-1990 period to 17 percent of the total in the 2000-2006 period. Injuries from passenger vessel accidents have grown at an even faster rate. While both fatalities and injuries have increased, the share of passenger ship injuries of total water transport injuries has grown faster – perhaps for obvious reasons relating to improved ER and SAR operations that have kept fatalities at a minimum. Passenger injuries have grown from 24 (16% of all water-transportation injuries) in 1970-1990 to 80 (43 percent of the injuries.) Since data for normalizing passenger vessel traffic and exposure measures are not available, the apparent disparity between improved overall safety of water transportation for freight vessels and passenger vessels cannot be explained as a consequence of the differing safety performance of the two sectors. (Table 12, Figure 11.)

Table 12 – Passenger Cruise Ship Casualties

Analysis Period	Average Annual Fatalities	Average Annual Injuries	Combined Casualties/yr
1970-1990	3	24	27
1991-1999	6	63	69
2000-2006	8	80	88

Source: USCG Accident Reports based on BTS, *Water Transportation Profile*.

Figure 11 - Passenger Cruise Vessel Casualties



Source: U.S. DOT, *Water Transportation Profile*

frequency of domestic passenger ship and ferry sailings raises the risk for an incident requiring a mass rescue operation.

Vulnerabilities

Reporting on the factors that contributed to the grounding of the *Royal Majesty* Cruise Line in Nantucket, Massachusetts in 1995, the National Transportation Safety Board (NTSB) determined that the probable cause of the grounding of the *Royal Majesty* was the watch officers' overreliance on the automated features of the integrated bridge system, the ships' failure to ensure that its officers were adequately trained in the automated features of the integrated bridge system and in the implications of this automation for bridge resource management, the deficiencies in the design and implementation of the integrated bridge system and in the procedures for its operation, and the second officer's failure to take corrective action after several cues indicated the vessel was off course. The NTSB report summarized the contributing factors as follows:

- The inadequacy of international training standards for watch standers aboard vessels equipped with electronic navigation systems and integrated bridge systems and the inadequacy of international standards for the design, installation, and testing of integrated bridge systems aboard;
- Overreliance of the watch officers on the accuracy of the GPS position, as they may have believed that because the global positioning system had demonstrated sufficient reliability over three and half years, the traditional practice of using at least two independent sources of position information was not necessary.
- Overreliance of the watch standing officers on the automated electronic chart display system (ECDIS). The report noted that the officers of the watch “for all intents and purposes, [were] sailing the map display instead of using navigation aids or lookout information.”³⁴

Mitigation Measures

In promoting passenger safety principles, the IMO has proposed a number of requisite carriage items for the passenger cruise vessels, chief among them access to state-of-the-art navigation safety equipment. For instance, the IMO Maritime Safety Committee (MSC) has emphasized preventive measures that strongly endorse greater use of storm- and water-level monitoring tools. The revised regulatory framework proposed by the MSC has placed greater emphasis on the “prevention of a casualty from occurring in the first place,” requiring that future passenger ships “be designed for improved survivability so that, in the event of a casualty, persons can stay safely on boards as the ship proceeds safely to port.”³⁵

With respect to potential beneficial impacts of access to real-time water-level information on grounding avoidance, it should be noted that of the 27 U.S. ports with passenger cruise service, 13 ports had access to PORTS[®] data.

³⁴ National Transportation Safety Board, Marine Accident Report on Passenger Ship *Royal Majesty* on Rose and Crown Shoal near Nantucket, MA, on June 10, 1995, BP-97-916401/NTSB March 1997

³⁵ IMO Passenger Ship Regulations, <http://www.imo.org/Safety/>

Recreational Boating

Threats

Grounding, capsizing, allisions, sinking, and collision with other vessel are among the initial events that can lead to vessel fatalities and injuries.

Exposure

There are approximately 12.9 million registered recreational boats and millions more unregistered boats (non-motorized canoes, kayaks, etc.) in the U.S., most of which are small boats of less than 20 feet in length. The growth rate has been from 11.9 million registered boats in 1996 to 12.9 million in 2007.³⁶ Included in this population are over 850,000 “Personal Watercraft.” The USCG has issued separate reports on the accidents involving personal watercraft, defined as boats that are: “craft designed to be operated by a person or persons sitting, standing, or kneeling on the craft rather than within the confines of the hull.” The population of personal watercraft in the U.S. has grown from 92,750 in 1987 to 868,936 in 2007, according to the USCG data obtained from the states, which are the entities which actually register recreational vessels.

Vulnerabilities

Recreational boating accidents arise primarily from human error relating to how boaters operate the boat (i.e., operational miscalculations and human-factor errors). Many grounding accidents are caused by a combination of human error and situational factors. In either case, the first event in the chain of events leading to boating accidents may be operator error (inattention, drowsiness, alcohol use, etc.) or striking a submerged object.³⁷ The boat may strike a submerged object, leading to a chain of events culminating in grounding, collisions, or other incidents.

The USCG analysis of the causes of boating accidents in *Recreational Boating Statistics* indicates that, in 2007, the primary contributing factors to recreational accident had to do with operator error caused by operator inattention, reckless navigation, drowsiness, alcohol use, drug use, excessive speed, lack of vessel light, lack of proper lookout, operator inexperience, restricted vision, rule of the road infraction, and a sharp turn. These operator-related causes, classified as “operation of the vessel,” accounted for nearly two thirds of all boating accidents and injuries. Operator-error causes of recreational boating accidents account for some 80 percent of all navigation accidents. Some of these errors have their roots in what is referred to as the “moral hazard” arising from excessive confidence in the protection afforded by an electronic product.

³⁶ Mr. Richard Schaefer, USCG, CG-5341, has pointed out that a potential exposure issue relates to the fact that the registered boats do not equal the number of boats actually on the water. The number of boats actually on the water could be much less given the current economic climate.

³⁷ Information from HSRP, with data obtained from BoatUS, the USCG Auxiliary, and the US Power Squadron

Consequences

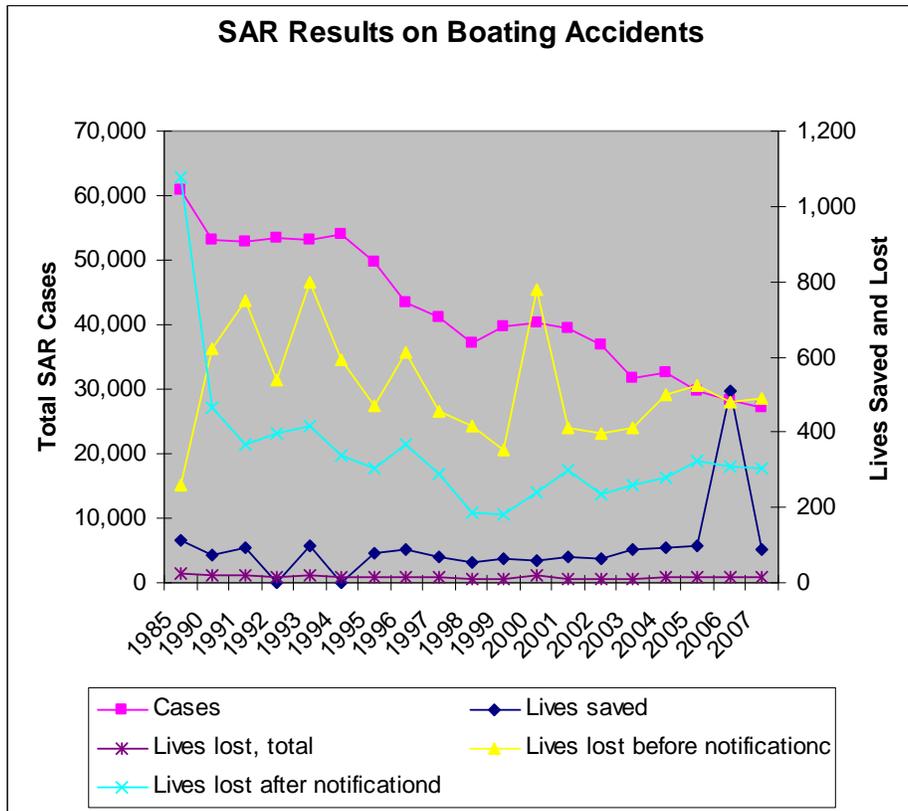
In 2007, the USCG reported 5,191 boating accidents, the consequences of which included 685 deaths, 3,673 injuries, and property damages amounting to \$53 million.³⁸ The casualties have remained at high levels, though average rates of recreational boating accidents have been declining, both in absolute terms and relative to the exposure levels.³⁹ Normalized by the number of boats in the waterways, 1973 has been the peak year for recreational boating fatalities. In 1973, there were 1,754 boating fatalities nationwide, at annual rate of 27.7 per 100,000 numbered boats. By 2004, fatalities had declined to the lowest number on record of 676 (a 61% decline) though the number of boats had more than doubled, to a rate of 5.3 fatalities per 100,000 boats (a 81% reduction.)

Grounding accidents involving recreational boaters have also shown a declining trend. The USCG Recreational Boating *Statistics* annual reports show that between 2003 and 2007, there were 1,373 grounding accidents, resulting in a total of 43 deaths, 946 injuries, and property damages totaling \$17 million, corresponding to an annual average of 275 accidents, 9 deaths, 189 injuries, and \$3.4 million in property damage, with a per-accident average of \$12,360 in damages per year.

³⁸ The USCG statistics are based on the Boating Accident Report (BAR), required to be filed by any operator or owner of a recreational boat involved in an accident in which a person: dies, disappears (presumed dead); or is injured (requiring medial treatment beyond first aid); or there are damages of \$2000 or more; or a complete loss of a vessel.

³⁹ As noted before, the measures of relative or absolute declines in accidents cannot be fully determined because the number of registered boats does not necessarily correspond to the number of boating hours, given the decline in demand for boating during periods of economic downturn, as pointed out by Mr. Richard Schaefer, USCG, CG-5341.

Figure 12 – SAR Results on Boating Accidents⁴⁰



Source: USCG, Boating Accident Report (BAR), 2007, based on the required accident reports filed by any operator or owner of a recreational boat involved in an accident in which a person: dies, disappears (presumed dead); or is injured (requiring medial treatment beyond first aid); or there are damages of \$2000 or more; or a complete loss of a vessel.

Table 13 – Grounding as the First Event in Boating Accidents, 2007

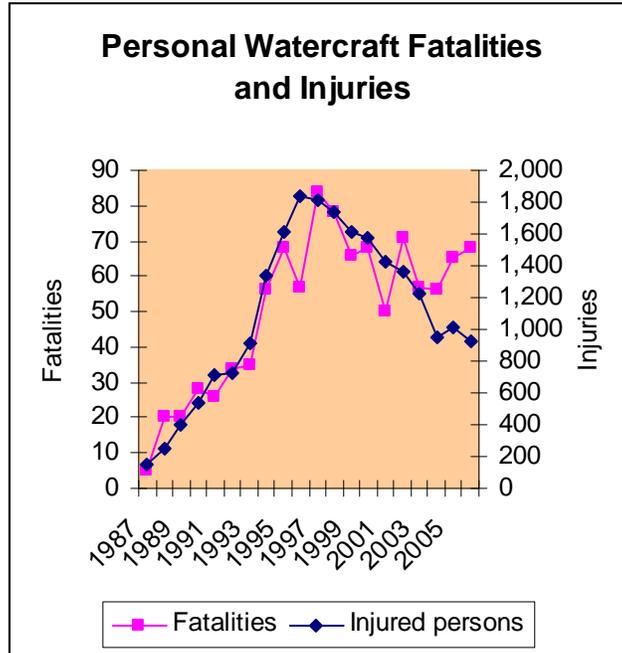
Accident Causes	# of Accidents	Number of Deaths	Number of Injuries	Property Damage	Property Damage per yr/per accident
Grounding Accidents (2003-2007 Annual Average)	275	9	189	\$3,400,000	\$12,360

Source: USCG, *Recreational Boating Statistics 2007*, Table 16, “First Events in Boating Accidents: Information on Number of Accidents, Vessels, Casualties Attributed to their First Event,” p. 32

Many of casualties resulting from recreational boating accidents involve “personal watercraft.” Figure 13 shows the trends in fatalities and injuries involving these small boats. Figure 14 shows the trends in fatality and injuries in all recreational boats.

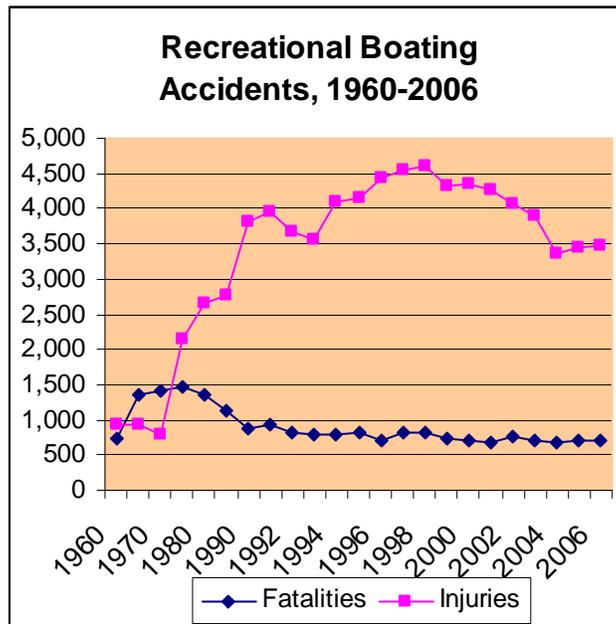
⁴⁰ As noted in previous sections, year-to-year fluctuations and peaks in reported commercial or recreational casualties can signify outlier events the details of which are beyond the scope of this report.

Figure 13 – Personal Watercraft Fatalities and Injuries



Source: Table 2-44 Personal Watercraft. Personal watercraft are craft designed to be operated by a person or persons sitting, standing, or kneeling on the craft rather than within the confines of the hull.

Figure 14 – Recreational Boating Injuries and Fatalities



In addition to operator related factors (that account for about 60 percent of boating accidents), “situational” or “environmental” factors are also significant. In 2007, there were 480 accidents that were caused by environmental factors (accounting for 9 percent

of the 5,191 boating accidents in 2007.) The causes of these environmental accidents are shown in Table 14.⁴¹

Table 14 – Recreational Boating Accident Causes, 2007

Accident Causes	Number of Boating Accidents	Deaths	Injuries
All Causes	5,191	685	3,673
Operator-Related Causes	2,986 (58%)	339 (49%)	2,317 (63%)
Environmental Causes (Addressable by NOS Products)			
Congested waters	107	1	72
Dam/Lock	14	13	12
Force of Wave/Wake	128	1	118
Hazardous Waters	83	11	61
Weather	148	36	70
All Environmental Causes	480 (9%)	62 (9%)	333 (9%)

Source: USCG, *Recreational Boating Statistics 2007*, Table 5, “Primary Contributing Factors of Accidents and Casualties 2007” p. 16.

Accident data show two parallel trends in boating safety. Accident rates have declined in absolute levels and relative to the exposure rates. Exposure, as measured by the number of vessels on the waterways during this period, increased from 11.9 million registered boats in 1996 to 12.9 million in 2007:⁴²

- In absolute terms, there have been 70 fewer fatalities between 1996 and 2007, and 663 fewer injuries. The USCG data show that between 1996 and 2007, a total of 77,431 boating accidents occurred, resulting in a total of 8,682 deaths and 48,462 injuries. Fatalities declined by 9 percent between the two periods (1996-1999 and 2000-2007), from 770 deaths per year to 700 deaths. Injuries declined by 15 percent, from 4,481 per year to 3,817. The average number of accidents also declined by 29 percent, from an average of 8,016 accidents per year to 5,671 accidents.⁴³
- Normalizing the accident data to take into account the growth in the user base demonstrates that while boaters remain a high-risk group for navigational accidents, accidents per registered boaters have declined. The USCG BAR accident statistics show that boating accidents have declined when normalized by the change in the volume of boats on navigable waterways.⁴⁴ Fatalities have declined from 6 deaths

⁴¹ USCG, *Recreational Boating Statistics 2007*, Table 17, p. 33, 5-Year Grounding Summary.

⁴² As previously pointed out by Mr. Richard Schaefer, USCG, CG-5341, the measures of relative or absolute declines in accidents cannot be fully determined because the number of registered boats does not necessarily correspond to the number of boating hours, given the decline in demand for boating during periods of economic downturn.

⁴³ BTS Table 2-45, USCG Search and Rescue Statistics, based on SAR data obtained from Search and Rescue Management Information System (SARMIS) database (for 1985-1993), and the USCG web-based data available on <http://www.uscg.mil/hq/>

⁴⁴ See footnote 42

⁴⁵ Relative to the growth in the number of boaters on the waterways, there has been a 17 percent decline in fatalities and injuries (1 fewer death and 9 fewer injuries for every 100,000 boater).

Mitigation Devices

Access to electronic navigation charts (ENC), GPS, and real-time data on weather/tide & current conditions could be effective in reducing off-shore recreational boater casualties when used properly. However, the number of off-shore recreational boater casualties is significantly less than inland waterway casualties; and the extent to which the products have proven efficacious in off-shore incidents is limited because boaters often do not use the products according to usage standards. The findings of a recent report on recreational boating and the capability of electronic navigation data to reduce boating accidents highlight the contribution of boater error and moral hazard to boating accidents. The report warns that the full scope of the benefits from these electronic devices has not yet been realized because recreational boaters presume that the data they can zoom in and out of are as accurate as the GPS system the users have in their cars. The report points out that ENC data are often only as good as paper charts if they are not updated. In contrast to a commercial shipping vessel which may have a high level of professional awareness of chart limitations, the average recreational boater may not be so knowledgeable.⁴⁶

Preventive measures such as the wearing of Personal Floatation Devices (PFD) have proven effective in reducing casualties (as over two-thirds of fatal accidents are typically due to drowning, and 90 percent of the drowned boaters are not wearing a PFD.)

Use of a cell phone to obtain Tides & Currents data is another mechanism available to off-shore recreational boaters and fishers. Cell phone providers are now offering the option of transmitting tidal prediction data on the subscribers' cell phone with color graphics displayed on the screen, displaying real-time data on high and low tides and storm or weather information. Ekkosoft.us has developed a program called *Salt Water Tides* that accesses data from NOAA servers and uses software based on NOAA algorithms to generate tide prediction graphics for thousands of locations around the United States coast. These applications provide high tide, low tide, sunrise, sunset and moon phases for over 2,300 locations.

⁴⁵ USCG *Recreational Boating Statistics* [1996-2007]

⁴⁶The Hydrographic Services Review Panel (HSRP, "HSRP Most Wanted Hydrographic Services Improvements," the HSRP Federal Advisory Committee Special Report, 2007

Section 6.0 Infrastructure-Vessel Interface Safety Risks

Some aspects of the MTS safety risks arising from the interface between vessel operations and the marine infrastructure have been reviewed in Task 1 Report on MTS Infrastructure Challenges. This section summarizes the findings of that report within the safety risk framework created for this task.

Threats

Infrastructure-vessel interface risks of grounding stem from inadequate channel draft, exposure of bulk port infrastructure to natural catastrophes and hazardous material incidents, and safety hazards from deficient dams and levees, faulty bridges, and overloaded intermodal connectors.

Exposure

The vast expanse of the U.S. coastal, intra-coastal, and inland waterway infrastructure and its deficiencies have been documented in previous reports.

Vulnerabilities

The system vulnerabilities that increase the probability that the threats would be realized are the weaknesses that stem from missing or deficient port access links, structurally defective bridges, poorly maintained locks, dams, and levees, and exposure to events involving hazardous cargo and weather.

Missing or deficient intermodal access links have been identified as more severe at the nation's ports than at other intermodal terminals. The National Highway System (NHS) 2000 Connector Report to Congress found connectors to marine port facilities to have twice the percentage of mileage with pavement deficiencies when compared to other facilities. A National Cooperative Highway Research Program (NCHRP) study based on the NHS report identified 253 connectors to port terminals (ocean and river), comprised of 532 miles of highway connection. The study assessed a total of 660 terminals and 1,222 miles of connectors, and found that the condition of 12 percent of the total pavement (as a percentage of the connector of mileage) was poor or very poor. By terminal type, 15 percent of the intermodal connectors at ocean/river port terminals were deemed poor or very poor.

The growing volume of constrained calls in channels with inadequate depth represent well recognized costs in terms of diminished efficiency and productivity. However vulnerability to safety risks and loss of life from inadequate channel capacity, failing locks and dams, or missing intermodal connections are no less significant. The 2007 Draft CMTS Report to the President stressed the potential threats to navigation safety from light-loading or "lightering."⁴⁷

⁴⁷Draft CMTS Report to the President, dated 11/14/07.

Structurally deficient bridges also represent a significant MTS vulnerability. In 2007, there were 600,000 bridges in the US. According to the National Bridge Inventory (NBI), a database maintained by the FHWA Office of Bridge Technology, 72,264 (12 percent) of these bridges were “structurally deficient,” and another 81,257 (14 percent) were “functionally obsolete.”⁴⁸

Bulk ports are vulnerable to catastrophic incidents caused by weather-related events and accidents triggered by the hazardous nature of the cargo handled. The location of these ports represents a key vulnerability to disruption stemming from their geographic susceptibility to natural disasters. Seven of the top ten U.S. bulk ports as represented by cargo tonnage volume are in the Gulf region. This concentration of dry and wet bulk trade along the coastline from Texas to Florida implies a significant vulnerability to major storms, as demonstrated in the aftermath of Hurricanes Katrina and Rita in 2005. Ports located in Southern Louisiana and in the mouth of the Mississippi are the arterial channel for the Midwest and the central south regions, as well as much of the petrochemical industry.

Lock failure is a significant vulnerability. The design life of an average lock is 50 years. Currently over half of the lock chambers in the U.S. waterway system exceed their design lives. Unavailability of the inland lock and dam system, the associated disruption in navigation due to unscheduled closures and delays, and the potential for loss of life and property damage due to dam failures pose significant threats to the viability of MTS infrastructure. Aging locks, levees, and dams, coupled with lack of funding for maintaining them, and inadequate lock size for accommodating modern vessels are key vulnerabilities that place the viability of the MTS waterway system at risk. Many of the older locks in need of maintenance and repair have not received the needed funding. Degraded lock performance stemming from the gap between the actual and optimal funding levels, has been estimated by the USACE Lakes and Rivers Division (LRD) tools developed to evaluate criteria for lock performance and improving the resiliency of the system. In 2006, LRD drafted a report on the agency’s Uniform Performance Standards used to rate 68 projects and provide a 5-year perspective on the status, needs, and expectations for Ohio River Basin and Great Lakes navigation. The report showed that 50 of the 68 projects were rated below their acceptable level.⁴⁹

Vulnerability to adverse weather and vessel incidents accounts for the majority of the lock downtimes. In 2005, the U.S.-maintained locks at the St. Lawrence Seaway, for instance, reported nearly 40 hours of downtime due to weather-related causes, vessel

⁴⁸ FHWA, National Bridge Inventory, <http://www.fhwa.dot.gov/bridge/>

⁴⁹ Stuart D. Foltz and David T. McKay, *Condition Assessment Aspects of an asset Management Program*, USACE, August 2007, p. 87-88; LRD Project Performance Level. The LRD report included the following information: lock statistics; navigational benefits, funding needs, and network level planning needs; 10-year actual and optimal out-year funding by FY for LRD and by project (FY01-FY11). [e.g. for FY01-06 actual funding = ~ \$150 million; for FY07-FY11 Optimum Funding = ~\$180 million; general and specific performance level rating and minimum acceptable levels for each project: A= no compromise; B= Minimal compromise; C=moderate compromise; D = significant compromise; F = Extreme compromise.

incidents, and other causes. Weather-related causes include poor visibility, ice conditions, and high wind; other causes contributing to lock problems include lock equipment malfunction, civil interference, pilotage, and water level and flow causes.⁵⁰

Inadequate infrastructure capacity and waterway configuration represents vulnerabilities that contribute to vessel accidents. The 1999 MTS Report to Congress noted that MTS safety was threatened by older, poorly placed terminals, cautioning that:

“MTS safety is a continuous consideration in the design and operation of terminals. Factors include terminal placement, age, staffing, and procedures. At oil and chemical terminals cargo transferring presents the greatest risks of spills. Currently, some U.S. commercial marine terminals are too small for ships that call on them and have inadequate mooring arrangements that could cause a breakout from passing large ships in narrow channels. Similar problems abound at older freight terminal which have not kept pace with the increasing demands of recent cargo tonnage throughput or the increasing size of vessels. Safety considerations should be part of the local planning and development of MTS facilities.”⁵¹

The nation’s dams and levees also represent a significant safety risk due to lack of maintenance. According to a recent study by the Urban Land Institute, engineers have identified 3,500 unsafe dams in the U.S., and not enough funding has been available for repairing them.⁵² Lack of adequate funding for levee and dam maintenance has compounded the effect of aging locks and created a backlog of maintenance and repair work, resulting in increasing downtimes and higher risks of a major component failure.⁵³

Consequences

In addition to the adverse consequences of inadequate performance for the MTS locks, dams and levees in terms of loss of life and property due to dam and levee failure, there are also shipping delays and economic costs due to frequent unscheduled facility closure. The rapid growth of lock unavailability and lock closures (with a fourfold increase in scheduled and unscheduled lock downtimes) have been reported to have had significant safety consequence, thus compounding the impacts on business costs and lost productivity.

An Urban Land Institute report has warned against the consequences of failure to repair the dams:

⁵⁰ BTS, <http://www.bts.gov> and <http://www.greatlakes-seaway.com>

⁵¹ U.S. DOT, “*An Assessment of the U.S. Marine Transportation System: A Report to Congress*”, September 1999.

⁵² Urban Land Institute, *Infrastructure 2007: A Global Perspective*, 2007. <http://www.uli.org/AM/>

⁵³ USACE provides maintenance funding out of the General Revenue funds. Funding for lock and dam rehabilitation is provided through Inland Waterway Trust Fund.

“Failures risk significant loss of life and substantial property damage. In the wake of dam construction years ago, many new communities across the country have been developed obviously in downriver flood plains, assuming breaches were not a threat.”⁵⁴

Loss-of-life consequences of bulk port incidents are potentially significant given their geographic distribution, as noted above. The safety consequences of levee failure due to poor maintenance of the federally maintained levee system are also potentially catastrophic. According to a USACE report released in February 2007, there are some 121 levee units – accounting for 6 percent of the 2000 levee units inspected by the Corps – that are in unacceptable condition.⁵⁵ The Urban Land Institute report cited above has the following warning about the failure of the levees damaged in Louisiana in the wake of the 2005 hurricane Katrina:

“...levees built and patched over the past 150 years breached and overflowed. For decades, officials knew that levees had been slowly sinking and realized protective barrier islands and wetlands along the coasts had been destroyed....A patchwork of local levee districts and the Army Corps of Engineers undertook ad hoc repairs, but political initiative was lacking to initiate the expensive steps to shore up the entire flood protection system and fend off potential catastrophe....The price tag for tax payers was too high, but a fraction of the \$110 billion in federal aid committed in the storm’s wake.”⁵⁶

The Urban Land Institute report concludes:

“ A combination of underfunding, unchecked development, and a blind eye to obvious dangers suggests taxpayers face a choice of paying more today or multiples tomorrow for a potential cascade of predictable, tragic Katrinalike outcomes.”

The safety risks and economic costs of inadequate intermodal connections are illustrated by obstructive marine rail bridges, as a recent USCG report has highlighted:

“It has been said that a waterway is no more efficient than the most inefficient and restrictive bridge within the waterway system. A case in point is the CSX Transportation swing bridge across the Mobile River at mile 13.3 near Hurricane, Alabama. This obstructive bridge creates a critical choke point in a large navigable waterway system..... [The bridge] not only curtails the movement of commercial tows to either above or below the drawbridge, but also eliminates a critical equipment and evacuation route for emergency responders. This single restrictive bridge seriously degrades the improvements provided by the locks,

⁵⁴ Urban Land Institute, *Infrastructure 2007: A Global Perspective*, 2007. <http://www.uli.org/AM/>

⁵⁵USACE, New Release, “U.S. Army Corps of Engineers Provides Locations of Unacceptably Maintained Levees,” February 1, 2007.

⁵⁶ Urban Land Institute, *Infrastructure 2007: A Global Perspective*, 2007, p 32.

dams and modern navigation system in the entire regional (Black-Warrior Tombigbee) waterway system.”⁵⁷

Countermeasures

Adoption of advanced navigation, communications, and surveillance technologies for inland waterways and domestic shipping have been rapid and proven effective in mitigating many of the risks. The Nationwide AIS system, and the USACE electronic chart systems (ECS) designed for inland waterways are among these effective countermeasures against vessel grounding. The Carnegie Mellon University SmartLock system, the University of Virginia Lock Upgrade study, and the Oak Ridge National Laboratory (ORNL) user fee study.

The SmartLock system is a technology initiative conducted to identify effective countermeasures for addressing performance of the MTS locks and dam system. The Port of Pittsburgh Commission, in coordination with the Carnegie Mellon University conceived the SmartLock system. Working with towing companies and other stakeholders, the team developed a prototype system based on the same principles used for the air traffic control system. This navigation, networking, and communication system establishes links between the tow and the lock and gives the pilot of the tow greater knowledge as to the position of the tow relative to the lock. This allows the operation of the lock to continue and speeds the locking process during periods of low-visibility and adverse conditions.

⁵⁷ USCG *Proceedings*, Dr. Kamal Elnahal, “Bridges are the Critical Links in Shaping Tomorrow’s Waterways”, Office of Bridge Administration, Summer 2007.

Section 7.0 Managing Safety Risks: Mitigation Measures and System Resiliency

This section reviews the components of *risk management* strategies that logically follow from the risks assessed in the previous sections. In previous reports we defined MTS resiliency as system attributes and safeguards that reduce the probability of a single-point failure, and outlined the principles that involve adaptive problem solving focused on maximizing the hardiness and fault tolerance of the system components, building redundancy, and deploying effective countermeasures. Resiliency engineering has four major components:⁵⁸

- a) System conditions that serve as preventive measures, make the system more fault tolerant, and reduce the totality of the events that “can go wrong”;
- b) Monitoring capabilities with built-in redundant components that mitigate the vulnerabilities;
- c) Response, intervention, mitigation, and recovery capabilities that reduce severity of the consequences of an accident; and
- d) Access to planning and preparedness information and intelligence to make the system adaptive to disruption.

The following sections review the strategies and countermeasures currently being used in various forms in the management of maritime transportation system in the United States and elsewhere, including:

- *Preventive* countermeasures used to reduce the frequency of root causes and build fault tolerance;
- *Monitoring and surveillance* strategies used to avoid potential incidents, build redundancy, and reduce the frequency of immediate causes or triggering events;
- *Response and interventions* that minimize the impact of incidents, mitigate the consequences of adverse events, and help with recovery;
- *Planning and preparedness* strategies with design elements and decision-support tools for creating an adaptive, robust and resilient system that withstands future threats.

These risk management strategies – preventive, monitoring, response and preparedness – are designed to interrupt the causal chain of events at different points of the chain. Together, they are implemented at crucial points in the system with linkages among them

⁵⁸ Discussions of resiliency are loosely based on Erik Hollnagel, David D. Woods, Nancy Leveson, editors, *Resilience Engineering: Concepts and Precepts*, Ashgate, 2006.

to augment system survivability and fault tolerance by preventing incidents and building layers of redundancy. Table 15 outlines the key components of the strategy.

Table 15 – Components of a Survivable and Resilient MTS

Strategy	Risk Mitigation Measures	Technology Components	Resiliency Outcomes
Prevention	<ul style="list-style-type: none"> -Early intervention to decrease frequency of root causes - Changing design components - Built-in redundancy 	<ul style="list-style-type: none"> - Virtual AtoN - ENC/PORTS® - Pilot escorts - Training - Regulatory measures - Vessel inspection - Double-Hull Tankers 	<ul style="list-style-type: none"> - System fault tolerance - Design-based hardiness - Layers of redundancy
Monitoring/ Surveillance	<ul style="list-style-type: none"> -Decrease frequency of incidents - Stop triggering events - Rapid receipt of distress alerts 	<ul style="list-style-type: none"> -VTS -AIS -ARPA -IBS -LRIT 	<ul style="list-style-type: none"> - Domain Awareness - Intervention capability
Response and Intervention	<ul style="list-style-type: none"> - Locate distressed vessels - Contain search area - Mitigate impacts 	<ul style="list-style-type: none"> - SAR vessels - SAR models - SARSAT - GDMSS 	<ul style="list-style-type: none"> - Rapid resumption of operations
Preparedness and Planning	<ul style="list-style-type: none"> - Evaluate accident causes - Plan for Mass Rescue Operations (MRO) 	<ul style="list-style-type: none"> - Near miss databases - Training - Data mining - MRO Drills 	<ul style="list-style-type: none"> - Adaptive decision support - Flexibility

7.1 Countermeasure Focusing on Prevention and Early Intervention

As the risk framework in Section 1.0 formulated, addressing root causes of accidents is a more effective approach to risk reduction than responding to events after they happen. The system has far more near-miss accidents than actual accidents. There are far more triggering incidents that have the potential for causing accidents than there are actual accidents, and far more errors, slips, and failures (immediate cause events) than there are triggering incidents. As the frequency of a single stage of events is reduced, the frequency of the event in the following stages is reduced proportionally. So in general an early intervention in the chain may have more cumulative effect than does a late intervention.

The 1991 *Ports Needs Study* (PNS) has attributed key causes of navigation risk to vessel behavior, requisite proficiency, transit conditions, and availability and proper use of

AtoN.⁵⁹ It notes that vessel behavior is influenced by factors that influence stopping distance (in the context of hydrodynamic forces acting on a ship when moving from deep- into shallow-draft waters or into constricted channels, and with forces such as wind, currents and wave effects in open seas in shallow water conditions the vessel.) The study notes that, unlike aviation, controlled hydrodynamic interaction for waterway management is difficult and waterway separation between vessels is not easily done. Transit consideration are also important factors in navigation safety, noting the nature of marine commerce and vessels, cargo types, length or exposure, and navigation support available both on and off vessel as key safety factors.

Preventive countermeasures are at the core of the USCG safety mission. Of the six non-homeland security mission areas for the USCG Ports and Waterways – SAR, Living Marine Resources, AtoN, Ice Operations, Marine Safety, and Marine Environmental Protection – one has direct preventive applications for MTS safety (AtoN); one has monitoring purposes (Marine Safety); and two have clear response and rescue functions (SAR and Ice Operations.) The USCG defines the purpose of Marine Safety in preventive terms as: “Setting standards and conducting vessel inspections to better ensure the safety of passengers and crew aboard commercial vessels, cruise ships, ferries, and other passenger vessels and partnering with states and boating safety organizations to reduce recreational boating deaths.” The Vessel Traffic Service (VTS) functions of the USCG are included in this mission area (reviewed in section 7-2.) This section reviews the AtoN and other preventive safety countermeasures in place.

AtoN and Local Notice to Mariners (LNM)

The USCG defines Aids to Navigation (AtoN) as “a device or system external to vessels that is designed and operated to enhance the safe and efficient navigation or vessel traffic.”⁶⁰ The USCG AtoN is primarily a lateral system that employs a simple arrangement of colors, shapes, numbers and light characteristics to mark the limits of navigational routes. The purpose of the AtoN system is: “Managing U.S. waterways and providing a safe, efficient and navigable marine transportation system maintaining the extensive system of navigation aids; monitoring marine traffic through vessel traffic service centers.”

The Navigation Center’s (NAVCEN) web site has served as a site for a broad spectrum of mariners to obtain information and tools to aid in navigation. One of those tools, the Local Notice to Mariners (LNM), has been a mainstay on the web site for several years. As reliance on the Internet and associated technologies has advanced, electronic distribution of navigation information, such as the LNM, has become routine.

NAVCEN has responsibility for the Local Notice to Mariners Automation project. The goal is to share information from several disparate (and non-compatible) aids to navigation databases and automate the collection and dissemination of aids to navigation

⁵⁹ *Ports Needs Study (Vessel Traffic Services Benefits)*, Volume I: Study Report, The Volpe National Transportation Systems Center, U.S. DOT, Augusts 1991.

⁶⁰ The International Association of Marine Aids to Navigation and Lighthouse Authorities (IALA) Navigation Guide.

information (e.g., LNM). The integration of the information into the current Aid to Navigation Information System (ATONIS) will put a wealth of data into one functional database.

The integrated ATONIS database is considered by NAVCEN to be an opportunity to facilitate the Coast Guard's transition to the use of electronic navigational charts (ENCs). NOAA's National Ocean Service (NOS) will be able to use the Coast Guard's ATONIS database to update ENCs automatically, thus enabling them to maintain a current portfolio of electronic charts. In turn, the Coast Guard, as well as any mariner using an electronic navigation system will benefit from this up-to-date ENC portfolio.

The USCG Light List (which resides on the USCG National Imagery and Mapping Agency or NIMA server) is another major AtoN database that benefits from close coordination with the NOS navigation data. USCG works with NOAA for collaborative updates on NOAA's internal AtoN databases. The two agencies are working on memoranda of agreement (MOA) to facilitate data sharing and chart update coordination.⁶¹

The USCG has 97,000 Short-Range AtoN such as buoys, lights, and beacons. There are also 11 VTS stations. Integrated AtoN Platform Modernization Program will replace, renovate, and standardize many of the small vessels the USCG uses to establish and maintain the nation's AtoN system. This will improve the viability of the AtoN and will result in a corresponding reduction in risk of collision, allisions, and grounding.

Virtual AtoN is an emerging component of the navigation safety infrastructure, defined as digital symbols represented on vector-based electronic charts indicating navigational hazards and AIS-equipped vessel movements. Structural components of *Virtual AtoN* include:

- Accurate, comprehensive, up-to-date electronic navigation charts;
- Accurate and reliable electronic positioning signals
- Information on a vessel's route, bearing, maneuvering parameters and other status items, in electronic format;
- Transmission of positional and navigational information from ship-to-shore, shore-to-ship and ship-to-ship, using AIS,
- Clear, integrated displays of the above information on board ship and ashore, using ECDIS;
- Information prioritization and alert capacity in risk situations on ship and ashore.

Defined broadly, the existing AtoN devices include an array of navigational tools including: charts, radar, VHF radios, publications, and other navigation tools, pilotage systems, navigation regulations, including the International and Inland Navigation Rules; current licensing and training requirements for mariners; existing navigation management systems; and existing USCG regulatory authority and enforcement practices make a significant contribution to the safety of navigation in U.S. ports and waterways today. These existing tools serve to ensure adequate levels of safety and environmental

⁶¹ USCG website, "Coast Guard Partners with NOAA", NAVCEN, www.

protection for segments of the waterways where the VTS systems are not needed. These preventive countermeasures are central elements of a resilient MTS system, preventing failures to occur in the first place.

In general, the array of navigation tools and AtoN available as accident preventive measures have different effects are navigation risks. Some are good for averting some risks but not others. For instance, radar and ARPA are affective collision avoidance tools in open-water situations, but not for close-quarters meeting situations in narrow channels. Similarly, electronic charts are demonstrated to be effective for grounding avoidance but not as a collision-avoidance mechanism.

USCG Vessel Inspection Programs

Another preventive MTS safety countermeasure is the USCG vessel inspection program. The agency targets vessels based on risk of non compliance, with criteria based on vessel inspection and compliance history, flag state, cargo carried, and other factors. USCG does not currently inspect the following vessels: Towing vessels/tug boats, commercial fishing vessels, and recreational boats. These vessels are regulated through the USCG Voluntary Responsible Carrier Program.

7.2 Monitoring and Surveillance: Vessel Control Countermeasures for Domain Awareness

The USCG Ports and Waterway programs have two interrelated safety and security components. The USCG spends the bulk of its budget on 11 programs, 5 related to homeland security and 6 related to non-homeland security. The five homeland-security-related programs are programs for: Illegal drug interdiction; Undocumented migrant interdiction; Defense Readiness; Foreign Fish Enforcement; and Ports, waterways, and coastal security. The latter program has clear functions as safety countermeasures: "Conducting harbor patrols, vulnerability assessments, intelligence gathering and analysis, and other activities to prevent terrorist attacks and minimize the damage from attacks that occur."

This section reviews to key USCG vessel safety monitoring programs for VTS and AIS.

Vessel Traffic Service (VTS) and Waterway Monitoring and Surveillance

The International Maritime Organization (IMO) has defined VTS as "a service implemented by a competent authority designed to improve safety and efficiency of vessel traffic and to protect the environment. The service should have the capability to interact with the traffic and to respond to traffic situations developing in the VTS area." In its proposed Guidelines for VTS, the IMO defines "competent authority" as "the authority made responsible, in whole or in part, by the government for the safety, including environmental safety, and efficiency of vessel traffic and protection of the environment."

The genesis of the VTS in the U.S. was with the January 18, 1971, collision of the tankers Arizona Standard and Oregon Standard under the Golden Gate Bridge. The incident received nationwide attention and resulted in two significant maritime related safety initiatives - The Bridge to Bridge Radiotelephone Act, Title 33 USC §1201 and The Ports and Waterways Safety Act of 1972 (PAWSA), Title 33 USC §1221. It is from the latter that the Coast Guard draws its authority to construct, maintain and operate VTSs. PWSA also authorizes the Coast Guard to require the carriage of electronic devices necessary for participation in the VTS system. The purpose of the act was to establish good order and predictability on United States waterways by implementing fundamental waterways management practices.

The concept of managing ship movements through a shore-side radar station is generally accepted to have first appeared in the port of Liverpool in 1949. In 1956, the Netherlands established a system of radar stations for the surveillance of traffic at the port of Rotterdam. As VTS evolved and spread in Western Europe, the commercial well being of the port was the stimulus for new or expanded service. This contrasts sharply with the U.S. experience, where the first U.S. Coast Guard VTS was an outgrowth of a 1968 research and development effort in San Francisco Bay called Harbor Advisory Radar. It was, as the name suggests, an advisory activity and participation in the system was voluntary. Because it was voluntary, not all vessels availed themselves of VTS assistance or contributed to the service.

Using PWSA as the authority and the San Francisco Harbor Advisory Radar as the operational model, the Coast Guard began to establish VTSs in critical, congested ports. San Francisco was formally established along with Puget Sound (Seattle) in 1972. Operations in Louisville, KY (only activated during high water in the Ohio River) were started in 1973. Houston-Galveston, Prince William Sound; Berwick Bay (Louisiana) and the St. Mary's River at Sault Ste Marie, MI. New Orleans and New York provided services on a voluntary basis throughout the 1970-80's. These operations were curtailed in 1988 due to budgetary restraints and brought back on-line subsequent to the EXXON VALDEZ disaster, when the Coast Guard was mandated by the Oil Pollution Act of 1990 to make participation mandatory at existing and future VTS systems. In January 1997, the USCG convened a national dialog with maritime and port community stakeholders to identify the needs of waterway users with respect to Vessel Traffic Service (VTS) systems or other means of ensuring the safety of navigation in U.S. ports and waterways.

Figure 14 – The Scope of the U.S. Vessel Traffic Service (VTS)



VTS systems have four distinct capabilities:

1. Monitoring of vessel movements;
2. Identification of vessels at risk of colliding or grounding;
3. Tracking of guiding of vessels at risk; and
4. Intervention if necessary.

The capabilities of the USCG VTS are currently limited to the first three. VTS-collected data are often shared with marine exchanges, but the USCG does not systematically collect them. Dissemination of pre-movement information specifically to facilitate port operators is not done routinely, and the management of vessel traffic is applied sparingly. Specific maneuvering orders are given only in emergency, even though the agency has considerable enabling authority to affect the movement of waterway traffic (Traffic control authority derived from the PWSA 1972 as amended). Intervention in these circumstances resides with the Captain of the Port (COTP), though immediate decisions are made in the Vessel Traffic Center (VTC) and on-board the affected vessel.⁶²

Automatic Identification System (AIS)

The AIS is a shipboard broadcast system operating in the VHF maritime band that acts like a transponder and is capable of handling well over 4,500 reports per minute and updates as often as every two seconds. It uses Self-Organizing Time Division Multiple Access (STDMA) technology to meet this high broadcast rate and ensure reliable ship-to-ship operation. On the shipboard radar display, with overlaid electronic chart data, AIS signals are displayed as a mark for every significant ship within radio range, each as desired with a velocity vector (indicating speed and heading). Each ship "mark" could

⁶² National Research Council, *Minding the Helm: Marine Navigation and Piloting*, 1994.

reflect the actual size of the ship, with position to GPS or differential GPS accuracy. Display information previously available only to modern Vessel Traffic Service operations centers could now be available to every AIS-equipped ship.

Why is the AIS needed?

The USCG Regulatory Plan provides the following *Statement of Need*:

“We do not have a current mechanism in place to capture vessel, crew, passenger, or specific cargo information on vessels less than or equal to 300 gross tons (GT) intending to arrive at or depart from U.S. ports unless they are arriving with certain dangerous cargo (CDC) or are arriving at a port in the 7th Coast Guard District. The lack of NOA information on this large and diverse population of vessels represents a substantial gap in our maritime domain awareness (MDA). We can minimize this gap and enhance MDA by

expanding the applicability of the NOAD regulation beyond vessels greater than 300 GT, cover all foreign commercial vessels, more U.S. commercial vessels, and all U.S. commercial vessels coming from a foreign port; and enhance maritime domain awareness by tracking them (and others) with AIS.”⁶³

AIS- Eligible Vessels

- Self-propelled vessels of 65 feet or more in length, other than passenger and fishing vessels, in commercial service and on an international voyage;
- Passenger vessel of 150 gross tons or more;
- Tankers, regardless of tonnage
- Vessels, other than passenger vessel or tankers, of $\geq 50,000$ GT but less than 50,000 GT;
- Self-propelled vessels of ≥ 65 feet in length, other than fishing vessels and passenger vessels certified to carry less than 151 passengers for hire;
- Towing vessels of ≥ 26 feet in length and more than 600 horsepower, in commercial service
- Passenger vessels certified to carry more than 150 passengers-for-hire.

The USCG is implementing the AIS as part of a shipboard radar display with overlaid electronic chart data, with AIS signals displayed as a mark for every eligible AIS-equipped ship within the radio range. Each “mark” has a velocity vector that indicates the vessel’s speed and heading. Each ship mark could reflect the actual size of the ships, along with an accurate position derived from GPS/DGPS. Officers, by clicking on a ship mark could learn the ship name, course, call-sign, speed, classification, and registration number. Other information to be obtained from AIS includes closest point of approach (CPA), time to closest point of approach (TCPA) and other navigation information. This information is more accurate and timely than information available from an automated radar plotting aid (ARPA). Display information previously available only to modern VTS operations centers are now available to every AIS-equipped ship.⁶⁴

⁶³ Federal Register, October 31, 2005, p. 64172

⁶⁴ USCS web-based information accessed on <http://www.navcen.uscg.gov/ais/AISFAQ.HTM>

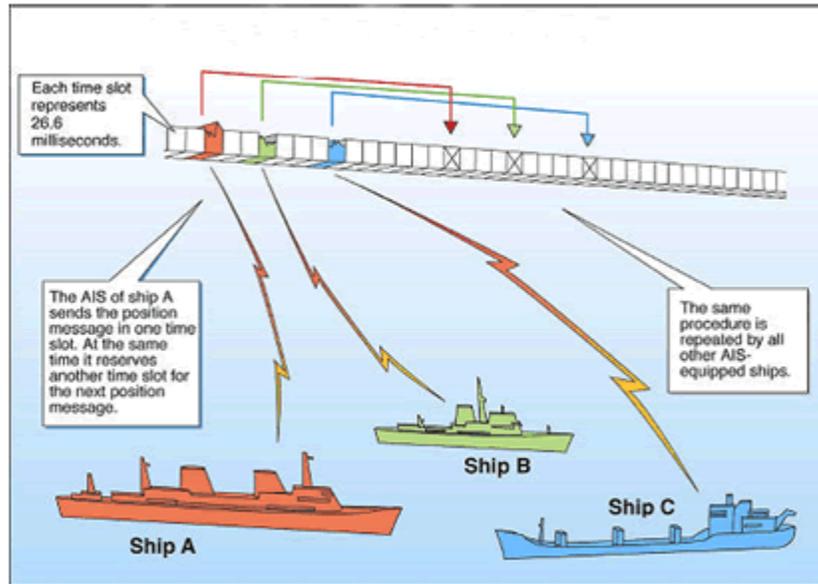
The USCG rulemaking regarding the AIS carriage requirements expands the AIS coverage requirements to all commercial vessels identified in the MTSA 2002, and would include ≥ 65 vessels carrying 50 or more passengers, versus the current 150 or more passengers for hire, high speed for-hire ferries carrying over 12 passenger, vessels towing certain dangerous cargo, and certain dredges. The Federal Register USCG regulatory plan covers approximately 17,400 foreign and domestic vessels covered under the AIS regulations. The USCG estimates that approximately 20,000 vessels greater than 300 gross tons, with foreign vessels comprising nearly 17,000 of this amount, are currently submitting a Notice of Arrival (NOA), a Notice of Departure (NOD), or Notice of Arrival and Departure (NOAD). AIS compliance requirements are expected to a sub segment of these vessels currently required to submit NOAD, as identified in Table 2.⁶⁵

With the available information, the AIS provides the capability to: call any ship over VHF radiotelephone by name, rather than by "ship off my port bow" or some other imprecise means; dial it up directly using GMDSS equipment; or send to the ship, or receive from it, short safety-related email messages.

Each AIS system consists of one VHF transmitter, two VHF STDMA receivers, one VHF DSC receiver, and standard marine electronic communications links to shipboard display and sensor systems (see the AIS Schematic). Position and timing information is normally derived from an integral or external global navigation satellite system (e.g. GPS) receiver, including a medium frequency differential GNSS receiver for precise position in coastal and inland waters. Other information broadcast by the AIS, if available, is electronically obtained from shipboard equipment through standard marine data connections. Heading information and course and speed over ground would normally be provided by all AIS-equipped ships. Other information, such as rate of turn, angle of heel, pitch and roll, and destination and ETA could also be provided.

⁶⁵ Federal Register, Vol. 70, No. 209, October 31, 2005, The Regulatory Plan, 51. Vessel Requirements for Notices of Arrival and Departure, and Carriage of Automatic Identification System (USCG-2005-21869)

Figure 15 – Schematic Depiction of an Automatic Identification System (AIS)



The required ship reporting capacity according to the IMO performance standard amounts to a minimum of 2000 time slots per minute, though the system provides 4500 time slots per minute. The STDMA broadcast mode allows the system to be overloaded by 400 to 500% through sharing of slots, and still provide nearly 100% throughput for ships closer than 8 to 10 NM to each other in a ship to ship mode. In the event of system overload, only targets further away will be subject to drop-out, in order to give preference to nearer targets that are a primary concern to ship operators. In practice, the capacity of the system is nearly unlimited, allowing for a great number of ships to be accommodated at the same time.

The system coverage range is similar to other VHF applications, essentially depending on the height of the antenna. Its propagation is slightly better than that of radar, due to the longer wavelength, so it's possible to "see" around bends and behind islands if the land masses are not too high. A typical value to be expected at sea is nominally 20 nautical miles. With the help of repeater stations, the coverage for both ship and VTS stations can be improved considerably.

Long Range Identification and Tracking (LRIT)

The Long Range Identification and Tracking (LRIT) system is a designated International Maritime Organization (IMO) system designed to collect and disseminate vessel position information received from IMO member States ships that are subject to the International Convention for the Safety of Life at Sea (SOLAS). The United States Coast Guard (USCG) is currently developing a National Data Center (NDC) for the United States, which will be fully operational on December 31st, 2008. In addition, the United States

has committed to build and operate a temporary International Data Exchange in support of the IMO and the international maritime community. LRIT will complement existing classified and unclassified systems to improve Maritime Domain Awareness. The NDC will monitor any IMO member state ships that are 300 gross tons or greater on international voyages and that are either bound for a U.S. port or traveling within 1000 nm of the U.S. coast.

The LRIT system consists of the ship borne LRIT information transmitting equipment, Communications Service Providers (CSPs), Application Service Providers (ASPs), LRIT Data Centers and the LRIT Data Distribution Plan (DDP) and the International LRIT Data Exchange. Certain aspects of the performance of the LRIT system are reviewed or audited by the LRIT Coordinator acting on behalf of the IMO and its Contracting Governments. For more detailed information regarding U.S. LRIT rulemaking, please refer to the LRIT Final Rule.

Real-Time Electronic Navigation Systems

An array of electronic charts and real-time tides and currents data, including the NOAA Electronic Chart Display and Information System (ECDIS) and Physical Oceanographic Real-time Systems (PORTS[®]) is available today to mariners for improved navigation safety and efficient voyage planning.

In the aftermath of the 1989 grounding of the tanker Exxon Valdez in Prince Williams Sound, Alaska, a greater impetus was created for broader ECDIS use. Hearing conducted by the National Transportation Safety Board (NTSB) concluded with the following recommendation:

“Increased federal support should be provided to reinforce industry efforts to develop, test, and install integrated bridge navigation systems on all tankers...One key element which can only be conducted and certified by the federal government is the digitization of navigational charts. This effort must be undertaken in order to accommodate modern computer technology currently available to enhance vessel navigation.”⁶⁶

Interface between AIS and VTS Systems

The VTS system at each port has a Vessel Traffic Center that receives vessel movement data from the AIS, surveillance sensors, other sources, or directly from vessels. Meteorological and hydrographic data is also received at the vessel traffic center and disseminated as needed. A major goal of the PAWSS VTS is to use AIS and other technologies that enable information gathering and dissemination in ways that add no additional operational burden to the mariner.

⁶⁶ “Proposed Findings of Fact, Conclusions and Recommendations Regarding Grounding of the Exxon Valdez,” Exxon Shipping Company to the National Transportation Safety Board, July 17, 1989.

The integrated VTS and AIS signals add value and improve safety and efficiency, without increasing the work load for vessel operators. AIS technology relies upon global navigational positioning systems (GPS), navigation sensors, and digital communication equipment operating according to standardized protocols (AIS transponders) that permit the voiceless exchange of navigation information between vessels and shore-side vessel traffic centers. AIS transponders can broadcast vessel information such as name or call sign, dimensions, type, GPS position, course, speed, and navigation status. This information is continually updated and received by all AIS-equipped vessels in its vicinity. An AIS-based VTS reduces the need for voice interactions, enhances mariners' ability to navigate, improves their situational awareness, and assists them in the performance of their duties thus reducing the risk of collisions. The U.S. Coast Guard has recognized the safety importance of AIS and has led the way on various international fronts for acceptance and adoption of this technology. The Coast Guard permits certain variations of AIS in VTS Prince William Sound and has conducted or participated in extensive operational tests of several Universal AIS (ITU-R M.1371) precursors. The most comprehensive test bed has been on the Lower Mississippi River.

In addition to VTS, AIS will also be eventually integrated with ECDIS or other electronic chart system (ECS) on all AIS compliant ships. Section 410 of the USCG and the 2004 MTSA (P.L. 108-293) directs the USCG to prescribe regulations that will require that “most” commercial vessels: “while operating on the navigable waters of the U.S. be equipped with and operate that this system be integrated with AIS.” Rule-making implementing this additional requirement for integration of ECS into AIS is in the process of being published. Until this rule-making is finalized, AIS is not required to be displayed on an ECS or other external display system, though USCG “highly recommends” this integration: “The full benefits of AIS are only achieved when it is fully integrated and displayed on other shipboard navigation systems” (e.g., ECDIS, ECS, radar/ARPA, tracking devices, personal software, etc.)⁶⁷

Voyage Data Recorder (VDR)

Data recorders in some form have been around for quite some time in the marine industry. They include, but are not limited to, log books, navigation charts, bell or engine order logs, course recorders, hull stress meters, propulsion and auxiliary engine computer logs, vessel traffic service (VTS) systems, Rescue Coordination Center (RCC) radio transmission tapes, and the Automatic Identification System (AIS). A marine voyage data recorder (VDR) centralizes the various measurements taken on board a vessel in one “protective” place from which data can be retrieved at a later date for analysis. Many companies have already taken the initiative of installing VDRs not only to obtain data in the event of an accident or incident, but also to assist in managing their fleets.

⁶⁷ USCG, <http://www.navcen.uscg.gov/ais/AISFAQ.HTM>

7-3 MTS Search and Rescue (SAR) Operations

The second key non-homeland security USCG safety function – in addition to land-side and waterside navigation monitoring and VTS functions – is SAR efforts to rescue vessels in distress and search for missing mariners. This section reviews the USCG SAR operations and the electronic systems available for distress communication.

Supporting the USCG SAR personnel are 6,000 members of the U.S. Power Squadron, and 36,000 charter members of the USCG Auxiliary. The U.S. Power Squadron does not directly support SAR, rather provides training through boating safety classes.⁶⁸

Availability of advanced vessel monitoring, chart display, location, and communications technologies, coupled with the growing skill levels of the USCG SAR officers, has improved navigation safety in two ways. The improved USCG SAR capabilities are demonstrated through several metrics, including the increased the efficacy of the SAR operations – i.e., ability to save more lives and avert fatalities. Greater success of the SAR operations has been demonstrated by the effectiveness of the USCG SAR systems such as Search and Rescue Optimal Planning System (SAROPS) that have improved the probability of success (POS) for Search operations, given their ability to improve their probability of hazard containment (POC) and probability of detection (POD) as measured by the number of lives saved and fatalities averted. Table 16 provides a summary of the measures of effectiveness for the USCG SAR operations.

⁶⁸ Comments of Mr. Richard Schaefer, USCG, CG-5341 and Paul Stocklin, CG-54121.

**Table 16 - Summary Measures of Effectiveness of the USCG Marine SAR Cases
All Users of Navigable Waterways, 1985-2007**

Measures of Effectiveness	Before 1990 (Average Annual Frequencies)	Between 1991-1999 (Average Annual Frequencies)	Between 2000- 2007 (Average Annual Frequencies)
# of Incidents/Cases	57,000	47,000	33,230
# of Incidents Responded to	67,600	60,570	48,120
# of Hours of SAR	108,000	94,700	70,700
# of Lives Saved	5,452	8,040	7,816
# of Lives Lost	1210	870	781
# of Lives Lost before Notification	441	554	500
# of Lives Lost after Notification	770	317	281
Property Losses (\$M)	\$396	\$282	\$157
Property Losses Averted (\$M)	\$1,289	\$2,100	\$118
Lives Saved as a % of Cases	9.6%	13.3%	23.5%
Lives Saved as % of SAR Hours	5.05%	8.5%	11.1%
SAR Hours per Life Saved	20 hours	11.8 hours	9 hours
Number of Commercial and Recreational Vessels	16,261,000	20,480,000	21,503,000
Lives Saved per 100,000 Vessels	33.53	39.26	36.35
Lives Lost per 100,000 Vessels	7.44	4.25	3.63

Source: BTS Table 2-45, based on the USCG Search and Rescue Statistics obtained from Search and Rescue Management Information System (SARMIS) database (for 1985-1993), and the USCG web-based data available on <http://www.uscg.mil/hq/>

The efficacy of the USCG SAR activities is enhanced by the availability of electronic and real-time data. The USCG uses NOS data for targeting high-risk vessels for inspection and for improving SAR operations. Vessels are targeted for inspection based on waterway hazards and vessel risks, with criteria based on vessel inspection and compliance history, flag state, cargo carried, and situational factors. USCG does not currently inspect towing vessels/tug boats, commercial fishing vessels, and recreational boats. These vessels are regulated through the USCG Voluntary Responsible Carrier Program.

Global Maritime Distress Safety System (GMDSS)

The origins of the GMDSS go back to 1979, when the IMO safety experts drafted the International Convention on Maritime Search and Rescue, calling for development of a global search and rescue plan to improve maritime distress and safety communications. This group also passed a resolution calling for development by IMO of a Global Maritime Distress and Safety System (GMDSS) to provide the communication support needed to implement the search and rescue plan. This system, which is being implemented by the world's maritime nations, including the United States, is based on a combination of satellite and terrestrial radio services, and has changed international distress communications from being primarily ship-to-ship based to ship-to-shore (Rescue Coordination Center) based. It spelled the end of Morse code communications

for all but a few users, such as Amateur Radio. The GMDSS regulations apply to all SOLAS vessels, including cargo ships of 300 gross tons and over when traveling on international voyages or in the open sea; and all passenger ships carrying more than twelve passengers when traveling on international voyages or in the open sea.⁶⁹

The IMO has also promulgated the International Ship and Port Facility Security (ISPS) Code, effective since July 1, 2004, to reduce the risks of grounding and spills and for establishing an international framework of cooperation among governments, governmental agencies and the shipping and port industries in order to detect and take preventive measures against security incidents affective ships or port facilities used international trade. The availability of the Global Marine Distress and Safety System (GDMSS) and safety data from the Marine Safety Information (MSI), and the International Maritime Convention for Prevention of Pollution from Ships (MARPOL), and the International Convention for the Control and Management of Ships' Ballast Water have further strengthened the safeguards in support of marine safety.

Here is how the GMDSS works.

The GMDSS provides for automatic distress alerting and locating in cases where a radio operator doesn't have time to send an SOS or MAYDAY call, and, for the first time, requires ships to receive broadcasts of maritime safety information which could prevent a distress from happening in the first place. In 1988, IMO amended the Safety of Life at Sea (SOLAS) Convention, requiring ships subject to it fit GMDSS equipment. Such ships were required to carry NAVTEX and satellite Emergency Position Indicating Radio Beacons (EPIRB) by 1 August 1993, and had to fit all other GMDSS equipment by 1 February 1999. US ships were allowed to fit GMDSS in lieu of Morse telegraphy equipment by the Telecommunications Act of 1996.⁷⁰

The GMDSS replaces the previous ship to ship safety system, which relied on a manual Morse Code system on 500 kHz and voice radiotelephony on Channel 16 and 2182 kHz. The GMDSS is primarily a vessel-to-shore alerting system where Rescue Coordination Centers receive distress alerts from vessels and then coordinate an appropriate rescue response. Vessel-to-vessel distress alerting is also a feature of GMDSS and operates in a

⁶⁹ Commercial vessels under 300 GT or those above 300 GT engaged on domestic voyages only are subject to the requirements of their Flag State.

⁷⁰ Since the invention of radio at the end of the 19th Century, ships at sea have relied on Morse code, invented by Samuel Morse and first used in 1844, for distress and safety telecommunications. The need for ship and coast radio stations to have and use radiotelegraph equipment, and to listen to a common radio frequency for Morse encoded distress calls, was recognized after the sinking of the liner Titanic in the North Atlantic in 1912. The U.S. Congress enacted legislation soon after, requiring U.S. ships to use Morse code radiotelegraph equipment for distress calls. The International Telecommunications Union (ITU), now a United Nations agency, followed suit for ships of all nations. Morse encoded distress calling has saved thousands of lives since its inception almost a century ago, but its use requires skilled radio operators spending many hours listening to the radio distress frequency. Its range on the medium frequency (MF) distress band (500 kHz) is limited, and the amount of traffic Morse signals can carry is also limited.

similar way to the current distress system. The advantages of the GMDSS over the previous system are that the GMDSS:

- Provides worldwide ship to shore alerting, it is not dependent upon passing ships;
- Simplifies radio operations, alerts may be sent by "two simple actions";
- Ensures redundancy of communications, as it requires two *separate systems* for alerting;
- Enables SAR operations to be coordinated from SAR Authority shore centers;
- Minimizes unanticipated emergencies at sea by including maritime safety information (MSI) broadcasts; and
- Eliminates reliance on a single person for communications by requiring at least two licensed GMDSS radio operators and typically two maintenance methods to ensure distress communications capability at all times.

In general, the GMDSS consists of several systems. The system reliably performs the following functions: alerting (including position determination of the unit in distress), search and rescue coordination, locating (homing), maritime safety information broadcasts, general communications, and bridge-to-bridge communications. Specific radio carriage requirements depend upon the ship's area of operation, rather than its tonnage. The system also provides redundant means of distress alerting, and emergency sources of power. The system dictates that the radio communications fitted onboard ships depend on the area of operation of the ship rather than the size. Because the various communication systems used in the GMDSS have different limitations with regard to range and services provided, GMDSS divides the world's oceans into 4 areas. The system is designed to provide an automatic means of transmitting and receiving distress alerts either by using Digital Selective Calling (DSC) via conventional radio or via the Inmarsat satellite system. DSC communication is much faster and has a greater probability of reception than the existing manually operated distress system. GMDSS also provides the capability to send distress alerts and locate signals by using Emergency Position Indicating Radio Beacons (EPIRB) and enabling radars to detect objects by using Search And Rescue radar Transponders (SART).⁷¹

National Distress System

Coast Guard currently operates a National Distress System, a network of about 300 VHF transceivers and antenna high-sites which are remotely controlled by regional communications centers to provide coverage extending out to at least 20 nautical miles from shore, and often much further. Coverage is reasonably continuous through most of the Atlantic, Gulf and Pacific Coasts, the Great Lakes, and many rivers. Many urban areas of the U.S. are also covered. This system serves as the primary means for mariners to contact the Coast Guard in a distress, with over 20,000 distress calls are received yearly over this system. The system also serves as the primary means for broadcasting urgent marine information to mariners, and a command and control system for Coast Guard and other vessels.

⁷¹ Comment of the Mr. Richard Schaefer, CG-5341

Of the 25 largest U.S. cities ranked by population in the 1990 census by the Department of Commerce Census Bureau, 19 cities, i.e. 76%, are close to navigable waters and are within at least partial coverage of the U.S. Coast Guard's VHF National Distress System.

Each National Distress System VHF site consists of a receiver guarding VHF Channel 16, the maritime distress, safety and calling channel, and a transceiver capable of operating on one of six fixed maritime channels. Two of these channels are always Channel 16 and 22A.

The system is not Global Maritime Distress & Safety System-compatible, coverage gaps exist in several locations, it cannot operate on public safety channels, it has no direction finding capability, distress calls cannot be received at a high site when the site is transmitting on any channel, and the system is near the end of its useful life. For these reasons, the Coast Guard began to modernize this system in 2003.

The National Distress System is operated by 45 Coast Guard Sector Group and Section Command Centers, each acting as a Maritime Rescue Coordination Center with a specific area of responsibility.

National Distress and Response System (NDRS) and *Rescue 21*

NDRS has now replaced the NDS. *Rescue 21*, operating as a component of the USCG NDRS, is a new distress communications system designed to improve the USCG ability to detect mayday calls from boaters, pinpoint the location of the source of the call, and coordinate rescue operations. *Rescue 21* is part of USCG advanced command, control, and communications system created to improve the ability to assist mariners in distress. The capabilities include portable radio towers (for disaster response), fully housed communications shelters, satellite backup communications, remotely located watch-stander equipment, and remotely located backroom operating equipment. The system:

- Incorporates direction-finding equipment to improve locating mariners in distress.
- Improves interoperability among federal, state, and local agencies,
- Enhances clarity of distress calls
- Allows simultaneous channel monitoring
- Upgrades the playback and recording features of distress calls
- Reduces coverage gaps for coastal communication and along navigable rivers and waterways
- Supports Digital Selective Calling for registered users
- In the contiguous 48, provides portable towers for restoration of communications during emergencies or natural disasters.

Search and Rescue Satellite Aided Tracking (SARSAT)

The international cooperative system Search and Rescue Satellite Aided Tracking (SARSAT), used in conjunction with the Russian COSPAS, is a NOAA-supported SAR system that relies on signal data from the National Polar-Orbiting Operational

Environmental Satellite System (NPOESS) to operate collaboratively with all federal agencies, the European Union, and 38 nations for monitoring weather and climate change. NPOESS is part of the emerging Global Earth Observation System of Systems (GEOSS) for the development of a global monitoring network for an integrated approach to monitoring climate and environmental events. The SAR successes of the COSPAS-SARSAT have included rescues of over 24,500 people worldwide and 6,025 people in the United States since 1982. NOAA operates SARSAT as an integral part of a worldwide SAR system to detect and locate mariners, aviators, and land-based operators in distress almost anywhere in the world. The SARSAT system uses NOAA satellites in low-earth and geostationary orbits to detect and locate people in distress. The satellites relay distress signals from emergency beacons to a network of ground stations and ultimately to the U.S. Mission Control Center (USMCC) in Suitland, Maryland. The USCG responds to the distress signal and dispatches the appropriate SAR units, pointing them to the location of the distressed individuals.

Harbor Pilots

Approximately 1,200 harbor pilots required to provide vessel escort to certain vessels entering a harbor. State and Federal laws require Coast Guard-licensed harbor pilots to board at sea all ships weighing ≥ 350 gross tons to embark on these vessels and bring them to port.⁷² In addition to access to standard navigational data such as ENC/PORTS[®] for assisting vessels for safe navigation in harbors, harbor pilots strongly rely on the technologies such as AIS and radar, the USCG AtoN, and the Portable Communications, Navigation, and Surveillance (PCNS) system. PCNS is a lightweight, compact unit carried aboard vessels by a pilot for on-site access to real-time navigation information. The primary components of a PCNS are a DGPS receiver with an ENC display and a VHF radio. PCNS-type systems are an indispensable part of port pilots' safety tool kit and can conveniently be integrated with the AIS and other components of a vessel's Integrated Bridge System (IBS).⁷³

Automated Mutual Assistance Vessel Rescue (Amver)

Amver, sponsored by the USCG, is a unique, computer based and voluntary global ship reporting system used worldwide by SAR Authorities to arrange for assistance to persons in distress at sea. With Amver, rescue coordinators can identify participating ships in the

⁷² State pilot services are compulsory escorts, required by state law for all vessels engaged in foreign commerce. State Pilots are commissioned by individual states to represent the public trust. State Pilots also hold a Federal Pilot license. State Pilots require much more training and experience than a Federal Pilot, which can only service vessels engaged in domestic trade. Other state/local users of the NOS products are Docking Masters, who are the employees of tug companies who offer tug assist to ships while docking. To the extent that docking masters are privately employed, (often promoted from tug captain) they do not represent the public.

⁷³ National Research Council, *Minding the Helm*, 1994. The NRC report refers to the capability of PCNS to be used with data links to an Automatic Dependent Surveillance (ADS) before its widespread implementation, emphasizing its advantages over radar. Today, AIS is the version of ADS that in 1994 was being explored as a significant mechanism for navigation safety and collision avoidance.

area of distress and divert the best-suited ship or ships to rescue.⁷⁴ Between 1958, when Amver began, and 2008, the number of average daily plots (i.e., the average number of vessels that actively participated in the Amver system for the year) increased to 3,421. During the same period, the maximum vessels on plot (i.e., the higher number of vessels that were on plot for any given day for the year) grew to 3,688.⁷⁵

Cellular Phone Blue Force Tracking (CBFT)

The USCG is taking advantage of cell phone technology to increase situational awareness with the Cellular Phone Blue Force Tracking (CBFT). The CBFT technology gives the USCG the ability to track assets every few minutes, using cell phones with an embedded GPS transceiver that transmits the position of an asset (e.g., small boats, boarding team, inspection teams or other assets) within cell phone range to the Common Operation Picture (COP) at the Sector District Area and the HQ Command Centers. The asset's name/number, type, position, time, course, and speed-over-ground are sent encrypted to the appropriate command center COP. This near-real-time position information can dramatically improve an operational command's situational awareness. CBFT allows continuous tracking of cutters, aircraft, boats and personnel throughout the area of responsibility. This provides valuable information during a SAR case. The USCG is making this technology available to port partners and first responders. Implementation of the necessary data exchange agreements with these agencies will allow their asset position information to include the USCG COP, helping the Command Centers to better allocate resources when responding to SAR calls.⁷⁶

SAR Transponder (SART), Direction Finder (DF) and Other Detection Means for Search Aircraft

Legacy aircraft have long used the DF-301F and NS-4 Direction Finder (DF) and homing system to locate the source of distress. A change in technology now provides the means to receive Emergency Position Indicating Radio Beacon (EPIRB) with GPS-based position signals in the aircraft. The new DF-430 system funded by the USCG Deepwater program allows USCG aircraft to receive EPIRB with GPS position or to home on the 406 MHz signal itself provide a line of bearing directly to the location of the active beacon. The advantage of having this DF capability is the range it offers: the higher you operate the DF antennas, the more range of detection and area coverage you can achieve. The USCG SAR aircraft are equipped with Search Radar. The radar allows the crew to navigate through rough weather and terrain obstacles and locate downed aircraft or mariners in distress. USCG is upgrading its radar capability through a new technology called the Active Electronically Scanned Array (AESA) similar to Joint Strike Fighter (JSF) technology. The radar can provide surveillance and detection capability regardless of day or night and in all weather conditions.

⁷⁴ Benjamin Strong, "Around the World with Amver", On Scene, Summer, 2007 or <http://www.amer.com>

⁷⁵ <http://www.amver.com/statistics.asp>

⁷⁶ "Cellular Technology Aids in Situational Awareness," On Scene, The Journal of the U.S. Coast Guard SAR, Summer 2007.

One of the active modes of the new system allows the radar to detect a Search and Rescue Transponder (SART). The SOLAS Convention requires SARTs to be carried onboard certain class of commercial and passenger transport vessels. These vessels are required to have two SARTs, one on each side of the vessel that can be removed and taken aboard the life boats or survivor rafts. A SART works on the 9GHz frequency range and when activated by a radar pulse it transmits a response signal that is displayed on the x-band radars in the form of 12 dashes and dots. SART signals provide the radar operator with a line of bearing to the beacon and distressed mariners. This enables an aircraft to transit and search a broad area, locate the SART, and provide a SAR response. In addition to SART, radar's basic search capability allows it to detect and locate vessels, debris and other objects. At night, visual searches over water become harder and riskier for air crews. The USCG air crews are using night vision devices (NVD) and electro-optical/Infrared (EO/IR) sensors. The EO/IR sensors are used with new technology to provide higher definition daytime color imagery and night time infra-red and loc-light amplified images. AIS is being added to USCG aircraft to allow the air crew to see and monitor all commercial shipping in an area within line of sight of the aircraft.

7- 4 Safety Information Systems and Databases

The USCG primary performance measure for marine safety is the 5-year average number of deaths and injuries of recreational boaters, marines, and passengers. The external data source for this performance measure is the Boating Accident Reporting Database (BARD) that relies on data collected and entered by the states and is managed by the USCG. In 1986, USCG began developing requirements for replacing its legacy Marine Safety Information System (MSIS) by 1995. In the early 1990s, the decision for replacement was delayed in order to integrate requirements for multiple systems into one system development effort called MISLE. In 1995, USCG awarded a contract to Computer Sciences Corp to develop and deliver a complete MISLE system by 2002, at a cost estimated at up to \$35 million. The contract was partially terminated in 1999 and transferred to a government owned Operations System Center.

The USCG cutters and SAR vessels use advanced communications, location, display, and detection technologies and software, the key components of which are NOS chart and T&C data, as described by the USCG Navigation Center:

“A key component of [the cutters and boats] is the “fuel” they use. This “fuel” is the electronic database from which the chart display is derived. Coupled with radio-navigation input from LORAN, GPS, DGPS, electronic chart systems significantly improve safety of navigation. In simple terms, it is much safer to know where you are right now (electronic navigation: one person evaluating an electronic chart – and little chance of human error), than where you were 3 minutes ago (traditional paper chart navigation using a large navigation team.)”⁷⁷

Ports and Waterways Safety System (PAWSS)

⁷⁷ USCG Navigation Center, “CG Partnering with NOAA”, <http://www.uscg.gov/enav>

The Coast Guard has a statutory responsibility under the Ports and Waterways Safety Act of 1972 (PWSA), Title 33 USC §1221 to ensure the safety and environmental protection of U.S. ports and waterways. The PWSA authorizes the Coast Guard to "...establish, operate and maintain vessel traffic services in ports and waterways subject to congestion."

PWSA also authorizes the Coast Guard to require the carriage of electronic devices necessary for participation in the VTS system. The purpose of the act was to establish good order and predictability on United States waterways by implementing fundamental waterways management practices. In September 1996, the U.S. Congress directed the Coast Guard to begin an analysis of future VTS system requirements to identify minimum user requirements for new VTS systems in consultation with local officials. Congress specifically directed the Coast Guard to revisit the VTS program and focus on user involvement, meeting minimum safety needs, using affordable systems, using off-the-shelf technology, and exploring public-private partnership opportunities. The Coast Guard's PAWSS project was established to meet these goals.

The PAWSS Vessel Traffic Service (VTS) project is a major acquisition project to build new VTS where necessary and replace existing systems. PAWSS is also a process that reaches out to port stakeholders to comprehensively assess safety and identify needed corrective actions. The PAWSS VTS project is designed as a national transportation system that collects, processes, and disseminates information on the marine operating environment and maritime vessel traffic in major U.S. ports and waterways. The PAWSS VTS mission is monitoring and assessing vessel movements within a Vessel Traffic Service Area, exchanging information regarding vessel movements with vessel and shore-based personnel, and providing advisories to vessel masters. Other Coast Guard missions are supported through the exchange of information with appropriate Coast Guard units.

Search and Rescue Optimal Planning System (SAROPS)

The Search and Rescue Optimal Planning System (SAROPS) is one of the systems relying heavily on NOS data. SAROPS, an ArcGIS desktop application for search planning, has been operational at over 50 USCG command centers since January 2007. Similar but superior to other USCG SAR software systems, SAROPS maximizes the probability of the search success by helping determine the vessel's probable location, and providing an optimal search plan. SAROPS uses the information displayed on ENC charts as the basis for determining optimal search areas and locating and rescuing the distressed vessels or mariners in a timely fashion.⁷⁸

SAROPS, as a new search-planning and drift modeling system, replaces two older programs – Joint Automated Work Station (JAWS) and Computer-Assisted Search Planning (CASP) – previously used by the USCG to find distressed mariners. Each

⁷⁸ Robert Netsch, "Search and Rescue Optimal Planning System (SAROPS), Command and Control Engineering Center, Portsmouth, VA, undated presentation, circa April 2008
http://gis.esri.com/library/userconf/feduc08/papers/esri_feduc_presentation_2008.pdf

USCG Rescue Sub Center (RSC) has SAROPS drift model that relies on situational data to contain and locate search targets. The SAR Search Theory algorithms, based on the available data and resource scarcity determines the “available effort” for the SAR operation. A search will be successful only if two conditions are satisfied: the search object is within the search area and it is detected. The probability of success (POS) for SAR is equal to the product of probability of containment (POC) and probability of detection (POD.) The search can maximize the POS by computing the POC and POD for every possible level of coverage permitted by the available resources. Resources available for reducing the risks of navigation have included an array electronic and real-time data.⁷⁹ The efficacy of the USCG SAR activities is enhanced by the availability of electronic and real-time data.

Mass Rescue Operations (MRO)

The need for Mass Rescue Operations (MRO) for major marine distress, aviation crashes and national disasters has become increasingly evident with the growing size of vessels and concentration of population and commercial activities in small areas. The IMO defines an MRO as an operation that involves the need for immediate assistance to large numbers of people in distress such that capabilities normally available to SAR authorities are inadequate. The USCG R&D Center in Groton, Connecticut, has monitored rescue events that have overwhelmed current USCG capabilities, and has built a strong business case for promoting the application of technology, implementation of policy, and/or alteration of procedures in MRO.⁸⁰ To assess the risks in the context of the USCG capabilities, the R&D Center launched a thorough scoping study aimed at identifying the mass rescue situations that will likely be encountered. The R&D Center convened a panel of experts in a MRO Scoping Effort Workshop held in Alexandria, Virginia, in September 2006. The workshop participants developed “Scenarios Risk Ranking” to identify the parameters. The participants worked on the following MRO Scenarios:

- A1 A large vessel sinks, and passengers and crew must be evacuated;
- A2 An oil rig sinks and the crew must be rescued;
- B1 A major casualty occurs aboard a cruise ship that requires evacuation
- B2 A major casualty occurs aboard a domestic passenger ferry that requires evacuation
- C An airplane crashes, requiring air, land, and water rescue;
- D A natural disaster occurs requiring air, land, and water rescue.

The values in the following matrix shows the “risk ranking” used in the MRO Scenario Workshop, with risk defined as the product of the frequency of event and the consequences (Table 17.)

⁷⁹ National Search and Rescue School, “ Search Theory for Controllers,” U.S. Coast Guard Training Center, 30 April 2003

⁸⁰ “Mass Rescue Operations: Closing the Gap” Mario B. Teixeira, LTJG, USCG SAR Journal, On Scene, Summer 2007.

Table 17 – Matrix of Values for MRO Scenario Planning

Event Frequency	Consequences (Fatalities Not Avoided)		
	Low (50-100)	Med (150-1,500)	High (>1,500)
High	7	10	10
Medium	4	8	10
Low	2	5	9
Very Low	1	3	6

The following assumptions apply to the Risk Probabilities:

Low risk numbers mean the scenario for evacuation is either less likely to occur; or the consequence was lower, or a combination of the two.

High risk numbers mean the scenario for evacuation is either more likely to occur, or the consequence is higher, or a combination of the two.

The following assumptions apply to Rescue Capabilities:

High USCG capability ranking means lower likelihood of performing an effective rescue;

Low USCG capability ranking means higher likelihood of an effective rescue mission.

The risk rankings were presented in the following matrix in Table 18.

Table 18 – Risk Rankings for MRO Scenarios

Risk Index	10		D							
	9		D					A1		
	8		D	B1		B2	B2			
	7									
	6									
	5					C				
	4		A2	A2	A2					
	3		A2	A2	A2					
	2		A2	A2	A2					
	1									
		1	2	3	4	5	6	7	8	9
Probability of Failure of Rescue Operations										

The findings included the following:

- Risks located in the top right-hand corners of the table are risks categorized as “unacceptable;” these are the risks that, as the workshop characterized “would need to be terminated, transferred, or treated.”
- Risks in the lower left-hand side of the table are the risks considered “acceptable” because they do not happen often, their consequence is not as great, or the USCG already has a high likelihood of rescue (or a combination of the three.)

The workshop participants concluded that scenario the USCG would most likely be called upon to respond, involving a magnitude of people that would overwhelm the agency’s current capabilities, is a large vessel sinking (A1), requiring rescue and evacuation of passengers and crew. Other scenarios of concern, based on the relative ranking tool used, were a domestic passenger vessel requiring evacuation (B2), a natural disaster requiring air, land, and sea rescue (D), and a major casualty aboard a cruise ship, requiring the evacuation and rescue of the passengers and crew.

7-5 Emerging Constraints, Priorities, and Risk Mitigation Countermeasures

To conclude, the safety of the U.S. marine transportation system has improved significantly in the past three decades. However four key obstacles remain relating to crewing levels, operator error, lack of reliable data for preventive and adaptive risk management, and the role of technology-assisted collisions and groundings.

Recommendation 1: Address Crew Fatigue and Adequate Crewing Levels in Commercial Vessels

Studies have indicated that human error is responsible for the majority of navigation accidents. However, human error is often not the real cause of accidents, but the symptom of other failures in managing a vessel's navigation. A recent report by DNV, the Norwegian classification society, has stated that 95% of human errors associated with marine accidents are caused by lack of knowledge, skill, instruction, or motivation. The report warns about a recent turn in accident trends. It points to some underlying failures that in recent years have led to an increasing incidence of serious accidents in several shipping segments compared to early 2000. The 20007200072007 DNV report cautions that the "accident numbers are going in the wrong direction" despite improved inspection, auditing, and standards of technical excellence and transparency. It warns that there is more stress and fatigues relating to the people and organizations both on board and on shore, to keep up with the growth in commercial shipping, partly because:

"...the general level of experience on board vessels has been reduced. There are more new recruits, less retention and faster promotion....The workload onboard with respect to paperwork and inspections has increased while the crew size is stable. [At the same time] the loss of experience is also a stress factor for those on board who continuously have to train new crew members."⁸¹

The DNV article recommends more focus on the crew on board and the management on shore to get the crew involved in safety programs. It stresses the need for the management to demonstrate more commitment to safety, and learn more from practices in offshore and aviation industries. Aviation and the offshore drilling (OSV/MODU) industries in the past 25 years, according to the report, have demonstrated intense focus on human and organizational factors with impressive results in reducing accident risks.⁸²

Recommendation 2 – Establish a Near-Miss Reporting System

Improving the quality of accident data and establishing a system for reporting near misses would be a positive step towards providing insight into actual and potential causes of accidents. Data on near-miss marine accidents, unusual events (e.g., loss of propulsion, steering, failure and near-miss that do not qualify as reportable), fires, including fires ashore detected through VTS surveillance systems) and other incidents of interest would provide valuable insight into root causes of accidents.⁸³ The near-miss data could be used through software systems for automated tracking of the incidents. These data could be either integrated with VTS computer-based operating systems or for planning and computerized risk assessment purposes. The reporting system would allow development of an Exposure Database to facilitate risk identification. The Risk Assessment programs

⁸¹ Safety at Sea International, "Manpower strains linked to accidents", <http://www.safetyatsea.net/>

⁸² DNV, "Increasing incidence of serious accidents", Stamford, Connecticut, October 9, 2007. <http://www.dnv.com/industry/maritime/publicationsanddownloads>

⁸³ Based on the National Research Council, *Minding the Helm*

that would draw on information on near-misses exposure data would result in improved marine traffic safety and help in setting national priorities.

Recommendation 3 - Develop a Better Understanding of Operator Error and Training Needs

Human factor issues pose an increasing threat to MTS safety. The complexity of forces influencing safe navigation has been noted by studies conducted to identify navigation risks. Accident data from the Marine Safety Information Management System (MSIS) database for 1996-2000 attributed the following causes to marine accidents, with over two thirds attributed to human factors:⁸⁴

- Equipment/mechanical failure: 21.2%
- Human factor: 67.3%
- Hazardous navigation: 0.5%
- Weather: 11.1%

Collision accidents, similar to grounding, are often caused by human error. A U.K. Marine Accident Investigation Branch (MAIB) study has shown that many of the root causes of collision accidents stem from operator error.⁸⁵ The study showed that key causes of collision accidents are poor bridge management resulting from inadequate crew skill and knowledge:

- Unaware of other vessel just before or at collision: 13%
- Poor or no lookout: 23%
- Infractions of Collision Regulations (COLREGS): 8%
- VHF communications confused: 9%
- Insufficient assessment of the situation: 24%
- Fatigue: 8%
- Poor bridge management: 4%
- Pilot/Master communications breakdown: 1%
- Officer of the Watch (OOW) fell asleep: 3%
- One man bridge operation: 7%

Human factor includes misunderstanding or ignoring hazard warnings, operating in adverse conditions without adequate monitoring, and navigation error. However, in complex waterway systems, the immediate and triggering causes of accidents are often different from the root causes. The propensity of vessels to get involved in an accident or incident may stem from diverse roots causes such as the inherent risks of the cargo or facility operations, mechanical failure, chart flaws, or vessel scheduling and shipping practices that ignore safe navigation principles.⁸⁶ Part of the problem is that most causal analysis of accidents is based on the “symptoms” rather than “underlying causes” of

⁸⁴ Based on BTS data in National Transportation Statistics, Table 4-1.

⁸⁵ Marine Accident Investigation Branch (MAIB), “Bridge Watchkeeping Safety Study,” July 2004.

⁸⁶ Based on John R. Harrald and Martha Grabowski, “Risk Mitigation in Passenger Vessel Operations,” Originally appeared in Disaster Recovery Journal (Vol. 7. No. 3, circa 2003).

navigation risk. As a report by National Research Council (NRC) on navigational risks has pointed out, the underlying causes of marine vessel accidents are complex and not systematically addressed:

“Underlying causes of marine accidents have not been addressed methodically or effectively by most shipping companies, marine safety authorities, or other interested parties. Furthermore, the available marine safety data are not adequate to support this objective. No public agency in the U.S. is systematically monitoring to detect problem ships, inadequate operating and management practices, and substandard crews. Some proprietary monitoring is conducted, but these data are usually not available. When accidents occur, pilotage is frequently an early target from blame. The overall result is that risk management in the marine operating environment depends to a great extent on perceptions of risk and personal judgment. Thus symptoms of problems rather than underlying causes are often treated.”⁸⁷

Recommendation 4 – Develop a Better Understanding of Technology-Assisted Collisions

Radar assisted collisions, GPS assisted collisions, and ECDIS-assisted collisions have for sometime been recognized as a paradoxical outcome of the availability of electronic AtoN. The 1991 Port Needs Study first pointed out this problem by noting that the role of AtoN in navigation safety is uncertain and that sometime AtoNs have been known to increase the risks. The report noted that radar is widely indicated for reducing stranding and collisions, but that in numerous cases “radar assisted” collisions have occurred because mariners focused too much attention on the radar picture or incorrectly interpreted radar information. The PNS pointed out that while technology advances can ameliorate some marine risks they can also introduce new ones.

More recently, the possibility of a radar-assisted collision has been investigated by the U.K. MAIB. The collision occurred in June 2004 between a UK-flagged Yyudais Dominion and the Hong Kong flagged Sky Hope in the Pacific Ocean. AIS, which was originally linked to improved navigation security and safety, is being investigated as a contributing factor to the accident. The reason is that only vessels of ≥ 300 gt are required to carry AIS, and smaller boats and fishing vessels are not covered. As a result, AIS alone will never give full awareness of all the vessels in the vicinity. The collision was possibly caused by excessive reliance on the AIS signals displayed on the ship bridge.

An issue closely related to the level of technology penetration is that analysis of data trends over several decades is associated with errors that have been introduced due to changes in ship building practices and navigation technologies. The performance of a

⁸⁷ National Research Council (NRC), *Minding the Helm: Marine Navigation and Piloting*, Committee on Advances in Navigation and Piloting, Marine Board, Commission on Engineering and Technical Systems, 1994

new navigation system is not routinely monitored through systematic data analysis. Major safety studies are generally derived from analysis of casualty data that are weak and faulty. Furthermore, there is no accepted method for normalizing data to accommodate vast difference among ports and waterway systems so that comparative safety performance can be assessed. Nor is there is any systematic performance monitoring program to aid in a systemic examination of the risk variables identified.

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ACRONYMS

AAPA	American Association of Port Authorities
AASHTO	American Association of State Highway and Transportation Officials
AIS	Automatic Identification System
Amver	Automated Mutual Assistance Vessel Rescue
ANS	Aquatic Nuisance Species
BAP	Bridge Administration Program
BARD	Boating Accident Reporting Database
CBFT	Cellular Phone Blue Force Tracking
CMTS	Committee on the Maritime Transportation System
DF	Direction Finder
DHS	Department of Homeland Security
DOE	Department of Energy
DSC	Digital Selective Calling
DWT	Deadweight Tonnage
EEZ	Exclusive Economic Zone
EPIRB	Emergency Position Indicating Radio Beacons
EPA	Environmental Protection Agency
ERDC	Engineering Research and Development Center
GMDSS	Global Maritime Distress and Safety System
GEOSS	Global Earth Observation System of Systems
GPS	Global Positioning System
IALA	International Association of Lighthouse Authorities
IAT	Integrated Action Team
IBS	Integrated Bridge System
ICMTS	Interagency Committee for the Maritime Transportation System
IRCS	Inland River Container Services
ISPS	International Ship and Port Facility Security
IWR	Institute for Water Resources
LOOP	Louisiana Offshore Oil Port
LRIT	Long Range Identification and Tracking
MARAD	Maritime Administration
MARPOL	International Convention for the Prevention of Pollution from Ships
MDA	Maritime Domain Awareness
MSIS	Marine Safety Information System
MISLEMISLE	Marine Information for Safety and Law Enforcement System
MRO	Mass Rescue Operations
MSI	Maritime Safety Information
MTS	Maritime Transportation System
MTSA	Maritime Transportation Security Act of 2002
MTSNAC	MTS National Advisory Council
NDNS	National Dredging Needs Study
NDRS	National Distress and Response System

NHS	National Highway System
NOAA	National Oceanic and Atmospheric Administration
NOS	National Ocean Service (NOAA)
NPOESS	National Polar-Orbiting Operational Environmental Satellite System
NRC	National Research Council
OOW	Officer of the Watch
OSV	Offshore Supply Vessel
PANY/NJ	Port Authority New York/New Jersey
PAWSA	Port and Waterway Safety Assessment
PAWSS	Port and Waterway Safety System
PCNS	Portable Communications, Navigation, and Surveillance
PFD	Personal Floatation Device
POC	Probability of Containment
POD	Probability of Detection
POS	Probability of Success
PWSA	Ports and Waterways Safety Act
RITA	Research and Innovative Technology Administration
RFID	Radio Frequency Identification
SARSAT	Search and Rescue Satellite Aided Tracking
SAROPS	Search and Rescue Optimal Planning System
SART	Search and Rescue Transponder
SOW	Scope of Work
SSS	Short Sea Shipping
STDMA	Self-organizing Time Division Multiple Access
TEU	Twenty Foot Equivalent Unit
TRB	Transportation Research Board
ULCC	Ultra Large Crude Carriers Carrier
USACE	United States Army Corps of Engineers
USCG	United States Coast Guard
USDA	United States Department of Agriculture
USDOD	United States Department of Defense
USDOT	United States Department of Transportation
VDR	Voyage Data Recorder
VLCC	Very Large Crude Carriers Carrier
VTS	Vessel Traffic Service
WRDA	Water Resources Development Act
WSCS	Waterborne Commerce Statistics Center
WCUS	Waterborne Commerce of the United States



Appendix E

Assessment of the Marine Transportation System (MTS) Challenges

Task 5: MTS Security Challenges

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Preface

This Draft report is Task 5 deliverable for the Volpe Center Reimbursable Agreement (RA) VH-99 with the United States Army Corps of Engineers (USACE). The report has been prepared by Dr. Bahar Barami, the Volpe Center project manager, to provide support to the Committee on Marine Transportation System (CMTS) in its mission to conduct an assessment of the Maritime Transportation System (MTS) challenges. The report has been revised to reflect the comments and inputs received from the project sponsors and members of the Needs Assessment Integrated Action Team (IAT), including the comments received from Richard Lolich, MARAD, and the following U.S. Coast Guard (USCG) officers: CDR Paul M. “Bo” Stocklin, CG-541; Anthony Regalbuto, Eric Chapman, Wayne Young, Captain Mike Mohn, and Alan Peek (with special thanks to Mr. Peek for editing and enhancing several sections of the report). At the Volpe Center, Rod Cook, Chief, Intermodal Infrastructure Security and Operations Division, provided peer-review and quality control input.

Introduction

This MTS Needs Assessment report is the fifth of six task reports for addressing the MTS infrastructure capacity challenges, economic and productivity issues, environmental concerns, safety and national security risks, and funding and institutional issues. Task 1 examined the MTS physical infrastructure and conducted an assessment of the baseline MTS characteristics within a risk and reliability assessment framework. It analyzed the present and projected threats to the continued performance of the infrastructure, and identified system vulnerabilities and potential countermeasures for enhancing system resiliency.

Task 2 Report built on the risk and resiliency analysis framework developed in Task 1 and conducted an analysis of the economic impacts and risks of MTS. Within this framework, the study estimated the magnitude of the global economic impacts of a disruption in system operations, identified the vulnerabilities relating to the dependence of the nation's trade system on MTS, and assessed system resiliency with respect to the flexibility of the MTS-dependent supply chains, users and vessel operators.

Task 3 Report addressed the environmental challenges arising from systemic risks and vulnerabilities inherent in MTS, including the threats to the Nation's environmental stewardship mission and the associated challenges of meeting the performance demands of a global transportation network. The report focused on the environmental and safety risks arising from the marine vessel engine emissions, oil spills and hazardous cargo incidents, contaminated dredged materials, and invasive non-indigenous species introduced by ballast water. Task 3 also identified measures for preventing pollution and addressed issues relating to sustainable environmental practices, the resilience of the marine ecology, and the ability of MTS to return to normal conditions after an environmental disaster.

Task 4 addressed the MTS safety challenges within the risk and resiliency framework created and used in other three task reports. The report identified the threats, vulnerabilities and exposure levels that contribute to vessel and navigational risks, evaluated the trends in marine accidents and safety threats, the adequacy of the existing safeguards, and the factors that enhance system resiliency.

Task 5 will address the MTS challenges arising from the implementation of the maritime security governance model and its impacts on MTS operations and opportunities for enhance MTS security and efficiency. Among the issues addressed will be the added burden on the shippers, vessel operators, and the small trading partners from maritime domain awareness activities, maritime security regime requirements and activities, and maritime security and response activities. The report will also identify the mission of the 15 Strategic Ports, provide a summary of the Maritime Transportation Security Act (MTSA) provisions and identify the components of a resilient transportation system,

including redundant security systems and backup provisions that would serve as a buffer against catastrophic disruptions in the MTS.

The approach of Task 5 to the assessment of the MTS security risk is different from that adopted for Tasks 1 through 4 in one key respect. The report does not specifically identify the MTS vulnerabilities and security breach consequences; instead, the report builds on the mission statements and objectives of the National Strategy for Maritime Security to identify and address:

- a) MTS security guidance and core concepts (Section 1.0);
- b) Maritime security governance activities (Section 2.0);
- c) Vessel and port security programs in the U.S. (Section 3.0);
- d) Costs and economic impacts of compliance with the MTSA security mandates (Section 4.0);
- e) Security and efficiency impacts of the existing countermeasures on the MTS resiliency (Section 5.0); and
- f) Progress, lessons learned, and implementation challenges (Section 6.0).

Section 1.0 MTS Security Guidance and Core Concepts

This section provides an overview of the MTS' strategic environment; the national-level strategies, directives, policy, and legislation that drive the approach to maritime security; and core concepts to maritime security. Also included is a discussion of international standards, the International Ship and Port Facility Security (ISPS) Code and a number of international security and safety stakeholders. This section concludes with a discussion of core concepts related to maritime security.

1.1 Strategic Environment

Ports are vulnerable to security threats and terrorist attacks the consequences of which can be highly disruptive and potentially catastrophic. Ports are open and accessible urban facilities interwoven with a complex transportation network close to crowded metropolitan areas, an accessibility that makes ports vulnerable to a variety of threat to the vessels and cargo containers. The vulnerabilities and attack consequences are also high because ports are a transfer point for high-value cargo vessels and adjacent to vulnerable facilities such as passenger cruise terminals, oil terminals and military bases that could be prominent targets of attack. The risks present at these facilities are therefore uniquely challenging.

The international maritime domain can be characterized as one of the least governed regions left on earth. Many millions of square miles of ocean are a global commons under no nation's jurisdiction. Unlike national land and air space, with clearly defined borders, much of the ocean is only lightly governed and its maritime borders are generally less restricted and are freely accessible to transit without the mechanisms for detection and investigation. Activity within the maritime domain can be described as the continuous intermingling of thousands of commercial deep draft vessels – vessels of dissimilar types and flags, bound for various distinct destinations, and carrying cargoes for all sorts of international customers who lack direct links to vessels or their flag states – with millions of recreational boats, domestic commercial fishing fleets, research vessels, and workboats.

The U.S. exercises certain sovereign rights over 3.4 million square miles of this ocean territory in the U.S. MTS and this strategy recognizes four unique regions. Foremost within the MTS are the coastal port areas along the 95,000 miles of shoreline and more than 300 ports of entry, from the largest mega-port to the small fishing harbors and marinas. The MTS also includes a system of interconnected inland rivers and the intra-coastal waterways (ICW) consisting of 12,000 miles of navigable water connecting inland metropolitan areas, industrial complexes, and the agricultural heartland of the country. Similar to the closed linear river system are the 2,300 miles of Great Lakes waters and 1500 miles of international shoreline, which connects the industrial north and

northern population centers through the St. Lawrence Seaway System to the Atlantic Ocean.

Both the inland rivers and Great Lakes waterways systems share limited entrance and exits, directional transits, well known and well-defined control points that are unique to these portions of the MTS and share only limited characteristics to the coastal ports area. Lastly, the nation's Exclusive Economic Zone (EEZ), and in particular, the highly industrialized Gulf of Mexico contains over 4,000 offshore structures spread over 169,000 square miles of ocean ranging from single pile production wells, to massive floating offshore drilling and production facilities' exploiting the oil beneath the outer continental shelf (OCS) and producing 25 percent of the nation's petroleum.

Contained within this MTS are 25,000 miles of navigable channels, 238 locks at 192 locations, over 3,700 marine terminals connected by over 174,000 miles of rail, 45,000 miles of interstate highway, supported by 115,000 miles of other roadways and 1,400 designated intermodal connections. The MTS helps our economy to grow, strengthens our national defense, and provides a higher standard percent of all overseas trade.¹ Therefore, the viability of the maritime domain and the U.S. MTS is vital to the nation's prosperity and security.

1.2 National-level Guidance to MTS Security

Requirements for aspects of MTS security are driven and/or influenced by a myriad of national-level strategies and plans including but not limited to: the National Strategy for Homeland Security; National Strategy to Enhance International Supply Chain Security; National Response Framework (NRF); National Infrastructure Protection Plan (NIPP); and National Maritime Transportation Security Plan (NMTSP). MTS security is also driven and/or influenced by a collection of National Security Presidential Directives (NSPDs) and Homeland Security Presidential Directives (HSPDs) including but not limited to:

- NSPD-41/HSPD-13; Maritime Security Policy. NSPD-41/HSPD-13 drove the creation of the National Strategy for Maritime Security (NSMS) and attending sub-plans:
 - National Plan to Achieve Maritime Domain Awareness,
 - Global Maritime Intelligence Integration Plan,
 - Maritime Operational Threat Response Plan,
 - International Outreach and Coordination Strategy,
 - Maritime Infrastructure Recovery Plan,
 - Maritime Transportation System Security Recommendations,
 - Maritime Commerce Security Plan,
 - Domestic Outreach Plan

¹ Passage based on Combating Maritime Terrorism (CMT) Performance Plan, suggested by the USCG reviewers.

- NSPD-46/HSPD-15; the War on Terrorism,
- HSPD-5; Management of Domestic Incidents (National Response Framework),
- HSPD-7; Critical Infrastructure Identification, Prioritization, and Protection,
- HSPD-8; National Preparedness,
- NSPD-5; Review of Intelligence,
- NSPD-9; Defeating the Terrorist Threat to the United States, and
- NSPD-17/HSPD-4; National Strategy to Combat Weapons of Mass Destruction (WMD).

Among the legislation enacted by Congress, are two landmark legislations: the Maritime Transportation and Security Act (MTSA) and the Security and Accountability for Every Port (SAFE Port) Act.

Maritime Transportation Security Act (MTSA)

The Maritime Transportation Security Act (MTSA) was enacted in November 2002, as Public Law 107-295, 116 Stat, 2060 (2002). The MTSA amends the Merchant Marine Act of 1936, enacted to “establish a program of greater security to the United States seaports, and for other purposes.” The Congress, in enacting the MTSA, noted the pivotal role of ports in the economy of the U.S., the difficulties inherent in attempting to secure the Nation’s ports and intermodal transportation system, the vulnerabilities of that system to acts of terrorism, and diverse types of federal crimes that are committed in the port environment.²

Title 33 Code of Federal Regulation (CFR) Navigation and Navigable Waters, Subchapter H – Maritime Security under MTSA is designed, in part, to help protect the Nation’s ports and waterways from terrorist attacks through a wide range of improvements, including requirements for a security plan developed and implemented for 33 CFR Part 104 regulated vessels and Part 105 facilities (such as cargo terminals, factories and power plants, certain individual cargo and passenger vessels, and entire ports.) The primary goal of such plans is to address potential vulnerabilities that could be exploited to harm people, cause environmental damage, or disrupt transportation systems and the economy, by developing measures to mitigate these vulnerabilities. Some of the key features of the MTSA are:

- Requirements to conduct port, facility, and vessel vulnerability assessments;
- Preparation by the Secretary of Transportation of a National Maritime Transportation Security Plan;
- Preparation of a port wide security plan, called an Area Maritime Security Plan (AMSP), by the USCG local Captain of the Port (COTP)³ serving in the capacity as the Federal Maritime Security Coordinator (FMSC) and an Area Maritime Security

² “Maritime Transportation Security Act of 2002: Section 109 Implementation: A Report to Congress,” Prepared by the United States Merchant Marine Academy for the Maritime Administration, May 2003.

³ The Captain of the Port (COTP) is a USCG officer who provides direction to the USCG law enforcement activities within the general proximity of the port in which assigned. Captains of the Port s enforce port safety and security and marine environmental protection within their respective areas. Currently there are 45 Captains of the Port nationwide.

Committee (AMSC) of federal, state, and local agencies, maritime industry, and port stakeholders;

- Development of security plans for required waterfront facilities and commercial vessels;
- The issuance and use of Transportation Worker Identification Credential (TWIC) cards for personnel whose responsibilities require them to access secure spaces aboard ships;
- Establishment of a permanent program of grants to facilitate the enhancement of maritime security, such as the Port Security Grant Program (PSGP);
- Assessment by the Secretary of Homeland Security⁴ of the effectiveness of antiterrorism measures at foreign ports;
- Establishment of an enhanced system of foreign seafarer identification;
- Creation of Maritime Security Advisory Committees at national and port-level Area Maritime Security Committee (AMSC);
- Installation and operation of Automatic Identification Systems (AIS) aboard certain commercial vessels;
- Establishment of a program to better secure international intermodal transportation systems, to include cargo screening, tracking, physical security, compliance monitoring, and related issues;
- Provision for COTP control and compliance measures as well as civil penalty provisions for violation of statutes or regulations;
- Extension of seaward jurisdiction of the Espionage Act of 1917 to 12 nautical miles offshore of the territorial sea baseline;
- Codification of the U.S. Coast Guard Sea Marshal program and consideration of utilizing merchant mariners and other personnel to assist the Coast Guard;
- Requirements that shipment data be provided electronically to U.S. Customs prior to arrival or departure of cargo;
- Reporting by the Secretary of Transportation to Congress on foreign-flag vessels calling at United States ports; and
- Development of standards and curriculum for maritime security professional training

The SAFE Port Act

In October 2006, Congress enacted the Security and Accountability for Every Port Act (SAFE Port Act, Public Law No. 109-347, 120 Stat. 1884, 2006). The Act made a number of adjustments to existing MTSA programs and created additional programs and initiatives. Among the provisions of the SAFE Port Act are:

- Codified the Container Security Initiative (CSI) and the Customs-Trade Partnership Against Terrorism (C-TPAT);
- Established the Domestic Nuclear Detection Office (DNDO) with responsibility for conducting research, development, testing and evaluation of radiation detection equipment;
- Established Interagency Operation Centers where agencies organize to fit the security needs of the port area at selected ports;
- Set an implementation schedule and fee restrictions for TWIC;
- Required that all containers entering high-volume U.S. ports be scanned for radiation sources by December 31, 2007;

⁴ Originally the Secretary of Transportation. Upon the CG's transfer to DHS, the Secretary of Homeland Security assumed this responsibility. (By Anthony Regalbuto)

- Required that additional data be made available to CBP for the Automated Targeting System (ATS) for targeting cargo containers for inspection; and
- Required that Area Maritime Security Plans include a salvage response plan to ensure efficient and quick reestablishment of flow of commerce following a maritime transportation security incident.
- Required periodic reassessments of the effectiveness of anti-terrorism measures in foreign ports.

1.3 International-level Guidance to MTS Security

The International Maritime Organization (IMO), the organization responsible for regulating international shipping with 167 governments as members, has developed international standards for port and vessel security.

The International Ship and Port Facility Security (ISPS) Code

On December 2002, the (IMO) adopted the International Ship and Port Facility Security (ISPS) Code, an international agreement that called for port security plans to be in place by July 1, 2004. The ISPS Code contains the following requirements for a Ship Security Plan:

“The Ship Security Plan should indicate the operational and physical security measures the ship itself should take to ensure it always operates at security level 1. The plan should also indicate the additional, or intensified, security measures the ship itself can take to move to and operate at security level 2 when instructed to do so. Furthermore, the plan should indicate the possible preparatory actions the ship could take to allow prompt response to instructions that may be issued to the ship at security level 3.⁵”

Ships will have to carry an International Ship Security Certificate indicating that they comply with the requirements of SOLAS chapter XI-2 and part A of the ISPS Code. When a ship is at a port or is proceeding to a port of Contracting Government, the Contracting Government has the right, under the provisions of regulation XI-2/9, to exercise various control and compliance measures with respect to that ship. The ship is subject to Port State Control inspections but such inspections will not normally extend to examination of the Ship Security Plan itself except in specific circumstances.”

⁵ Security level 3 is defined as “exceptional”, the level applying for the period of time when there is the probable or imminent risk of a security incident. Security level 3 means the level for which further specific protective security measures shall be maintained for a limited period of time when a security incident is probable or imminent, although it may not be possible to identify the specific target. In contrast, Security level 1 is defined as “normal”, i.e., the level for which minimum appropriate protective security measures shall be maintained at all times. Security level 2 is defined as “heightened”, i.e. the level for which appropriate additional protective security measures shall be maintained for a period of time as a result of heightened risk of a security incident.

The ISPS Code contains the following requirement for conducting a Port Facility Security Assessment:

“Each Contracting Government has to ensure completion of a Port Facility Security Assessment for each port facility within its territory that serves ships engaged on international voyages. The Port Facility Security Assessment is fundamentally a risk analysis of all aspects of a port facility's operation in order to determine which parts of it are more susceptible, and/or more likely, to be the subject of attack. Security risk is seen a function of the threat of an attack coupled with the vulnerability of the target and the consequences of an attack.

On completion of the analysis, it will be possible to produce an overall assessment of the level of risk. The Port Facility Security Assessment will help determine which port facilities are required to appoint a Port Facility Security Officer and prepare a Port Facility Security Plan. This plan should indicate the operational and physical security measures the port facility should take to ensure that it always operates at security level 1. The plan should also indicate the additional, or intensified, security measures the port facility can take to move to and operate at security level 2 when instructed to do so. It should also indicate the possible preparatory actions the port facility could take to allow prompt response to the instructions that may be issued at security level 3.”

ISPS-designated authorities – the USCG in the U.S. – set security levels at a country's ports, review vessel and facility security-plans and implement the plans that meet the ISPS Code and the flag state security standards.

The impacts of the 2002 ISPS resolutions and requirements for development of a Security Plan directly impact MTS. Resolutions 6 through 9, for instance, pertain to the early implementation of special measures to enhance maritime security, establish appropriate measures to enhance the security of ships, port facilities, mobile offshore drilling units on location and fixed and floating platforms, and enhance security through cooperation with the International Labor Organization and the World Customs Organization. ISPS Resolution 10 on the Early Implementation of Long-Range Ships' Identification and Tracking has also significant impacts on MTS operations and security by promoting broader implementation of a global AIS capability. Resolution 10 maintains that: “Long-range identification and tracking of ships at sea is a measure that fully contributes to the enhancement of the maritime and coastal States security and notes that Inmarsat-C polling is currently an appropriate system for long-range identification and tracking of ships. It urges Governments to take, as a matter of high priority, any action needed at national level to give effect to implementing and beginning the long-range identification and tracking of ships, and invites Contracting Governments to encourage ships entitled to fly the flag of their State to take the necessary measures so that they are prepared to respond automatically to Inmarsat-C polling or to other available systems. It also requests Governments to consider all aspects related to the introduction of long-range identification and tracking of ships, including its potential for misuse as an aid to ship targeting and the need for confidentiality in respect of the information so gathered.”

International Security and Safety Stakeholders

The European Union (EU) has also initiated several security measures, including measures to strengthen security of vessels and ports, following the 2004 terrorist attacks in Madrid and the 2005 attacks in London. The measures include proposed requirements for port security assessments and plans, designation of a port security officer responsible for coordinating security measures, regulations on supply chain security, and an amendment to the EU Customs Codes that establishes an Authorized Economic Operator (AEO) program similar to the “trusted accounts” for the U.S. C-TPAT program. An AEO is considered a private company that complies with the EU Customs’ security requirements. The program would require that the company file cargo data in advance of cargo arrival in exchange for benefits in the form of expedited treatment of the shipment.⁶

Asia Pacific Economic Cooperation (APEC), another international agency with maritime mission, is an intergovernmental economic forum comprising 21 member economies in the Asia Pacific rim. The forum aims to promote trade liberalization and business facilitation in participating nations. Given that some 21 of the world’s 30 top container seaports are in APEC economies, the world trading nations consider it vital both from an economic and national security standpoint that the integrity of the goods in the containers remain intact throughout the supply chain. APEC works to facilitate maritime security by encouraging public-private security partnerships and through its ISPS Implementation Assistance Program. In May 2002, APEC’s Ministers of Transportation, at a meeting in Lima, Peru, issued a Ministerial Directive recommending that APEC demonstrate the effectiveness of advanced information and communication technologies and facilitate the development of intelligent transportation system (ITS) standards that enhance interoperability among APEC economies. In October 2002, the APEC heads of governments issued their Statement of Fighting Terrorism and Promoting Growth, reflecting the leaders’ commitment to prevent terrorist attacks on targets that move global trade. One of APEC’s technology deployment pilots for testing the performance of container security safeguards is the Smart and Secure Tradelanes (SST) initiative carried out in selected APEC supply chains. The goal of the industry-driven initiative was to accelerate the voluntary implementation of container security practices to test new tracking technologies to reduce supply chain vulnerability to terrorism. (SST program and findings of pilot tests are described in Section 3.0)

Other international safety and security stakeholders include the International Maritime Bureau, a division of the International Chamber of Commerce that works to suppress piracy around the world. The Bureau has a Piracy Reporting Center that broadcasts a daily bulletin of piracy attacks directly to ships at sea, and reports on piracy incidents to law enforcement authorities.

The Baltic and International Maritime Council (BIMCO) is another international security stakeholder representing over 65 percent of the world’s tanker fleet. BIMCO coordinates with international organizations, governments, and members to improve port and ship

⁶ Lyndon B. Johnson School of Public Affairs, “*Port and Supply Chain Security Initiatives in the United States and Abroad*,” The University of Texas at Austin, Policy Research Project Report, 2006.

security, address piracy and stowaway problems, and ensure an adequate supply of well-trained seafarers.

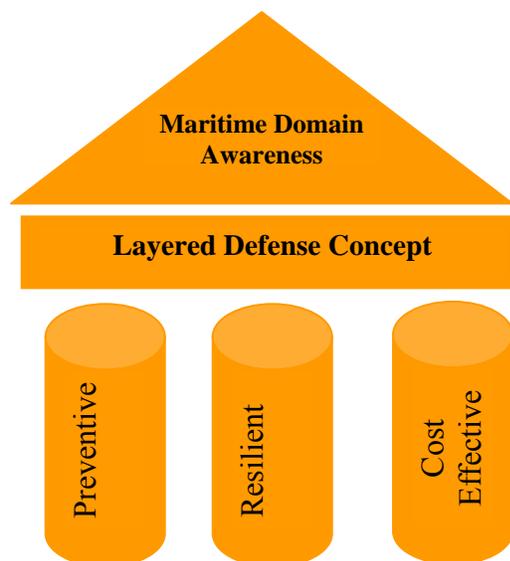
Intertanko, an association of independent tanker owners and operators, is another international stakeholder with an interest in tanker security. Intertanko maintains a database that reports on security conditions at port-of-call throughout the world. Lloyd's Market Association is another maritime trade association that provides research support for Lloyd's insurance underwriters. It lists areas endangered by war, strikes, terrorism, and related perils, areas where underwriters can charge higher premiums for vessels.

1.4 Core Concepts

Maritime Domain Awareness (MDA) as the Overarching MTS Security Concept

The security of the MTS is intrinsically linked with the security of the maritime domain. The MTS depends on networks of critical infrastructure, both physical networks and cyber networks of the interlinked computer systems. The MTS CIKRs share components and interfaces with many other critical infrastructures, most notably the nation's IT and communications systems, dams, energy sources, intermodal highway and rail links and bridges, and ER services. Because of this high degree of interdependence between the MTS and other CIKRs, information sharing and interagency collaboration are of critical importance for any risk assessment or decisions to prioritize deployment of security countermeasures. Pivotal to any information collection, analysis, and dissemination is overarching concept of maritime domain awareness (MDA.)

As envisioned in this report, MDA serves as an overarching concept connecting several core notions of MTS: an interdependent *system of systems* built on *layers of defense-in-depth* with strategies to harden the infrastructure, share critical information to detect, deter, and prevent threats, ensure system resiliency after a disruption, and use resources on cost-effective countermeasures.



At the core of the 2005 *National Strategy for Maritime Security* (NSMS) is the recognition that MDA is the overarching concept for maritime safety, security, and economic viability. The NSMS has defined MDA as the “effective understanding of anything associated with the global maritime domain that could impact the security, safety, economy or environment of the U.S.” It points out that the information and knowledge generated by the nation’s MDA capability enables the U.S. Coast Guard (USCG) and other maritime decision makers to determine the appropriate response to maritime safety and security threats.

MDA is broken down into four component activities: collection, fusion, analysis, and dissemination. First, data on cargo, vessels and regulatory activities are collected. Then they are fused and analyzed to provide situation awareness and reveal anomalies and patterns. Resulting intelligence is then made available through a variety of channels. For each of the 18 Critical Infrastructure/Key Resources (CIKRs) sectors, a Sector-Specific Agency (SSA) is designated to head the modal Council to evaluate threat information and implement the requirements for deterring and preventing sources of threat. The Council works with industry partners to implement the NIPP for the specific sector CIKR protection and help prevent, prepare for, protect against, respond to, and recover from a transportation security incident (TSI), natural disaster, and other emergencies.⁷

The MDA component of the DHS *2005 National Security Strategy* is addressed in "National Plan to Achieve Maritime Domain Awareness." The Plan points out that effective understanding of the elements associated with the global maritime domain does not mean that knowing everything everywhere in the maritime domain is a requirement to achieving MDA. It points out that, conceptually, MDA is the integration of Global Maritime Intelligence and Global Maritime Situational Awareness. Global Maritime Intelligence is the product of the nation’s intelligence capabilities, while Global Maritime Situational Awareness results from the monitoring of maritime activities so that trends and anomalies can be identified, with the essential tasks of:

- Persistently monitoring (in the global maritime domain) vessels and craft, cargo, vessel crews and passengers, and all identified areas of interest; and
- Collecting, fusing, analyzing, and disseminating information to decision makers to facilitate effective understanding of the maritime domain.

The goals of MTS security are to promote risk-informed measures to ensure a safe, secure, efficient, and resilient MTS. Actions taken to promote MTS security and resiliency rely on a number of countermeasures, including technologies for detection, deterrence, and prevention of threats. Ashton Carter, the prominent national security scholar, has identified eight “decision variables” corresponding to eight risk management phases in a national security strategy. These decision variables are deployed along with strategies such as reengineering and realignment of civilian and military institutions and infrastructure.⁸

⁷ National Infrastructure Protection Plan, 2006.

⁸ Ashton Carter, “The Architecture of Government in the Face of Terrorism,” *International Security*, vol. 26, No. 3, PP. 5-23, Winter 2001-2002.

1. Detection,
2. Prevention,
3. Protection,
4. Interdiction,
5. Containment,
6. Attribution,
7. Analysis,
8. Intervention.

These eight phases or layers of risk management can be used as the conceptual framework for linking MDA and the threefold NIPP goals for information sharing to deter, detect, prevent attacks and create a resilient and cost effective MTS.

Layered Defense-in-Depth for Ensuring MTS Resiliency and Security

The underlying approach to MTS security rests on the recognition that MTS is not a single system, but rather a complex “*system of systems*” consisting of multiple layers of interdependent subsystems that need to be integrated. The concept of a *system of systems* was first popularized by Admiral William Owens, vice chairman of the Joint Chiefs of Staff in the mid-90s, who used it in reference to lack of integration of the technologies that supported the “revolution in military affairs” of the U.S. military. In his book *Lifting the Fog of War*, Owens maintained that the military needs to integrate all its disparate technologies into a single common picture in order to achieve the revolution. He pointed out the example of the Army mobile handsets that were on different frequencies than those carried by the Navy. By fully exploiting advances in computers, sensor technologies, robotics and precision-guided munitions, and integrating all this into a single network, he suggest that one could revolutionize the military and “lift the fog” of uncertainty.⁹

The concept of a *layered defense-in-depth* offers a framework for examining the vulnerability-based elements of a complex infrastructure system. The concept is used as an umbrella term to convey an integrated and systemic approach to infrastructure security. In this respect, *defense in depth* represents multiple layers of interventions in the chain of disruptive events at multiple points and reduce the probability of a single-point failure – rather than a more typical interpretation that rests on erecting multiple rings of security around a physical asset. These layers of defense help prevent the possibility a single point failure and contribute to a system that is resilient, adaptive, fault tolerant, and survivable. A RAND report on homeland security described the elements of a *layered defense-in-depth* as one that “cuts across civilian and military agencies” and achieves a “robust, three-layered defense that does not create the possibility of single-point failures.” The report described the first layer of protection as one focused on

⁹ Mark Williams and Andrew Madden, “Military Revolution,” in *Red Herring*, August 1,2001. The authors point out that Admiral Owens’ use of the term “fog of wars” was in reference to the 1830s German military documents that stated “three quarters of the factors on which action is based are wrapped in a fog of greater or lesser uncertainty.”

preventive measures; the second on pre-incident activities to prepare and defend against possible attacks; and the third on responding to attacks and managing their consequences.¹⁰

At the operational level, the concept of operations for a layered security is presented by the need for disaggregating cargo security into three areas of control: cargo certification, physical security, and inspection. A research team at the Center for the National Defense University (NDU) identified the need for enforcement of controls within three domains: the container/cargo domain, the in-transit/vessel domain, and the port domain, with extensive series of tasks relating to each step – container loading, transaction and shipping documents, container seals, tracking and location the container – to ensure integrity of the cargo and container.¹¹

At the core of a *layered defense in-depth security* is the strategic deployment of risk-driven countermeasures. This could involve application of multiple technologies for sensing and detecting different sources of threat, or deployment of multiple technologies in conjunction with multiple applications of the same technology in multiple locations. In the National Strategy for Maritime Security, the layered defense is described as a “family of plans” approach that “establishes a layered system of protection that involves all maritime stakeholders.” An array of DHS initiatives – C-TPAT, the 24-hour rule for submitting shipping manifests before the container is loaded, the analysis of the manifest information through the sophisticated Automatic Targeting System (ATS), and the Operation Safe Commerce (OSC) initiative that identifies and closes the gaps in the supply chain with the help of detection, tracking, and identification devices – have been designed to provide layers of security measures to enhance port-of-entry security processes.¹²

The key challenge of prevention and interdiction is that the countermeasures requires a fivefold task: *Collecting* information to identify terrorists; *collating* information from diverse sources; *analyzing* raw data; *sharing* the information with those who can make use of it; and *deploying* it in a way that is useful and timely. To address these tasks systematically within a defense in depth framework, a group of George Washington University researchers formulated a framework for managing the risks of a maritime attack at an intermodal marine port. The framework tracked the evolution of each subsystem within a port – e.g., intermodal rail, container loading dock facilities, regional load centers – and identified the extent to which the subsystems have been driven by economic efficiency rather than security. The framework created a terrorist event-chain for each of the subsystems at a port, identifying the potential interventions at each stage of the chain of disruptive events. The report emphasized that security should be incorporated in the evolution of each subsystems within a port, and report concluded that

¹⁰ Larson, Eric V. and John E. Peters, *Preparing the U.S. Army for Homeland Security: Concepts, Issues, and Options*, RAND, ISBN: 0-8330-2919-3, 2001.

¹¹ Binnendijk, Hans, Leigh C. Caraher, Timothy Coffey, and H. Scott Wynfield, 2002. “The Virtual Border: Countering Seaborne Container Terrorism”, National Defense University, Center for Technology and National Security Policy, Defense Horizons, Number 16, August 2002. <http://www.ndu.edu>.

¹² Admiral Thomas Collins, statement at a congressional testimony in June 2003.

in order to build security into US port and waterways retroactively, one should go beyond protecting assets and instead implement systemic interventions in all of the subsystems operating in a port.¹³

Layers of security countermeasures focused on in this report include:¹⁴

Layer 1 – Detection, Prevention, Deterrence Abroad. Countermeasures include:

- Container Security Initiative (CSI)
- Secure Freight Initiative (SFI)
- 24-Hour Rule
- Megaports
- Customs Trade Partnership Against Terrorism (C-TPAT)
- International Port Security Program (IPSP)
- SAFE Port Act provision for 100% Scanning

Layer 2 – Prevention, Detection of Vessel/Cargo Threats In-Transit. Countermeasures include:

- Automated Targeting System (ATS)
- 96-Hour ANA
- Ship Security Alert System
- Automatic Identification System (AIS)
- Maritime Safety and Security Information System (MSSIS)

Layer 3 – Protective Measures at Domestic Infrastructure to Build Resiliency. Countermeasures include:

- Fault tolerant and robust infrastructures
- Redundant safeguards
- Adaptive responses to disruption
- Survivable structures.

Layer 4 – Measures at Home- Port to interdict, contain, analyze, attribute, intervene, and assist recovery: Countermeasures include:

- National Targeting Center (NTC)
- USCG Security Boarding
- Non-Intrusive Inspection (NII) Technology
- Transportation Worker Identification and Credential (TWIC)
- Data Mining

¹³Harrald, John, Hugh Stephens, Johann Rene vanDorp, “A Framework for Sustainable Port Security,” *Journal of Homeland Security and Emergency Management*, Volume 1, Issue 2. 2004.

¹⁴Some of the measures are based on Sean T. Connaughton, “Regulations of Commercial Interests for Port Security in the United States”, Presentation at the OAS Committee on Ports/Port Security Conference, April 8, 2008.

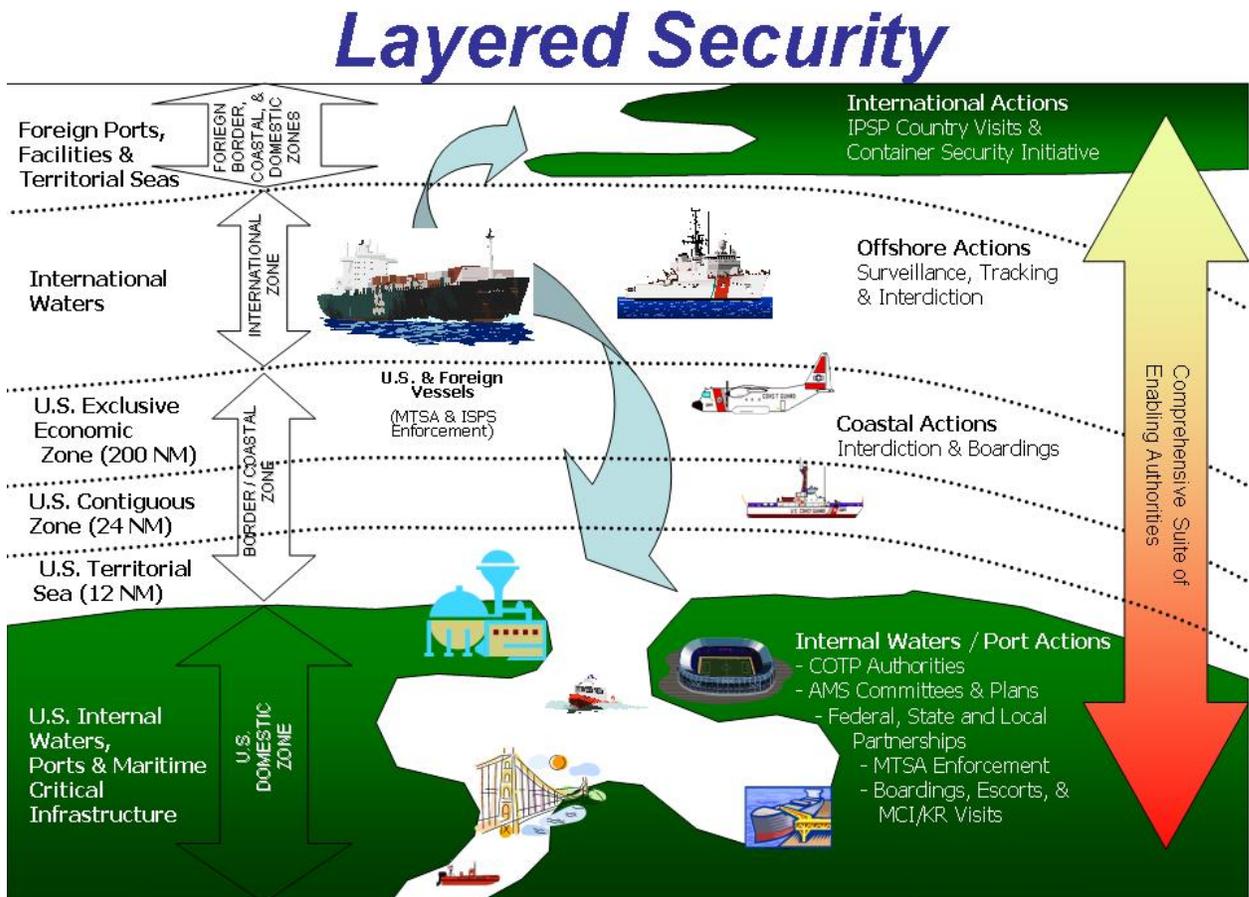
- Port Security Grants
- Risk Assessment and Plan (AMSC, AMSP)

Maritime security stakeholders seek an active, seamless, layered security posture that:

- Deters terrorist and other malicious actors;
- Maximizes early warning, detection, and interdiction of emerging threats originating from outside or inside our borders;
- Capitalizes on multiple opportunities to disrupt terrorists' operational planning;
- Robustly protects maritime critical infrastructure and key resources;
- Ensures that decisive responses can be rapidly executed
- Mitigates the consequences of a maritime-related transportation security incident;
- Facilitates the rapid recovery of the MTS; and
- Ensures the resiliency of the MTS layered maritime security is achieved through the various security stakeholders carrying out their shared security responsibilities.

Layered maritime security has both geographic and functional aspects. Figure 1 depicts the functional and geographic scope of the layered maritime security concept.

Figure 1 – Functional and Geographic Scope of Layered Security



Risk-Informed Decision-Making

The global maritime domain and MTS are too expansive to protect in a resource-constrained environment. Terrorists and other malicious actors understand this limitation and seek to take advantage of it. The success of maritime security therefore hinges, in part on the risk-informed prioritization of maritime security activities. Area Maritime Security Committees are required to conduct maritime security assessments of their areas to include the threats to critical MTS infrastructure and operations in the ports; the vulnerability of such infrastructure and port operations, and the consequences to them from a terrorist attack. To facilitate these assessments, the Coast Guard developed and implemented the Maritime Security Risk Assessment Model (MSRAM). Section 111 of the SAFE Port Act requires that the MSRAM be used by the Captains of the Ports/Federal Maritime Security Coordinators (FMSCs) and Area Maritime Security Committees (AMSC) to analyze and prioritize scenario-based risks within their areas of responsibility. The tool is also designed to measure risk reduction potential in the evaluation of port security grant program proposals. FMSC and AMSCs are required to validate the MSRAM data on annual basis.

Leveraging Intelligence Information to Guide Maritime Security Activities

An active, seamless, layered maritime security relies on early warning of emerging threats in order to quickly deploy the various security activities and to execute a decisive response. The Coast Guard is a member of the national intelligence community. It and the other maritime security stakeholders must continually strive to adapt to and integrate all available information to maximize the timeliness and fidelity of their common intelligence pictures (CIPs). CIPs inform their understanding of active threats and the risks they lead to within the maritime domain. This intelligence is used, in turn, as a basis for structuring preventative activities to reduce these security risks and to prompt decisive protective operations as needed to address the threats. Intelligence is therefore integral to the design of maritime security plans and the conduct of activities that achieve the maximum reduction of risk.

Facilitating Commerce

Disrupting the U.S. economy is a primary terrorist goal. Therefore the provision of security must be accomplished while preserving the freedom of the maritime domain for legitimate pursuits. It is necessary to establish effective partnerships and coalitions with international, Federal, State, local, and tribal agencies, as well as the private sector and academia.

1.5 Enforcement Mechanisms for Maritime Security Rules

There are generally two enforcements mechanisms in place for ensuring that marine vessels in international voyage are in compliance with applicable regulation, laws and conventions: Flag State Controls and Port State Controls. The Flag State, the country in which the vessel is registered, enforces certain requirements that set the standards for the operation and maintenance of all vessels flying that flag. If the flag state is a contracting government to the International Maritime Organization (IMO) Safety of Life at Sea (SOLAS) Convention, these standards are required to be at least as stringent as those include in the ISPS Code. The Port State, the country where the destination port is located, has a process by which it exercises its authority over foreign flagged vessels operating in waters subject to its jurisdiction. The Port State Control is intended to ensure that vessels comply with all domestic requirements for ensuring safety and security of the port, environment and personnel. The United States Coast Guard (USCG) is the primary agent of marine safety and security enforcement for vessels entering the U.S. harbors.

Section 2.0 Maritime Security Governance Activities

The following strategic objectives are common to the significant volume of strategy, directive, policy, legislation and other guidance:

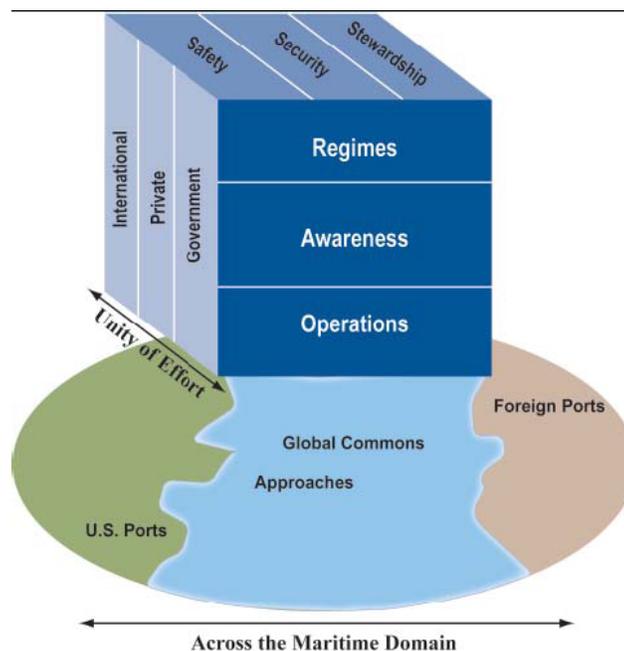
- Prevent terrorist attacks and criminal or hostile acts;
- Protect maritime-related population centers and critical infrastructures;
- Minimize damage and expedite recovery;
- Safeguard the ocean and its resources.

Five strategic *actions* are intended to achieve the objectives of this strategy:

- Enhance international cooperation to ensure lawful and timely enforcement actions against maritime threats;
- Maximize domain awareness to support effective decision-making;
- Embed security into commercial practices to reduce vulnerabilities and facilitate commerce;
- Deploy layered security to unify public and private security measures;
- Assure continuity of the MTS to maintain vital commerce and defense readiness.

The maritime security governance model covers these strategic actions and more.

Figure 2 - Conceptual Depiction of Maritime Security Governance Model



As shown in figure 2, international, government, and private security stakeholders, together, addresses maritime security across the global maritime domain using an interlocking system that consists of maritime security regimes, maritime domain awareness, and maritime security and response operations.

2.1 Maritime Security Regime

Maritime regimes are the system of rules consistent with the established legal order (including international law; regional, multinational, or bilateral agreements; domestic laws and regulations; and standard practices and procedures) that shape and define acceptable activity and enforcement schemes. The following are some of the regime activities conducted by the security stakeholders:

National Infrastructure Protection Plan (NIPP)

Homeland Security Directive 7 (HSPD-7) required that the DHS develop a National Infrastructure Protection Plan (NIPP) as a comprehensive risk management framework to define critical infrastructure protection roles and responsibilities for DHS, the Sector-Specific Agencies (SSAs), and other Federal, State, local, tribal, and private sector security partners. The NIPP identified 18 critical infrastructure and key resource (CIKR) sectors, and has designated specific Federal Department or Agency as SSAs for each sector. SSAs are responsible for working with DHS to implement the NIPP sector partnership model and risk management framework, develop protective programs, and provide sector-level CIKR protection guidance (See text box on the 18 sector To achieve the goals of building a safer, more secure, and more resilient infrastructure, the NIPP outlines strategies for deterring threats, mitigating vulnerabilities, and minimizing the consequences. To meet the objectives of the above strategic goals the following *actions* are implemented:¹⁵

1. *Understanding and sharing information about threats and hazards.* This action involves promoting Maritime Domain Awareness (MDA) and the flow of timely and accurate information and intelligence by establishing effective information sharing processes and protocols among CIKR partners; analyzing, warehousing, and sharing risk assessment data in a secure manner; and providing protocols for real-time threat and incident reporting, alerts and protection of sensitive information. Building partnerships to share information and implement CIKR protection and resiliency programs is another component of intelligence gathering strategy. These partnerships provide a framework for exchange of ideas and best practices and enhancing domain awareness; facilitate security planning and resource allocation; establish effective coordination with the international community; provide needed training; and build public awareness.

¹⁵ Based on National Infrastructure Protection Plan: Partnering to Enhance Protection and Resiliency, DHS, 2009, http://www.dhs.gov/xlibrary/assets/NIPP_Plan.pff

2. *Implementing a long-term risk management and infrastructure resiliency program.* This action involves hardening and diversifying the CIKR against known threats and hazards; developing and deploying new technologies to enable more effective and efficient CIKR protection; providing a system for measuring and improving CIKR protection; establishing performance metrics to track effectiveness of the protection and resiliency strategies; developing processes to interdict threats to prevent potential attacks; and planning for rapid response to CIKR disruptions to limit the impact on public health, safety, economy, and government functions.

3. *Maximizing the efficient use of resources for CIKR protection.* This action involves developing a coordinated annual process for program implementation that support prioritization of activities within and across sectors; informing the annual budgeting process; helping align federal resources and the CIKR protection mission; drawing on expertise across organizational boundaries; sharing expertise and best practices; recognizing the need to build a business case to support further private sector CIKR protection investment; and identifying potential incentives for preparedness where they do not naturally exist in the market place.

The CIKR protection mission is to prevent catastrophic loss of life and manage potential cascading and disruptive impacts of security incidents on the U.S. and global economies. To achieve this goal, the NIPP attempts to balance infrastructure resiliency with focused and cost-effective risk-informed prevention, detection, and preparedness.

¹⁶ For the marine section, the NIPP provides a coordinated approach to establishing national priorities for infrastructure protection by promoting three key strategic goals:

Goal 1- Prevent and deter acts of terrorism against the MTS;

Goal 2 – Enhance the resiliency of the MTS;

Goal 3: Maximize cost-effectiveness for the limited resources of the MTS.

- | NIPP Designated Sectors | |
|--------------------------------|--|
| 1. | Agriculture and food; |
| 2. | Defense Industrial Base; |
| 3. | Energy; |
| 4. | Public Health and Healthcare; |
| 5. | National Monuments and Icons; |
| 6. | Banking and Finance; |
| 7. | Drinking Water/ Water Treatment Systems; |
| 8. | Chemical Manufacturing; |
| 9. | Commercial Facilities; |
| 10. | Dams; |
| 11. | Emergency Response (ER) Services; |
| 12. | Nuclear Reaction, Materials, and Waste; |
| 13. | Information Technology; |
| 14. | Communications Systems; |
| 15. | Postal and Shipping; |
| 16. | Transportation Systems; |
| 17. | Government Facilities. |
| 18. | Critical Manufacturing |

¹⁶ National Infrastructure Protection Plan: Partnering to Enhance Protection and Resiliency, DHS, 2009, http://www.dhs.gov/xlibrary/assets/NIPP_Plan.pff

Maritime Transportation Security Act (MTSA) Regulations

The NIPP 2006 outlines the requirements for preventing transportation security incidents (TSI) as represented by the following key elements of 33 CFR:

- a. **Development of a “Family” of Security Plans.** The “family” consists of: 9,200 vessel security plans; 3,200 facilities plans; 43 Area Maritime Security (AMS) Plans and a National Maritime Transportation Security Plan.
- b. **Establishment of Security Advisory Committees.** This strategic component of NIPP consists 1 National Maritime Security Advisory Committee (NMSAC) and 47 Area Maritime Security (AMS) Committees
- c. **Establishment of Maritime Security (MARSEC) Levels.** The MARSEC levels are set to reflect the prevailing threat environment. MARSEC directives are developed by the USCG Commandant¹⁷ (COTP) and issued by the USCG Commander mandating specific security measures for vessels and ports. MARSEC levels range from MARSEC 1, requiring minimal appropriate security measures, to MARSEC 3 indicating an imminent TSI and involvement of federal and state security teams.

Table 2 describes the threat levels and attendant security measures for each of the MARSEC levels.¹⁸

Table 1 – Maritime Security (MARSEC) Levels by Threat Level and Representative Security Measures

MARSEC Level	Threat Level Description	Representative Security Measures with Focus on:
MARSEC 1	Minimal appropriate security measures shall be maintained at all times	Intelligence and data fusion, Harbor Patrol; Vessel Escorts; Protection of Assets
MARSEC 2	Appropriate additional security measures shall be maintained for a period of time as a result of heightened threat	Air surveillance, critical infrastructure protection, security zone enforcement; cutters and aircraft use of force; Harbor Patrol Center...
MARSEC 3	A TSI probable or imminent	Federal and state security team involvement.

Source: National Infrastructures Protection Plan, 2006

¹⁷ Per 33 CFR 101.405, Commandant develops MARSEC Directives.

¹⁸ Table 2 overlooks fact that MTSA-required vessel and facility security plans have scaled security measures that are keyed to MARSEC levels.

Homeport and Information Sharing Elements of Maritime Security

A key component of the SAFE Port Act of 2006 is the formation of the Area Maritime Security Committees¹⁹ (AMSCs) under the auspices of the USCG. The Coast Guard had already established AMSCs in 2002 but the act legislatively mandated them. In October 2005, the Coast Guard officially announced its initial deployment of an Internet portal, Homeport. Homeport (version 1.0) is the official Coast Guard information technology system for maritime security created to provide information and services to the maritime community and the public over the Internet.²⁰

Coast Guard Federal Maritime Security Coordinators will use Homeport as a primary means for the day-to-day management and communication of port security matters with Area Maritime Security Committee (AMSC) members, commercial vessel and facility owners and operators, government partners, and the public. Homeport will provide instant access to information necessary to support increased information sharing requirements amongst Federal, state, local and industry decision makers for security management and increased maritime domain awareness.

The publicly accessible Internet portal Homeport provides all users with current maritime security information, and serves as the Coast Guard's communication tool designed to support the sharing, collection and dissemination of sensitive but unclassified information to targeted groups of registered users within the port community. Homeport meets critical mission requirements in support of the MTSA 2002 for sharing security information, and has the potential to revolutionize the way the Coast Guard communicates with the public, its partners and maritime stakeholders.

Area Maritime Security Training and Exercise Program (AMSTEP)

The Area Maritime Security Training & Exercise Program (AMSTEP) is a USCG program conducted for state and regional port security planning in collaboration with the FBI, Governor's Office of Homeland Security and Emergency Preparedness (GOHSEP), and state and local security agencies. The program develops exercise plans for coordination, communication and capabilities of everything from ambulances to bomb sniffing dogs that may be involved in a terrorist, or any emergency situation. The AMSTEP exercise program is an annual requirement where agencies responsible for the security of the port and the surrounding population come together to respond to a terrorist event. The interaction and lessons learned help responders react to any joint agency emergency.²¹

Current port security exercise programs, 33 CFR 105.220(c), Section 114, require that the Coast Guard conduct live, risk-based exercises that are realistic and evaluate total capability by focusing on the port community in order to evaluate the entire capability.

¹⁹ SAFE Port was enacted in 2006. AMSC's were in existence prior to 2006 . See pg.49 on this report. AMSC's were established by MTSA in 2002. (By Anthony Regalbuto)

²⁰ <http://homeport.uscg.mil/mycg/portal/ep/home.do>

²¹ Coast Guard News, <http://coastguardnews.com/coast-guard-to-participate-in-joint-agency-readiness-training/2008/03/25/>

Since October 2005, the Coast Guard has sponsored its own Area Maritime Security Training and Exercise Program (AMStep), in addition to assisting TSA in implementing their Port Security Training and Exercise Program (PortSTEP). AMStep exercises the port stakeholder's ability to implement the provisions of the Area Maritime Security Plan. The Coast Guard and TSA have synchronized AMStep and PortSTEP to maximize coverage across the U.S. and minimize duplication of effort. In FY07, these two programs collectively sponsored 41 port security exercises. Exercise types have included basic and advanced table-top, discussion-based exercises to full-scale, operations-based exercises. The type of exercise and scenario selected are collectively decided upon by Area Maritime Security Committee (AMSC) members, through application of their most current risk-based port assessment and assessment of preparedness needs. The results of both these exercise programs and all lessons learned, best practices, and corrective actions are documented in a semi-annual report to Congress.

These exercises involve State and local governments, as well as facilities and vessels, to ensure that consistent methodology is applied and that all requirements are met as a result. Although current programs do not mandate facility participation in these annual exercises, participation has been strong and continues to increase. Facilities, as well as vessels, are encouraged to observe and/or participate in these port security exercises. When they choose to participate, they are offered the opportunity to put forth exercise objectives tailored to meet their specific needs. The "Training" aspect of current port security exercise programs focuses on the National Incident Management System (NIMS) Incident Command System (ICS). The Program's performance measures for port security exercises are currently being revised to align with MTSA requirements to test the AMSPs and with the Homeland Security Exercise and Evaluation Program. All Lessons Learned, Best Practices, and Remedial Action Items are captured in the Coast Guard's Contingency Preparedness System (CPS), which can be accessed by the entire Coast Guard. Additionally, through the use of Homeport, the Coast Guard's communications and collaborations Information Technology application, Lessons Learned and Best Practices, can be made available to the entire port community (Federal, state, local, tribal and industry).

Although AMStep is currently being carried out under contract support, the Coast Guard has begun the hiring of personnel to staff National-level and Regional-level exercise support teams. These teams will assist Coast Guard Sector Commands (port-level) and Districts with the following contingency exercise programs: port security, oil/hazardous substance response, natural disaster, mass rescue, alien migration interdiction, civil disturbance, counterterrorism, military outload, combatant commander support, and physical security/force protection. This is an "All Threats / All Hazards" approach.

The authority for AMStep is derived from 33 CFR 105.220(c), Section 115 Facility Exercise Requirements, requiring facilities to conduct an annual exercise. These exercises may include either live, tabletop, or participation in a non-site-specific exercise. In order to meet the requirement in Section 115, the Coast Guard has initiated a regulatory project to update 33 CFR Subchapter H regulations and will incorporate definition of "high risk facility" and the requirement for high risk facilities to conduct bi-annual full-scale

exercises. The NPRM for this rulemaking is scheduled to be published in the spring of 2008.

Port Security Training Exercise Program (PortSTEP)

In August 2005, Transportation Security Administration (TSA) initiated a new program for homeland security exercises for U.S. seaports dubbed the Port Security Training Exercises Program (PortSTEP). PortSTEP is focused on building links within the Area Maritime Security Committee (AMSC). The committee assists the captain of the port (COTP) in writing, reviewing and updating an AMS Plan in addition to supporting other transportation entities that depend upon the port being secure. PortSTEP is designed to benefit maritime and surface transportation security communities throughout the U.S. via a suite of training exercises, evaluations and accompanying information technology products. The exercises will allow the maritime security agencies to continually test and evaluate the ports' readiness to deal with an actual threat.

The exercise involves the entire port community, including both public governmental agencies and private industry. The partnership is intended to improve connectivity of various surface transportation modes and enhance current Area Maritime Security Plans (AMSP.) Scenarios range from how officials react to discovering a suspect cargo container to an explosion at a seaport rail yard. Communication and coordination abilities of the government and maritime industry will be tested at each of the 40 seaports scheduled to participate over the next three years.

PortSTEP supports institutional relationships within the port environment including the surface transportation and maritime industry, transportation and port security managers, emergency managers, law enforcement, medical professionals, private security personnel, and all others involved in preparing for and responding to a Transportation Security Incident (TSI). In addition, PortSTEP will be carried out with the participation of various federal, state and local government agencies.

Transportation Security Agency (TSA) has awarded contracts to four companies to initiate the program: Community Research Associates of Alexandria, Va.; Booz Allen Hamilton, Inc. of McLean, Va.; UNITECH of Centreville, Va.; and Applied Science Associates of Narragansett, R.I. The contractors developed TSI-related scenarios including simulation software and databases to monitor and evaluate the exercises. In addition to TSA, the U.S. Coast Guard, the Federal Highway Administration and the Maritime Administration are among the federal participants in the PortSTEP exercise.

International Port Security (IPS) Program

As directed by MTSA, the International Port Security (IPS) Program visits foreign countries to assess the effectiveness of anti-terrorism measures in the ports of the nations conducting maritime trade with the United States. In cases where the Coast Guard finds that effective anti-terrorism measures are not in place, Conditions of Entry (COE) are placed on vessels arriving to the United States from those ports. The COE require those vessels to take additional security measures while in those international ports. In

addition, those vessels receive additional port state control scrutiny upon arrival to the U.S. The number of countries with inadequate anti-terrorism measures varies based on the continuing series of assessments, but as of 1 April 09 included some fourteen countries.

America's Waterway Watch (AWW)

AWW is similar to the Coast Watch program of World War II, which caused the early growth of the Coast Guard Auxiliary, a group of citizen-volunteers who were mobilized as a uniformed, civilian component of the Coast Guard to scan the coast for U-boats and saboteurs attempting to infiltrate the shores of the United States. Today, AWW goes one step further: It calls on ordinary citizens who spend much of their time on and around America's waterways to assist with the War on Terrorism on the Domestic Front.

Small Vessel Security Strategy

The DHS defines a. A vessel of 300 GT is approximately 100 feet in length, although there is no exact correlation between a vessel's length and its gross tonnage. Small vessels can include commercial fishing vessels, recreational boats and yachts, towing vessels, uninspected passenger vessels, or any other commercial vessels involved in foreign or U.S. voyages.²²

In 2008, DHS developed a strategy to broaden the focus of federal interest to encompass small watercraft less than 300 gross tons (GT), regardless of method of propulsion. Small vessels, approximately 100 feet in length, can include commercial fishing vessels, recreational boats and yachts, towing vessels, uninspected passenger vessels, or any other commercial vessels involved in foreign or U.S. voyages.²³ This strategy expands the scope of the recent U.S. maritime security efforts that have typically focused on regulating cargo containers and large vessels at official Ports of Entry (POE), through regulations such as the 96 Hour Notice of Arrival, 24-Hour Rule on transmission of cargo manifest and crew list, and the carriage requirement for the Automatic Identification System (AIS). The Small Vessel Security Strategy takes into account the security risks from terrorist exploitation of the small vessel community, including a wide range of vessels, from small commercial vessels, such as uninspected towing vessels and passenger vessels, to commercial fishing vessels and recreational boats, whether personal watercraft or large power and sail boats. Appendix 4 provides a detailed analysis of the DHS Small Vessel Security Strategy within the risk and resiliency framework developed for the assessment of MTS challenges.

Container Security Initiative (CSI)

The predecessor of CBP, the U.S. Customs developed the Container Security Initiative (CSI) to detect and deter acts of container related terrorism at the earliest point possible along the supply chain. Initiated as part of the MTSA, the CSI program is today

²² This section is based on DHS, *Small Vessel Security Strategy*, April 2008

²³ This section is based on DHS, *Small Vessel Security Strategy*, April 2008

established in approximately 25 ports in 14 countries. The operations consist of CBP sending an assessment team to the CSI port to collect information about the ports' physical and cyber infrastructure and host-country customs operations. The goal of the program is to prevent acts of terrorism by detecting cargo-, personnel-, or vessel-based threats before they enter the U.S. ports. For this purpose, CSI enters interagency agreements with partner international ports to place customs officials in key foreign ports to inspect containers to detect hazardous cargo and weapons of mass destruction (WMD) prior to the arrival in the U.S. and to deter terrorists from using containers to deliver a WMD.

The CSI program has several key components: a) the Customs-Trade Partnership Against Terrorism (C-TPAT) for arrangements to pre-screen shippers; b) the Automated Targeting System (ATS) to screen container data arriving at CSI ports by land, rail, or sea en route to the U.S. and selecting them for inspection; c) cargo inspections involving co-location of U.S. and foreign inspectors; d) 24-Hour Rule for dispatch of cargo manifest; e) the 96-Hour Advance Notice of Arrival (ANA); f) deployment of non-intrusive inspection (NII) and detection technologies to scan high-risk containers; and g) the use of Electronic seals for securing cargo containers. These program elements are briefly described in this section.

Customs-Trade Partnership Against Terrorism (C-TPAT)

C-TPAT is a CBP/U.S Customs initiative developed to address concerns about supply chain vulnerabilities in conjunction with implementation of CSI. C-TPAT establishes partnerships between the private-sector and Customs to improve the overall security of the international supply chains and offer incentives to participants with assurances about lower chances of inspection for containers that are in compliance. C-TPAT was rolled out shortly after CSI implementation, with approximately 1,700 companies currently participating.

Smart and Secure Tradelanes (SST) Initiative

Smart and Secure Tradelanes (SST) is a supply chain security initiative developed by the trade industry to promote container security throughout the global supply chain. The initiative began as a program of the Strategic Council on Security Technology (SCST), and supported by the Asia Pacific Economic Cooperation (APEC.) The SST program tests and validates the deployment of a number of technologies including radio frequency identification (RFID) transponders, tracking and container management software, non-intrusive inspection (NII) and detection mechanisms, and automated video surveillance. SST was designed as a complement to and in compliance with C-TPAT, CSI, and Operation Safe Commerce (OSC) initiatives and in support of ISPS security programs.

SST initiative was launched in 2002 at the U.S. the East Coast and West Coast ports and international ports on the Pacific and Atlantic. On the Eastern Seaboard, the initiative involved participation of the Port Authority New York/New Jersey, and two other Atlantic Coast ports: Port of Antwerp and Port of Felixstowe (in U.K.) The West Coast

initiative was launched in the State of Washington, with participants from ports of Seattle-Tacoma, Hong Kong and Singapore.²⁴

SST Phase I program was completed in 2005, evaluated by APEC members, with private funding from participating industries. It involved 18 trade lanes and 65 partners and participating carriers and shippers, and conducted tests of RFID transponder seals based on the requirement of the U.S. DOD global Intransit Visibility (ITV) system for transponder performance. The software flagged containers that strayed from pre-planned route to exceeded transit time. SST Phase 2 is designed to test the “Smart Container” enhancement, integrate additional capabilities such as GPS, and Gamma Ray intrusion detection software, and expand supply chain participation and network coverage to China, Taipei, Japan, Korea, Pakistan, and Thailand.²⁵ Phase 2 SST project will include pilot tests in the Yantian-Seattle lane, Japan RFID in the Hong-Kong-Yokohama lane, Nested Visibility in the China-Hong Kong-Europe/US lanes, and Project Pakistan in the Pakistan-Norfolk lane.

Operation Safe Commerce (OCS)

Jointly administered by the U.S. DOT and CBP, Operation Safe Commerce (OSC) was initiated in 2002 as a public-private partnership designed to determine current supply chain vulnerabilities, test new technologies and security strategies, and ultimately enhance container security for cargo moving throughout the international supply chain. The public-private partnership was between OSRAM SYLVANIA, a private manufacturing firm, states of New Hampshire and Vermont, the U.S. Department of Justice, the U.S. Customs Service, and the USCG. OSRAM ships approximately 20 million automobile lamps per year from Nove Zamky, Slovakia, to New Hampshire. Phase I pilot project described the movement from the point at which the container was packed in Slovakia, through transshipment points in Hamburg, Germany and Montreal, Canada to its destination in the OSRAM SYLVANIA automobile lamp distribution facility in Hillsborough, New Hampshire. Data were collected for four channels of the supply chain: distribution, communications, transactions, and custody. The relatively simple supply chain consisted of a single commodity, single points of origin and destination, and a single carrier and freight forwarder. The containers were loaded with 400,000 automobile tail lamps, and were destined for installation in new vehicles. Completed in February 2002, Phase 1 OCS consisted of three major tasks relating to container security technology assessment, supply chain analysis, and a technology demonstration to address three key components to secure supply chain management: a) ensuring that a shipper exerts reasonable care and due diligence in properly packing, securing, and manifesting the contents of a shipment of goods; b) ensuring that the electronic documentation accompanying a cargo shipment is complete, accurate and secure from unauthorized access; and c) implementing enhanced manifest data elements; and d) ensuring in-transit cargo security by tracking and testing container seal integrity to

²⁴ The political support for the East Coast initiative was provided by New York’s Senator Schumer, and for the West Coast initiative by Senator Patty Murray, of Washington State.

²⁵ Walter Kulyk, “APEC Secure Trade Project: ITS Technologies and Standards and U.S. DOT’s Leadership Role,” Chair, APEC Intelligent Transportation Systems (ITS) Experts Group Meeting, February 17, 2005.

determine which applications are most effective in securing international and domestic shipments.

Transportation Worker Identification Credential (TWIC)

To control access to secure areas of port facilities and vessels, the MTSA required that the DHS Secretary implement the Transportation Worker Identification Credential (TWIC) and issue identity cards that use biometrics such as fingerprints. TWIC is a tamper resistant biometric identification card to help restrict access to secure areas to only authorized personnel and ensure that individuals posing security threats do not gain access to U.S. ports and transportation facilities.

When MTSA was enacted in 2002, TSA had already initiated a program to create a TWIC by collecting personal and biometric information to validate the workers' identities, conduct background checks to ensure the workers do not pose a threat to security, issue tamper-resistant biometric credential that cannot be counterfeited, verify credentials using biometric access control systems before a worker is granted unescorted access to a secure area, and revoke credentials if disqualifying information is discovered, or if a card is lost, damaged, or stolen. TWIC will be funded with a \$139 user fee for issuing a card valid for 5 years. Vessels and port authorities are required to integrate TWIC into their existing access control systems, update security plans accordingly, and purchase special card readers.²⁶

The SAFE Port Act required TSA to implement TWIC at the 10 highest-risk ports by July 1, 2007, conduct a pilot program to test TWIC access control technologies in the maritime environment; issue regulations requiring TWIC card readers based on the findings of the pilots; and periodically report to Congress on the status of the program. TSA, in partnership with the USCG, is focusing initial implementation on maritime facilities. TSA did not meet the July 1, 2007 deadline, citing the need to conduct additional testing to the systems and technologies that would be used to enroll the estimated 770,000 workers that will be required to obtain a TWIC card. A GAO report on the TWIC program has voiced concerns about the TSA capability to meet the timeframe for its implementation plan, and additional challenges arising from ability to monitor the effectiveness of contract planning and oversight. The GAO report noted that TSA has developed a quality assurance surveillance plan with performance metrics that the enrollment contractor must meet to receive payment.²⁷

Shiprider Program

On May 26, 2009, an international agreement called the "Integrated Cross-Border Maritime Law Enforcement" was signed between U.S. and Canada. Coined the "Shiprider Program", it allows the USCG and U.S. marine patrol police forces to work alongside Royal Canadian Mounted Police, including jointly-crewed vessels in shared waterways, to combat cross-border security threats.

²⁶ GAO *Maritime Security: One Year Later: A Progress Report on the SAFE Port Act*, October 16, 2007.

²⁷ GAO, *Maritime Security: One Year Later: A Progress Report on the SAFE Port Act*, October 16, 2007.

2.2 Maritime Domain Awareness and Cargo Security

Information-Sharing and Data Mining

As noted above, MDA requires access to real-time intelligence and activity information that is shared with key system security agents. The NIPP and National Maritime Strategy requirements for data sharing – e.g., formation of Area Maritime Security Committees and the Threat Analysis Center – rely on output from risk assessment, threat analysis, using systems such as ATS, and data mining.

Data mining is one element of an integrated process of risk analysis – i.e., Detection, prevention, mitigation – that could help link threat analysis to intelligence gathering, vulnerability assessment, and consequence management. Increasingly, data mining is incorporated in the process of analyzing data from sensors, detection devices, and video surveillance technologies. Increasingly, security technologies are deployed in tandem with data mining, pattern recognition, and decision-support software. Data mining has its origins in applied statistics. It has been defined as a tool for discovery of meaningful patterns in data. The sources of data can be past documents, sensors, biometrics, video, graphic, and audio data. The goal of any data mining exercise is to extract meaningful intelligence from the patterns that emerge within a database after it has been cleaned, sorted and processed.

What makes data mining – essentially a process for collection of information and intelligence – different from national security agency operations is the amorphous nature of the maritime threats and targets. Artificial intelligence (AI) and intelligent agents (IA) relate to some of the techniques deployed in data mining.²⁸ DOD's DARPA has developed data mining tools as dual use technologies that have commercially viable applications for both defense and non-defense civilian purposes. In the late 1990s, the DOD stepped up acquisition programs in IT systems and technology; distributed training systems; affordable sensors; environmental monitoring; and advanced structural systems for high-speed ships. DARPA's Video Surveillance and Monitoring (VSAM) program is another example of technologies available for making sense of security threat data. The goal of VSAM is to develop an "automated video understanding" technology for use in urban and battlefield surveillance applications. Through this technology, a single human operator would be able to monitor activities over a broad area using a distributed network of active video sensors. The sensor platforms are autonomous, designed to notify the operator only of salient information as it occurs. Carnegie Mellon University Robotics Institute is leading a team to develop a testbed system demonstrating a wide range of advanced surveillance techniques, including real-time moving object detection and tracking from stationary and moving camera platforms; recognition of generic object classes (e.g., human, sedan, truck); and real time data dissemination, data logging, and dynamic scene visualization. Ultimately, the goal of VSAM is go beyond the prevalent applications of video surveillance, which are used only as an "after the fact" forensic tool.

To conclude, the concept of smart infrastructure for securing marine terminals and facilities is not a futuristic vision. Today, embedded security is widespread, as facilities

²⁸ Bruce Gabrielson, "Security Using Intelligent Agents and Data Mining," Center for Information Security Technology, Science Applications International Corporation, Columbia, MD, June 29, 1999.

are becoming intelligent and adaptive, and “structural monitoring,” i.e., sensing buildings, bridges, marine terminals or railway tracks are able to detect structural changes with fiber optic and other data collection sensors are being built into facilities.

96-Hour Advance Notice of Arrival (ANOA)

The USCG requires that all vessels scheduled to call at U.S. ports must report their arrival to the USCG 96 hours in advance. The rule also requires submission of information on passengers, crew, and cargo manifest. The USCG reviews and analyzes the ANA to determine the vessel and crew’s risk levels and take additional security precautions entailing boarding the ship while it is still at sea and/or armed escort during transit to and from certain ports. The ANA requirements are jointly implemented by the USCG, CBP and Immigration and Customs Enforcement (ICE).

Automatic Targeting System (ATS)

The ATS evaluates U.S.-bound cargo manifest data electronically and determines the container’s risk level. The manifest is issued by carrier or its agent and provides data on: shipper, consignee, point/country of origin of goods, export declaration, carrier, port of lading, port of discharge, description of packaging, and the date of cargo lading.

The principal value of ATS is that it provides a vehicle for information sharing-abroad. ATS flags unfamiliar consignees as high-risk and allows their risk status to be identified upon inspection. Based on the outcome of the ATS cargo risk assessment, the host country’s customs inspects containers designated as high-risk. The U.S. officials have attempted to negotiate agreements with host countries to participate in the inspection, since a key tenet of the CSI is the capability for the U.S. official to observe and verify the inspection.

Most important potential benefit of CSI derives from co-location of U.S. customs with foreign officials. Prior to implementation of CSI, customs officials in U.S. ports screened container data using ATS and inspected high risk containers as they arrived at the U.S. port. Another benefit of the CSI is that it facilitates freight flows and reduces processing time because screening will take place during “down times” before the containers are loaded onto vessels.

National Targeting Center (NTC), created in November 2001 to operate under the DHS with the primary function of analyzing threats to national security and to supply CBP with information needed to predict terrorist behavior, collaborates and shares information with the FBI, USCG, TSA, and the Department of Energy (DOE.)

24-Hour Rule for Container Manifest

The 24-Hour Rule was necessitated by the need for advance cargo manifest in compliance with the CSI implementation process. In the early stages of CSI implementation, Customs entered into numerous bilateral agreements with foreign governments to place Customs officials at CSI ports and deploy the process of CSI inspections. At the Port of Rotterdam, they faced logistical and legal challenges and were

not able to obtain manifest data on time. Implementation of the 24-Hour Rule has allowed the CBP to directly receive cargo manifest information from carriers and provide necessary data for determining which containers should be scanned and inspected overseas.

The process, initially referred to as the Smart Border Declaration, was used in Canada at 3 ports before the 24-Hour Rule was fully implemented. Between 2001 and 2003, U.S. and Canadian CSI teams screened manifest data for 600,000 containers, identified 7,091 high-risk containers and inspected them. The finalized 24-Hour Rule required the carriers to present complete vessel cargo declaration to Customs 24 hours before loading cargo aboard a vessel at foreign port, regardless of whether the port is a CSI or Non-CSI port. (See the Electronic Seal description below.)

Importer Security Filing (SFI)“10+2”Program

The purpose of the new Customs and Border Protection (CBP) Importer Security Filing (SFI) “10+2” program is to help prevent terrorist weapons from being transported to the United States by requiring both importers and carriers to submit additional cargo information to CBP before the cargo is brought into the United States by vessel.²⁹ The SFI interim final rule took effect on January 26, 2009, following a notice of proposed rulemaking (NPRM) published on January 2, 2008. The SFI compliance date is scheduled for follow on January 26, 2010. These regulations specifically fulfill the requirements of the Security and Accountability for Every (SAFE) Port Act of 2006 and the Trade Act of 2002, as amended by the Maritime Transportation Security Act of 2002.

SFI improves on the "24-Hour Rule", according to which carriers are required to submit advance cargo information for vessels no later than 24 hours before the cargo is laden aboard a vessel at a foreign port. SFI requires that the carriers submit vessel two additional stow plans and container status messages to CBP, as follows:

- *Vessel Stow Plan*: Carriers must transmit the stow plan, via the Automated Manifest system (AMS), secure file transfer protocol or email, so that it is received by CBP no later than 48 hours after the carrier's departure from the last foreign port. For voyages less than 48 hours, CBP must receive the information prior to the vessel's arrival at the first port in the U.S. The stow-plan must include the vessel name, vessel operator and voyage number. With regard to each container, the vessel stow plan must also include the container operator and the equipment number, equipment size and type, stow position, hazmat code, port of lading and port of discharge.
- *Container Status Messages (CSM)*: CSMs must be submitted to CBP daily for certain events relating to all containers laden with cargo destined for the U.S. by vessel. Carriers must submit a CSM when any of the required events occurs if the carrier creates or collects a CSM in its tracking system reporting that event. For

²⁹ Information based on CBP website:
http://www.cbp.gov/xp/cgov/trade/cargo_security/carriers/security_filing/

ISF requires that importers or their agents to provide eight data elements, generally no later than 24 hours before the cargo is laden aboard a vessel destined to the United States, for shipments consisting of goods intended to be entered into the United States and goods intended to be delivered to a foreign trade zone (FTZ). Those 8 data elements include identify of seller; Buyer; Importer of record number / FTZ applicant identification number; Consignee number(s); Manufacturer (or supplier); Ship to party; Country of origin; and Commodity Harmonized Tariff Schedule of the United States (HTSUS) number.

The SFI rule provides flexibility for importers with respect to the submission of four of these data elements. In lieu of a single specific response, importers may submit a range of responses for each of the following data elements: manufacturer (or supplier), ship to party, country of origin, and commodity HTSUS number. The ISF must be updated as soon as more accurate or precise data becomes available and no later than 24 hours prior to the ship's arrival at a U.S. port.

The Northern Border E-Seal Pilot Project³⁰

To test the performance of a tamper-proof seal as part of the U.S. Customs Container Security Initiative (CSI), the Northern Border E-Seal was developed as a pilot project for securing oceangoing sea containers and validating the performance of electronic container seals. The CSI initially consisted of four core elements:

- a) Establishing security criteria for identifying high-risk containers;
- b) Pre-screening containers before they arrive at U.S. ports;
- c) Using technology to pre-screen high-risk containers; and
- d) Developing and using smart and secure containers.

The objective of the CSI was to first engage the ports that send the highest volumes of container traffic into the United States, as well as the governments in these locations, in a way that would facilitate detection of potential problems at their earliest possible opportunity. The Northern Border E-seal Pilot Project was implemented beginning in May 2002 in Vancouver, British Columbia and at several truck and railroad border crossings between Canada and the U.S. The E-seal Pilot Project came about in conjunction with joint Canadian-U.S. efforts to perform customs clearance of freight away from the borders. A Volpe Center team conducted an evaluation of the pilot program and found that there were challenging problems in implementation of the Pilot Project as Customs inspectors at Vancouver electronically sealed the containers and other

³⁰ The Northern Border E-Seal Pilot Project Evaluation and Review, Final Report, Prepared for the United States Customs Service, Applied Technology Division, Volpe Center, U.S. DOT, September 17, 2002

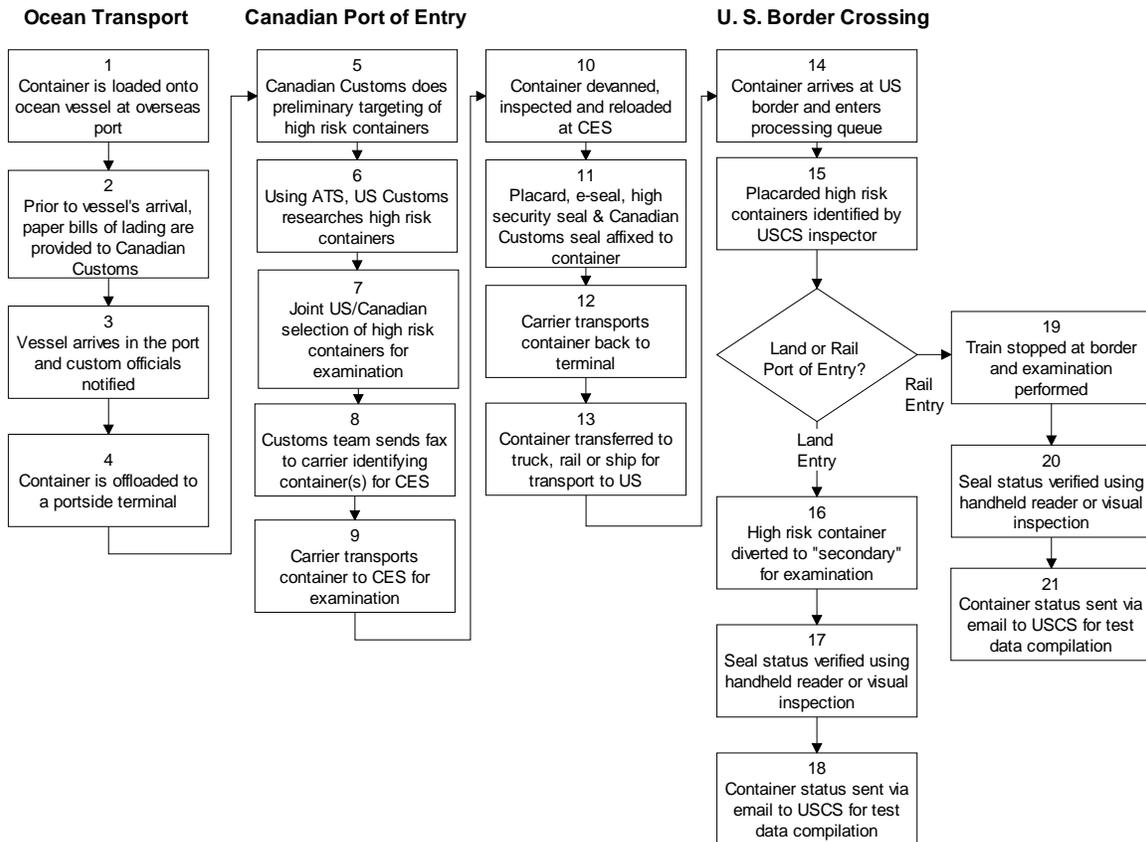
inspectors at selected border crossings read those seals on the high-risk containers. For example, it was difficult to visually identify the containers at busy border crossings. However, the project team concluded that on the whole, the objective of providing better seals for high-risk containers was achieved, and the application of e-seals on those containers is now a routine part of operation of the Vancouver Container Examination Station, and recommended that the project should be expanded.

The study noted that in order to expand the pilot to more Canadian ports or to other foreign ports, significant coordination was needed, starting at the US Customs headquarters level with their counterparts in the countries involved. While the process for the use of e-seals in this pilot could be improved upon (e.g., providing more automated data and better information on container destination,) the Pilot Project has demonstrated the viability of the process and identified the next steps should be to expand the use of e-seals to other ports. Expansion to other ports would require:

- Obtaining appropriate e-seals and readers in accordance with international standards and local restrictions
- Coordinating with appropriate customs organizations in other countries
- Improving means of identifying high-risk containers at U.S. borders
- Refining and obtaining approval for operating procedures at respective customs headquarters

The following chart depicts the movement of a container inbound to the Port of Vancouver destined for the United States. As noted above, this identification of high-risk containers had been underway in Canada for many years. The E-seal Pilot Program involved only the application, reading, and reporting on e-seals for high-risk containers. Appendix 1 shows the Process Flow the tracking the movement of the test containers in the Northern Border E-Seal Pilot Project. Figure 3 shows the process flow for tracking and flagging of high risk test containers.

Figure 3 - Process Flow for Tracking and Identification of High-Risk Containers



Source: Volpe Center, Northern Border Container Security Study

2.3 Maritime Security and Response Operations

Operation Neptune Shield and the Maritime Safety and Security Teams (MSST)

Operation Neptune Shield is a security matrix developed by the USCG as an internal plan to identify, prevent and protect facility and vessel operations from terrorist attacks with the potential for material consequences. This matrix establishes a protocol of risk awareness, surveillance, vessel tracking, air patrols, cutter presence, security zones, and security boarding at vessels.

Maritime Sentinel

The USCG is required by the SAFE Port Act of 2006 to develop an Area Port Security Plan for combating terrorism. Maritime Sentinel is the US Coast Guard Strategic Plan for Maritime Security. Maritime Sentinel describes the Coast Guard's efforts to combat maritime terrorism, in terms of Ports, Waterways, and Coastal Security (PWCS) activities and Extended Offshore Security Operations (EOSO). PWCS activities are those that focus mainly on inshore and near-shore regions, leveraging Captain of the Port (COTP)

authorities and the Coast Guard's relationships with State and local authorities, as well as the maritime industry. EOSO activities generally occur farther seaward and leverage the Coast Guard's presence and law enforcement competencies that apply throughout the full expanse of the maritime domain.

In March 2006, the Coast Guard published Maritime Sentinel, outlining its efforts to fight maritime terrorism through PWCS and EOSO coastal, shore-side and offshore security operations. The plan enables the USCG to assess threats, deal with the vulnerabilities, and set a course of action for implementing the plan and measuring its performance.

Three specially trained rapid response Maritime Safety and Security Teams (MSSTs) are among the Coast Guard's newest tools for combating terrorism in 361 major U.S. ports. Each MSST is composed of about 40 active duty Coast Guard officers equipped with armed boats and trained to patrol, detect and counter maritime terrorism threats in U.S. ports and waterways.

Non-Intrusive Inspection (NII) with Vehicle and Cargo Inspection Systems (VACIS)

VACIS is a family of cargo security system that supports the DHS strategic interest in promoting Non-Intrusive Inspection (NII) devices at the nation's ports of entry. VACIS uses gamma rays, naturally occurring isotopes widely used in industrial applications, instead of the conventional x-ray, to create high-resolution images of the contents of a cargo container. The VACIS gamma rays offer a radiation source with single energy, with higher effective penetration, measuring vehicle density and variances that can detect hidden compartments, voids, and cargo anomalies. It is smaller than the x-ray machines, and has proven safer, less costly, easier to use, and faster – takes 45 seconds to scan a loaded container. VACIS uses less power and requires little additional infrastructure, and easier to maintain, and potentially allows 100% inspection of all cargo. Ports of Jacksonville, Charleston, Miami, Vancouver, and Otay Mesa are among the U.S. ports of entry currently deploying VACIS, a system introduced and operated by Science Applications International Corporation (SAIC).

The Port of Jacksonville system is known as Portal VACIS, called Stolen Automobile and Recovery System (STARS), a system that provides real-time non-intrusive images of containerized cargo and can detect the presence of vehicles and other equipment to stem the illegal exportation of stolen vehicles. The system uses small Cesium-127 gamma ray sources and a detection tower located on a pedestal at port checkpoint. As the truck drives the container through the detection field, the inspector can scan the contents of the container without any need to stop the truck.

At the Port of Charleston, VACIS is being deployed as part of Project Seahawk, designed to investigate suspicious containers, cargo, vessels, boats, barges, events, person and businesses which may threaten the port. VACIS supports an information- and intelligence-sharing venture among the members of the Project Seahawk Task Force comprised of the FBI, ICE, CBP, USCG, South Carolina Law Enforcement Division, and local law enforcement agencies. The Port of Charleston website has an entry that

announces the candidacy of the Charleston Harbor as a site for a “port intelligence team.” The website points out that the harbor patrol team was established to work with the local Coast Guard, and law enforcement agencies, to showcase the VACIS and unmanned drones. For the demonstration of the unmanned drones, the website points out that a team from Space and Naval Warfare Systems will demonstrate an unmanned personnel watercraft to be used for surveillance.

Other types of NII inspection equipment include: Radiation Portal Monitors for detecting nuclear and radiological threats hidden in a container; Radiation Isotope Identifier hand-held devices to help inspectors to identify sources of radiation; and Personal Radiation Detectors, pager-sized devices used to detect localized sources of radiation. The increased availability and effectiveness of NII equipment provide support for the strategic objective of inspecting marine cargo without disrupting flow of commerce. As the performance of these technologies improves, the labor-intensive physical inspection of cargo will be less necessary.

Secure Border Initiative (SBI)

The Secure Border Initiative (SBI), launched in November 2005, is a comprehensive multi-year plan established to secure America’s borders, reduce illegal cross-border activity, and prevent terrorist attacks and other transnational crimes. In addition, SBI will coordinate DHS efforts to ensure the legal entry and exit of people and goods moving across our borders and the enforcement of immigration, customs, and agriculture laws at our borders, within the country and abroad. SBI focuses on effective integration of border security programs, and attempts to gain effective control of the borders through substantial investments in technology, infrastructure, and enforcement personnel. The SBI is an example of security strategies relying heavily on sensor information and data mining for assessing security risk levels. Some seven 7 key technologies are currently supporting the domestic security efforts underway for SBI and other initiatives, including: GPS location technologies; GIS and electronic chart and mapping; Biometrics; Wireless/RFID, Auto-ID, including Smart Card and travel document technologies; Portal/Web technologies/cyber system security/encryption; Data mining and interagency collaboration tools; Simulation and modeling tools; and Sensor technologies, including video surveillance.³¹

Among the components of SBI is a technology development program, *SBI*net initiative, launched to develop and deploys new integrated technology solutions to provide enhanced detection, tracking, response, and situational awareness capabilities. This mix, combined with existing resources, will assist front-line CBP personnel to more effectively deter, detect, and resolve illegal cross-border activity. A key part of the *SBI*net Technology Program is a Command, Control, Communications, and Intelligence (C3I) Common Operating Picture (COP), which will provide Border Patrol agents with real-time situational awareness of their area of responsibility and act as a force multiplier,

³¹ The Smart Border initiative was premised on a 30-point agreement involving the U.S. Customs Service, the border agencies in Canada and Mexico, and the TSA, among others. The USCS Container Security Initiative (CSI), the Customs Trade Partnership Against Terrorism (C-TPAT), Smart and Secure Trade-lanes, and the TSA/USCG maritime security initiatives – including Operation Safe Commerce (OSC) – are among the current demonstration projects.

allowing fewer agents to cover more ground. SBInet provides tactical infrastructure (including road and vehicle barriers and pedestrian fence) and through a COP for a uniform presentation of activities within specific areas along the border. Through integration of myriad signals from sensors, radars, and cameras, software and hardware a COP is created to be transmitted to the Command Center.

Customs and Border Protection (CBP), the agency within the DHS responsible for preventing terrorists and weapons of mass destruction (WMD) from entering the United States, has consolidated all marine assets, program and personnel and placed them under the newly titled Office of CBP Air and Marine. The Air and Marine CBP utilizes over 700 pilots, 267 aircraft (including the use of unmanned aircraft systems) and over 200 vessels. The Air and Marine forces provide support to CBP's anti-terrorism mission at U.S. borders including, air-to-ground interception of people and contraband illegally crossing land borders, air-to-air interception of aircraft, air-to-water interception of transportation vessels; and traditional duties relating to border interceptions unrelated to terrorism.

Section 3.0 Vessel and Port Security Programs in the U.S.

This section reviews the relevant MTS security components of the National Defense Reserve Fleet, the Military Sealift Command (MSC), the Maritime Security Program (MSP), and the National Port Readiness Network (NPRN).

3.1 The National Defense Reserve Fleet (NDRF) ³²

The Maritime Administration (MARAD) administers the National Defense Reserve Fleet (NDRF), established under Section 11 of the Merchant Ship Sales Act of 1946 to serve as a reserve of ships for national defense and national emergency purposes. Anchorages for NDRF vessels were originally located at the following ports: Stony Point in New York; Fort Eustis in the James River, Virginia; Wilmington, North Carolina; Mobile, Alabama; Beaumont, Texas; Benicia in Suisun Bay, California; Astoria in Oregon; and Olympia in Washington. At its peak in 1950, the NDRF consisted of 2,277 ships. Today, NDRF vessels are located at the James River, Beaumont and Suisun Bay anchorages and at designated port facility berths. The program primarily consists of dry cargo ships with some tankers and military auxiliaries. As of December 31, 2008, there were 186 vessels in the NDRF.

In addition to the vessels used by the U.S. Transportation Command (USTRANSCOM) for logistics, the NDRF has two vessels sponsored by the Missile Defense Agency for missile tracking. One vessel is currently operational and a second vessel is scheduled to be delivered in FY2010. The NDRF also includes 11 ships used for training purposes. The State Maritime Schools in New York, Massachusetts, Maine, Texas, California, and Michigan have 6 ships that are used for training merchant marine officers. There are 5 additional ships that are dedicated for military and homeland security training.

The Ready Reserve Force (RRF)

The Ready Reserve Force (RRF) was initiated in 1976 as a subset of the NDRF to support rapid deployment of the U.S. military forces worldwide and provide a ready source of surge shipping. The RRF is composed of a group of vessels maintained in a ready and reliable condition to provide strategic sealift to the armed forces of the United States and to provide, with the concurrence of the United States Transportation Command (TRANSCOM), humanitarian support during national emergencies.

The RRF is comprised of 52 vessels, primarily Roll-on/Roll-off type vessels, which DOD prefers due to ease of loading.³³ The RRF vessels, positioned throughout the United States, can be activated in 5 days, except for two ships that can be activated in 10 days

³²http://marad.dot.gov/ships_shipping_landing_page/national_security/ship_operations/national_defense_reserve_fleet/national_defense_reserve_fleet.htm

³³ As of October 1, 2008, per MARAD website <http://marad.dot.gov>

(per DOD-DOT Memorandum of Agreement). Recapitalization of the RRF is required, given that the age of RRF vessels ranges from 20 to 60 years old. Service life extension studies have estimated life extension takes ships to 50 years of age, if funding is available.

In 2005, in response to hurricanes Katrina and Rita, the Federal Emergency Management Agency (FEMA) used NDRF vessels to support relief efforts. Five RRF ships and four other NDRF ships were called into service. These ships supported the recovery mostly with relief and berthing for refinery workers, oil spill response teams, and longshoremen. To improve future ship-based responses and support, i.e., rapidly available, prepositioned supplies and ship-based command centers, the establishment of a dedicated Disaster Relief Fleet is being promoted.

3.2 The Military Sealift Command (MSC)

MSC is a United States Navy (USN) organization that controls most of the replenishment and military transport ships of the Navy. It first came into existence on July 9, 1949 when the Military Sea Transportation Service (MSTS) became solely responsible for the Department of Defense's ocean transport needs. The MSTS was renamed the Military Sealift Command in 1970.

MSC ships are civilian manned, and are referred to be as being in service, rather than in commission. Some, owned by the U.S. Government, have the prefix USNS, standing for United States Naval Ship, whilst others, on charter or equivalent, are simply the normal merchant MV or SS. Their hull numbers have the prefix *T-* in addition to the normal hull number that an equivalent commissioned U.S. Naval ship would have.

MSC is comprised of four programs: Sealift, Naval Fleet Auxiliary Force (NFAF), Special Mission, and Prepositioning. The Sealift program provides the bulk of MSC's supply-carrying operation and operates tankers for fuel transport and dry-cargo ships that transport equipment, vehicles, helicopters, ammunition, and supplies. The NFAF's role is to directly replenish ships that are underway at sea, enabling them to deploy for long periods of time without having to return to port. The Special Mission program operates vessels for unique military and federal government tasks, such as submarine support and missile flight data collection and tracking. The Prepositioning program sustains the U.S. military's forward presence strategy by deploying supply ships in key areas of the ocean.

3.3 Maritime Security Program (MSP)

On October 8, 1996, the President signed the Maritime Security Act of 1996 establishing the Maritime Security Program (MSP) for Fiscal Years (FY) 1996 through 2005. On November 24, 2003, the President signed the National Defense Authorization Act for Fiscal Year 2004, which contained the Maritime Security Act of 2003 (MSA 2003) reauthorizing the MSP for FY 2006 through FY 2015.

MSA 2003 requires that the Secretary of Transportation, in consultation with the Secretary of Defense, establish a fleet of active, commercially viable, militarily useful, privately-owned vessels to meet national defense and other security requirements. MSA 2003 authorizes \$156 million annually for FYs 2006, 2007, and 2008; \$174 million annually for FYs 2009, 2010, and 2011; and \$186 million annually for FYs 2012, 2013, 2014 and 2015 to support the operation of 60 U.S.-flag vessels in the foreign commerce of the United States. Participating operators are required to make their ships and commercial transportation resources available upon request by the Secretary of Defense during times of war or national emergency.

The MSP maintains a modern U.S.-flag fleet providing military access to vessels and vessel capacity, as well as a total global, intermodal transportation network. This network includes not only vessels, but logistics management services, infrastructure, terminal facilities and U.S. citizen merchant mariners to crew the government owned/controlled and commercial fleets.

The MSP carriers are required to commit 100 percent of their MSP vessel capacity to Stage III of the Department of Defense (DOD) approved Emergency Preparedness Program and Voluntary Intermodal Sealift Agreement (VISA). The MSP contributes over 77 percent of the total capacity committed to VISA (See below.) The Voluntary Tanker Agreement (VTA) is another security agreement contained in the MSP. As of October 1, 2008, the MSP fleet consisted of the following 12 carriers and 59 vessels:³⁴

1. American International Shipping, LLC (1 RO/RO vessel)
2. APL Marine Services, Ltd. (9 containerships)
3. Central Gulf Lines, Inc. (4 RO/RO vessels)
4. Fidelio Limited Partnership (7 RO/RO vessels)
5. Hapag-Lloyd USA, LLC (5 Geared Container vessels)
6. Liberty Global Logistics (1 RO/RO vessel)
7. Maersk Line, Ltd. (17 containerships and 2 Geared container vessels)
8. Marmar Tanker LLC (1 tanker)
9. Luxmar Tanker LLC (1 tanker)
10. Patriot Shipping LLC (1 Heavy Lift)
11. Patriot Titan LLC (1 Heavy Lift vessel)
12. Waterman Steamship Corp. (2 RO/RO, 2 Geared Container vessels.)

Voluntary Intermodal Sealift Agreement (VISA)

The Voluntary Intermodal Sealift Agreement (VISA) program is a partnership between the U.S. Government and the maritime industry to provide the DOD with assured access to commercial sealift and intermodal capacity to support the emergency deployment and sustainment of U.S. military forces.

³⁴ A 13th carrier, Farrell Lines Inc. (with 2 Ro/Ro vessels and 3 containerships) has since been bought by P & O Nedlloyd, and subsequently purchased by Maersk, as noted by Richard Lolich, MARAD.

The VISA program is authorized under the Maritime Administration's authority under the Defense Production Act of 1950, and the Maritime Security Act of 2003, and was approved as a DOD commercial sealift readiness program on January 30, 1997. The program provides for a time-phased activation of state-of-the-art commercial intermodal equipment to coincide with DOD requirements while minimizing disruption to U.S. commercial operations. The VISA program can be activated in three stages as determined by DOD with each stage representing a higher level of capacity commitment. In Stage III participants must commit at least 50 percent of their capacity. Dry cargo vessels enrolled in the Maritime Security Program must commit 100 percent during Stage III.

3.4 National Port Readiness Network (NPRN)

In 1984, a Memorandum of Understanding (MOU) on Port Readiness established the National Port Readiness Network (NPRN) to help train port and DOD personnel in using relevant emergency procedures and coordinates deployment through ports. The NPRN is an organization made up of an executive level Steering Group, a staff level Working Group and local Port Readiness Committees (PRCs). The NPRN is comprised of nine federal agencies:

- the U.S. Coast Guard (USCG);
- the Surface Deployment and Distribution Command (SDDC);
- the Military Sealift Command (MSC);
- the Transportation Security Administration (TSA);
- the United States Transportation Command (USTRANSCOM);
- the U.S. Northern Command;
- the U.S. Army Forces Command;
- MARAD; and
- the U.S. Army Corps of Engineers.³⁵

The agencies missions are to support the secure movement of military cargo during deployments or other national emergencies. This training and coordination is accomplished through the local NPRN Port Readiness Committees. National Port Readiness Steering Group and National Port Readiness Working Groups are organizations providing coordination and cooperation to ensure readiness of commercial ports to support force deployment during contingencies and other defense emergencies.

Members of the NPRN Steering Group provide policy direction and set broad priorities for accomplishing the objectives set forth in the MOU. The Working Group is then responsible for implementing the policies and priorities set by the Steering Group. Overall, the Federal agencies and organizations who are party to the MOU have responsibility for support of the movement of military forces and supplies through U.S. ports in a national emergency.

³⁵ NPRN components have been updated to change Maritime Defense Zones to Northern Command; change the US Joint Forces Command to the TSA; change Military Traffic Management to SDDC, per http://www.marad.dot.gov/ports_landing_page/nprn/home.htm

The NPRN has established Port Readiness Committees (PRCs) at each of the designated 15 strategic commercial ports. The PRCs are chaired by the USCG Captain of the Port (COTP), and provide a mechanism to coordinate peacetime preparations for emergency port operations and for coordinating port operations during an actual national defense emergency.

The NPRN has been addressing port security concerns through national training workshops, PRC meetings, port readiness exercises (PRXs) and the use of the Incident Command System (ICS) during deployments. The ICS is a unified command structure that provides efficient coordination of port security during military deployments. The NPRN organization performed successfully during Desert Storm and Desert Shield. Last year, MARAD, in cooperation with the American Association of Port Authorities and the NRPN, sponsored a "National Strategic Commercial Port Workshop." Port and waterways security was specifically identified as a priority issue at this workshop. MARAD also continues its outreach and training efforts in order to elevate the awareness of strategic port operations and port security. To maintain heightened readiness and performance at strategic ports, MARAD assisted its NPRN partners in conducting port readiness assessments, monthly readiness status reports, mobilization planning, vulnerability assessments, and improving the deployment process. MARAD has also partnered with other agencies in the development of risk assessments at the strategic ports. For example, MARAD participated in the vulnerability assessments conducted by the Defense Threat Reduction Agency (DTRA) and the USCG at four strategic commercial ports. These assessments helped establish the methodology for future assessments. MARAD, as part of its semi-annual port readiness assessment, also conducts a general assessment of port security, and has worked closely with USTRANSCOM on its Critical Infrastructure Protection Program. USTRANSCOM has emphasized the security importance of its relations with their partner strategic seaports through involvement in the NPRN, pointing out that the NPRN ensures military and commercial seaport systems are ready to support deployment of military cargo.³⁶

Strategic Ports

The National Port Readiness Network (NRPN) consists of 15 DOD-designated strategic commercial ports and 5 strategic military ports. The NRPN Memorandum of Understanding (MOU) on Port Readiness (revision 6), requires that these ports be made available for contingency military operations. Per the NRPN MOU, the local Coast Guard COTP chairs the Port Readiness Committee established in each NPRN strategic seaport, thus leads the planning and coordination of the port level goals of the NPRN: to ensure military and U.S. commercial seaport and related intermodal system readiness to support the secure deployment of military personnel and cargo in the event of mobilization or other national emergency through enhanced coordination and cooperation among the NPRN stakeholder agencies.

³⁶ Statement of General Norton A. Schwartz, USAF, Commander, United States Transportation Command (USTRANSCOM), Before the House Armed Services Committee, On the State of the Command, March 21, 2007.

The National Shipping Authority (NSA) has granted MARAD control over national vessels and ports at times of emergency. MARAD oversees planning of these ports to provide end-to-end supply chain support for delivery of equipment and supplies throughout the world. The DOD relies on these ports for delivery of equipment and supplies throughout the world. There are 15 strategic commercial ports and 5 strategic military ports (with Charleston serving both as a commercial and military port, creating a total of 19 strategic ports). Below are the 19 strategic ports (with the strategic military seaports indicated with an “*”):

1. Anchorage, Alaska
2. Tacoma, Washington
3. *Indian Island, Washington
4. Oakland, California
5. *Military Ocean Terminal Concord (MOTCO), California
6. Long Beach, California
7. *Port Hueneme, California
8. San Diego, California
9. Corpus Christi, Texas
10. Beaumont, Texas,
11. Jacksonville, Florida
12. Savannah, Georgia
13. Charleston, South Carolina (both a strategic commercial and military port)
14. Wilmington, North Carolina
15. Morehead City, North Carolina
16. *Military Ocean Terminal Sunny Point (MOTSU), North Carolina
17. Norfolk, Virginia
18. Philadelphia, Pennsylvania
19. New York, New York

These seaports have assets that are used not only for mobilization for military operations, but also to address threats to the homeland and threats from natural disasters. The majority of these strategic ports are national leaders in deployment of technology-intensive advance security initiatives. Among them are projects for ensuring personnel security with deployment of technologies such as biometrics and smart ID cards and gate control devices; monitoring vessel transit and ensuring navigation security with deployment of systems such as Vessel Traffic Service (VTS), Automatic Identification System (AIS) and electronic Aids to Navigation (AtoN); conduct cargo screening and secure containers with technologies such as electronic seals (e-Seals) and Vehicle and Cargo Inspection Systems (VACIS); and monitor the security of the supply chain through deployment of programs such as Container Security Initiative (CSI), Operation Safe Commerce (OSC) and Smart and Secure Tradelanes (SST). Some of these initiatives are reviewed in Section 2.0

Port Security Grant Program (PSGP)

The PSGP provides grant funding to port areas for the protection of critical port infrastructure from terrorism. PSGP funds are primarily intended to assist ports in enhancing maritime domain awareness (MDA), enhancing risk management capabilities to prevent, detect, respond to and recover from attacks involving improvised explosive devices (IEDs), weapons of mass destruction (WMDs) and other non-conventional weapons, as well as training and exercises and Transportation Worker Identification Credential (TWIC) implementation.

Section 4.0 The Cost Impacts of Compliance with the MTS Security Programs

4.1 Criteria for Assessing Program Impacts

The array of programs and initiatives evaluated in the previous sections has economic impacts as well as impacts on marine container security and operational efficiency. The economic impacts of security program can be evaluated with respect to a number of broadly accepted efficiency and cost effectiveness criteria. In general, three criteria are commonly used for assessing a program's performance and evaluating success of government projects:

1. Do the countermeasures work? This criterion has to do with the *efficacy* of the program elements: Do the security measures result in improved agency capability for detection, defense and protection, and avert potential threats?
2. Are the programs worth the costs? Are the countermeasures *efficient*? Is the ratio of output (benefits from improved security) divided by input (program implementation and resource costs) positive?
3. Do the countermeasures work better than other alternative strategies? This has to do with *cost effectiveness* of each program and asks: Among alternative approaches and technologies to prevent security threats, which one meets the long-term MTS security goals of USCG/DHS or the nation as a whole? ³⁷

The threefold NIPP performance criteria outlined previously have the following implicit performance criteria:

- Do they prevent, detect, and deter threats to maritime security?
- Do they enhance the resiliency of the maritime infrastructure?
- Are they cost effective: i.e., do they help derive maximum value out of the resources expanded?

This section focuses on the efficiency and cost-effectiveness of the programs implemented in compliance with the MTSA 2002 and the 2006 SAFE Port Act.

³⁷ Distinctions between *efficacy* and *effectiveness* and the human factors issues involved in product use need to be noted as critical to the analysis of the impact of any technology. *Efficacy* of a product such as radiation detectors, etc. may be close to 100 percent on the condition that it is used as prescribed and with full training and required operator skill. *Effectiveness* of a technology deployed under diverse use conditions, however, may be far less than 100 percent, because of the myriad intervening factors.

4.2 Calculating the Economic Impacts of Security Mandates: EO 12866

The MTSA security requirements and mandates have an economic impact. The security benefits of these mandates should be weighed against the economic costs to the users of the Nation's maritime resources.

The Executive Order 12866 directs all Federal agencies to develop both preliminary and final regulatory analyses if their proposed regulations are likely to be "significant regulatory actions" that may have an annual impact on the economy of \$100 million. The Executive Order also requires a determination as to whether a proposed rule could adversely affect the economy or a section of the economy in terms of productivity and employment, the environment, public health or safety. In accordance with the regulatory philosophy and principles provided in Sections 1(a) and (b) and Section 6(a)(3)(C) of Executive Order 12866, an economic analysis of the proposed regulatory changes is required.³⁸

Estimated Costs of MTSA Implementation

In accordance with Executive Order 12866 the USCG conducted a preliminary cost estimate of the MTSA implementation. The USCG estimated that its rules for facilities and vessels would have an annual cost of \$832 million in current, undiscounted dollars, proving the MTSA implementation to be a "significant regulatory action" with an annual effect on the economy in excess of \$100 million. Based on this annual cost estimate, a Government Accountability Office (GAO) report issued in June 2004 report estimated the total cost of MTSA implementation and compliance at \$7.3 billion over a 10-year period from 2003 to 2012. More than 90 percent of these costs were incurred by vessels and facility owners in order to comply with the requirements of increased security for facilities and vessels.³⁹

Consistent with best practices for preparing economic analysis of significant regulatory actions, the GAO was interested in conducting a sensitivity analysis on the cost estimates generated by the USCG to explore other implementation cost elements. For this purpose, the GAO conducted "uncertainty analysis" on the cost estimates, deploying a Monte Carlo simulation tool that generates random numbers to measure the effects of uncertainty. The simulation was based on a number of assumptions about the probability distributions of the values the USCG used to estimate the labor and equipment costs. The GAO simulation model found that the USCG compliance cost estimates of \$7.3 billion could be more than \$1 billion higher or lower, using generalized assumptions about cost uncertainty.

³⁸ OMB, "Economic Analysis of Federal Regulations under Executive Order 12866," January 11, 1996 <http://www.whitehouse.gov/omb/inforeg/print/riaguide.html>

³⁹ GAO, "Maritime Security: Substantial Work Remains to Translate New Planning Requirements into Effective Port Security," GAO-04-838, June 2004.

The GAO analysis further concluded that the MTSA security-related requirements are not limited to a 10-year period. Consistent with best practices for preparing economic impact analysis called for by Executive Order 12866, the GAO study found that extending the analysis period by 10 years to 2022 would raise total costs by nearly 50 percent to \$10.7 billion. The average annual cost to the industry under the extended impact period, according to GAO, would be \$884 million in current, undiscounted costs of operation and maintenance, equipment replacement, and security guard costs incurred with each additional year. Table 4 compares the results of cost estimates by the USCG and the GAO for two time periods: 2003-2012 and 2003-2022.

Table 2 – Estimates of the MTSA Compliance Costs

Compliance Cost Component	Number of Entities Involved	USCG MTSA Cost Estimates (2003-2012) (\$Millions)	GAO Cost Estimates (Monte Carlo Uncertainty Analysis (2003-2012) \$Million)
Securing facilities	4,965 Facilities	\$5,400	\$4,500 - \$6,400
Securing vessels	10,234 Vessels	\$1,400	\$1,200 - \$1,500
Other costs	NA	\$500	\$500
Total Compliance Costs (2003-2012) \$Billion	15,199 Facilities and Vessels	\$7,300	\$6,200 - \$8,400
Total Compliance Costs (2003-2022) \$Billion (GAO Monte Carlo Analysis)			\$10,700
Annual Costs (2003-2012)		\$832/yr	
Annual Costs (2003-2022)			\$884/yr

Source: GAO, “Maritime Security: Substantial Work Remains to Translate New Planning Requirements into Effective Port Security,” GAO-04-838, June 2004

The USCG and GAO estimates of the MTSA compliance costs included only the added labor costs for preparing plans and guarding the facilities and purchasing detection and access control equipment. The costs estimates did not extend beyond the marine transportation industry. For instance, the costs did not include losses associated with possible delays experienced by users in gaining access to more secure port facilities and the services they provide. Nor did the estimates include incremental costs borne by the USCG to develop and enforce these new requirements. Also excluded from the costs of security were higher prices for goods and services as the maritime industry tries to pass along higher security costs to its customers. For instance, higher shipping rates could mean reduced water transportation services and reduced consumption and production of goods and services dependent on those services and the associated economic losses.

The net effects of the above considerations, taking into account the tradeoff of the added security benefits, the associated costs of compliance – direct and indirect, measured and unmeasured – and other impacts are not known. The potentials tradeoffs of security benefits and the economic costs were considered in the June 2004 GAO report which considered the concerns for disruptions in free and expeditious flow of goods, particularly with respect to just-in-time deliveries. In this respect, the GAO cautioned that

100 percent security is not achievable, and concluded the report with a caveat that: “total security cannot be bought no matter how much spent on it.”⁴⁰

Estimated MTSA Compliance Rate

Compliance rate with the MTSA requirements was relatively high. Overall, 3,150 facilities, 9,200 vessels operating in over 300 ports nationwide were required to submit plans identifying a) access control; b) response to threats; and c) drills and training. By December 31, 2003, vessels and facilities subject to MTSA requirements had to submit security plans to the USCG for review; or alternatively, self-certify that their plans would be developed and implemented by July 1, 2004. By the December deadline, 90 percent of the facilities and vessels had met the deadline (with penalties to the amount of \$10,000 issued to entities that had failed to comply.)⁴¹

4.3 Economic Costs of a Transportation Security Incident (TSI) and Port Disruption

Costs of compliance with mandated security plans and preventive measures should be compared to the costs of not taking appropriate measures to avert potential threats. This section reviews only the evidence on the economic costs of transportation security incidents (TSI) and other incidents that have disrupted port operations and led to port closure.

Port closure, whether due to natural disasters, labor strikes or terrorist threats, has become a relatively common occurrence in recent years. Studies have suggested that loss of trade revenues arising from an actual or anticipated port closure could not only result in losses to ports, shippers, and vessel operators, but also be manifested through indirect economic losses to regions or losses due to the emergence of new networks of shipping lanes and cargo handling facilities.

Estimates of the economic losses from the September 11, 2001 terrorist attacks were initially estimated at \$40 billion in direct losses from the attacks. The full extent of direct, indirect, and secondary losses to the economy was estimated at \$165 billion when a team of researchers at Duke University calculated the cascading ripple effects on the economy.⁴²

A simulation of a terrorist attack at a single commercial port that results in temporary closure of all commercial ports in the U.S. arrived at estimated losses of \$58 billion to the U.S. economy. The costs included losses from spoilage, lost sales, manufacturing

⁴⁰ GAO, “*Maritime Security: Substantial Work Remains to Translate New Planning Requirements into Effective Port Security*,” GAO-04-838, June 2004.

⁴¹ 5,923 facilities or vessels prepared under option B (234 facilities; 5689 vessels); while 2,913 facilities or vessels prepared plans under option A.

⁴² Campbell R. Harvey, Duke University, “The Financial and Economic Impact of September 11, 2001,” October 8, 2001.

slowdowns, and a halt in production of goods and service relying on seaports. Consulting firm Booz Allen and Hamilton, and the Conference Board sponsored the simulation in 2002. The simulation process consisted of a panel of representatives from the industry and government who participated in development of a scenario involving port shut down subsequent to detonation of a bomb hidden in a cargo container.

The Brookings Institution developed several threat scenarios in 2002 to estimate the consequences of a successful terrorist attack.⁴³ One threat scenario consisted of a high-consequence, low-probability attack involving biological agent or a weapon of mass destruction (WMD) such as a bomb shipped by container and detonated in a major U.S. city, with the potential damage to the economy of as much as \$1 trillion. Other attack scenarios involving explosives with some loss of life and property damage were estimated to have economic impacts in the range of billions of dollars. The study assumed port vulnerabilities to stem from inadequate security measures as well as from challenges of monitoring the vast and rapidly increasing volume of cargo, persons, and vessels passing through the ports.

To provide a frame of reference for the scale of losses from a terrorist attack compared to disruptions caused by economic factors, several studies can serve as a benchmark. In the aftermath of the 10-day shutdown of the Southern California container ports in 2002 due to a labor dispute, a study by Martine Associates estimated the losses from the disruption in container movement at \$1.96 billion per day.⁴⁴ This estimate of the economic impact of a port closure has been widely believed unreliable and inflated. The Congressional Budget Office (CBO) conducted a study in 2006, largely to correct the \$1.96 billion estimate, estimated the costs based on the scenarios similar to the 2002 West Coast labor dispute. The CBO study examined two scenarios: a 1-week shutdown and a 3-year shutdown of operations at the Ports of Los Angeles and Long Beach. The one-week shutdown was estimated to lead to losses between \$65 million to \$150 million per day, with an estimated loss of \$450 million for an average week of shutdown. The 3-year shutdown was estimated to lead to greater losses, estimated to amount between 0.35 percent and 0.55 percent of the Gross Domestic Product (GDP), equivalent of a loss of \$45 billion to \$70 billion per year. The CBO study assumed that in the aftermath of the closure, the backlog of ships waiting to enter ports would be resolved by a number of strategies, including carrier flexibility to shift port calls to alternative ports, reconfigured supply chains (albeit at higher costs), and the possibility that producers might turn to domestic sources of supply and consumers consume a different mix of goods.⁴⁵ Another study conducted for the Department of Labor in 2002 estimated that a 7-day shutdown of container traffic through the ports of LA/LB would generate losses to the economy of roughly \$75 million per day.

⁴³ Protecting the American Homeland: A Preliminary Analysis, Michael E. O'Hanlon, Peter R. Orszag, Ivo H. Daalder, I.M. Destler, David L. Gunter, Robert R. Litan, James B. Steinberg, Washington, D.C. Brookings Institution Press, 2002.

⁴⁴ The estimated losses of \$1.96 billion per day were based on Martin Associates, *An Assessment of the Impact of West Coast Container Operations and the Potential Impacts of an Interruption of Port Operations*, 2000.

⁴⁵ Congressional Budget Office (CBO), *The Economic Costs of Disruptions in Container Shipments*, March 29, 2006. http://www.cbo.gov/ftpdoct/71xx/doc7106/03_29_container_shipments.pdf

5.0 Effectiveness of the Current Security Strategies in Creating a Resilient MTS

This section evaluates the extent to which the components of MTS security strategies enable the maritime security community to effectively meet the performance criteria laid out in the National Infrastructure Protection Plan (NIPP) and the National Strategy for Maritime Security (NSMS).

Driving the NIPP strategies for protection of the nation's critical infrastructure and key resources (CIKR), as noted in Section 3.0, are three key goals for detecting and preventing attacks, ensuring system resiliency, and prioritizing investment plans to ensure cost effective measures. This section evaluates the current MTS security strategies with respect to these goals:

- Prevent, deter and detect threats;
- Enhance resiliency; and
- Use resources cost effectively.

These goals will be evaluated within the risk and resiliency assessment framework created in previous task reports, characterizing system resiliency as:⁴⁶

- a) System conditions that serve as preventive measures, make the system more fault tolerant, and reduce the totality of the events that “can go wrong”;
- b) Layered monitoring capabilities with built-in redundant components that mitigate the vulnerabilities;
- c) Response, intervention, mitigation, and recovery capabilities that reduce severity of the consequences of an accident; and
- d) Access to planning and preparedness information and intelligence to make the system adaptive to disruption.

This section describes the elements of a framework for creating a resilient and survivable MTS and the strategic use of risk analysis through risk assessment systems such as the Maritime Risk Analysis Model (MSRAM). The section builds on the strategies promoted by the MTSA 2002 and the SAFE Port Act of 2006, and the core concepts and overarching elements of the MTS security articulated in Section 1.0 on *Maritime Domain Awareness* (MDA) and a *layered defense-in-depth*, for a security strategy that uses information to protect and detect threats, build a resilient MTS, and make efficient use of the limited resources available.

⁴⁶ Discussions of resiliency are loosely based on Erik Hollnagel, David D. Woods, Nancy Leveson, editors, *Resilience Engineering: Concepts and Precepts*, Ashgate, 2006.

5.1 A Framework for Creating a Resilient and Survivable MTS

In this report, in the context of addressing MTS security risks, the terms *resiliency*, *survivability*, *continuity of operations*, and *sustainability* are used interchangeably to refer to the ability of the marine transportation network to sustain system functions.

Ultimately, achieving sustainability can be done only through a systemic approach that builds security into the transportation system.

A risk management strategy for enhancing system survivability and resiliency addresses system vulnerabilities through a three-pronged approach of: a) reducing the exposure of the infrastructure components/user population to harm by integrating the multitude of countermeasures and technology solutions for protection and response; b) increasing the hardiness and robustness of the critical infrastructure, in part by reducing the probability of single-point failures; and c) enhancing the infrastructure resilience to help with recovery from a disruption and resume normal operations.

Building robustness reduces system vulnerability through well-designed fault tolerant infrastructures and security systems that are integrated with transportation operations. A 2002 National Research Council report has concluded that infrastructure security elements, taken together, can provide a multi-tiered security system that not only deters and protects but also improves safety, thus potentially making the system more efficient. Such integration would require the concerted and coordinated efforts of federal, state, and local law enforcement authorities and other public and private entities, the report recommends, to plan, develop, own, and operate transport infrastructure and assets and the agencies responsible for border/freight security and safety.⁴⁷

Building robust MTS infrastructures can take two forms: design-level hardening of new facilities and terminals, and perimeter-protection measures for existing facilities. Design-based hardening can be done during construction of new infrastructure facilities and vessels, or by incorporating cost-effective features when refurbishing the existing ones to create blast-resistant structures and emergency evacuation routes. Perimeter protection measures can be added where free access is not required, e.g., terminal gate or on-dock rail yard, fences, police patrols. R&D efforts at the Sandia National Laboratories' Intelligent Robust Infrastructure Systems (IRIS) program provide a good example of efforts to build infrastructures that "are aware, actively adapt, preserve their function, and protect their users." IRIS relies on readily available tools to develop intelligent systems for some types of infrastructure, while striking a balance between human control and intelligent machines. Some examples of the Sandia IRIS project include systems with real-time bio-detectors, and a wide-band web of intelligent sensors. These networks of sensors can be built around buildings and infrastructures, or around a region covered with an information web of ubiquitous sensors, resulting in a system of buildings or even cities that are instrumented to make them interconnected and able to share information with each other and help with decision-making, adaptation and response.⁴⁸

⁴⁷ National Research Council, *Deterrence, Protection, and Preparation: The New Transportation Security Imperative*, TRB Special Report 270, 2002.

⁴⁸ Gerald Yonas, Presentation at MIT, Sandia National Laboratory, 2002.)

As an engineering discipline, designing resilient and survivable critical infrastructure focuses on identifying the influence of the design, configuration, and operation of city and regional infrastructures on the ability of these structures to withstand disasters. The Institute for Civil Infrastructure Systems (ICIS), New York University, for instance, is conducting research and training on the elements of resilient infrastructure, including the concept of “structure monitoring” which creates a system for “sensing” the relevant structures through the use of built-in fiber-optic sensors. The sensors monitor the facilities’ structural changes to see if the structure is deteriorating or how it would respond to adverse events.⁴⁹ Survivability lessons from the 9/11 disasters are significant. Researchers have maintained that resilient communities or systems have in place robust systems and institutions that possess a good deal of redundancy, and fare the best under disaster. They provide support for the general premise that resilient communities (i.e., those able to recover quickly) are those having in place robust (failure-resistant through design and/or construction techniques) systems and institutions that possess a good deal of redundancy (duplicative capacity for service delivery) usually fair the best in the face of natural or man-made disruptions.⁵⁰

Building Efficient Layers of Redundancy

Redundancy, defined as building duplicate countermeasures to prevent the failure of an entire system subsequent to the failure of a single component, has traditionally been associated with inefficiency, poor inventory management. Strategies for reducing redundant supply chain elements include practices such as supplier consolidation, just-in-time (JIT) inventory control, “lean inventories” and “pull logistics” are common concepts and strategies associated with efforts to eliminate redundancy. Redundancy is, however, a core component of managing the vulnerabilities of a system to create a sustainable transportation system.

In the context of survivability principle, redundancy could be an economically efficient method of dealing with security threats, even though it is likely to generate potential inefficiencies, when viewed as short-term tactics. Building redundancy, in the context of managing systemic risk, incorporates key elements of building survivable transportation system. However, redundancy is not the equivalent of senseless duplication and inefficiency. Analytical efforts to balance a security measure’s cost against its effectiveness – as discussed above in the definition of layered defense-in-depth concept – could provide a safeguard against inefficient duplication. In general, even if deployment of multiple layers of detection-protection devices has potential efficiency tradeoffs, in the long run redundancy can be conducive to greater efficiency if deployed as part of a layered system of reducing vulnerabilities and preventing threats from materializing.

⁴⁹ Zimmerman, Rae 2002b. “Building Resilient Infrastructure to Combat Terrorism: Lessons from September 11,” Lecture at MIT’s Technology and Policy Program and Engineering Systems Division, November 14.

⁵⁰ Zimmerman, 2002a, “Enhancing Resilience of Integrated Civil Infrastructure Systems. Proceedings of the Workshop on Lessons Learned” SUNY, Multidisciplinary Center for Earthquake Engineering Research.

Building Resiliency and Survivability by Hardening the Vulnerable Infrastructure Components

Vulnerability assessment is a systematic examination of a system or facility to determine the adequacy of security measures. Narrowly defined, vulnerability assessments identify security deficiencies, provide data from which to predict the effectiveness of proposed security measures, and confirm the adequacy of such measures after implementation.⁵¹ A process used by the U.S. Navy to assess the vulnerability of each potential Navy asset target illustrates the application of vulnerability assessment as a method for enhancing system resiliency and survivability. The criteria for selecting deterrence and protective measures to reduce system vulnerability are based on how the efficacy as well as cost-effectiveness of the measures.

At a December 12-13, 2001 conference on Energy Assurance, a team of experts from Argonne National Laboratory presented lessons learned from industry Vulnerability Assessments conducted in the aftermath of September 11. Argonne's Vulnerability and Risk Analysis Program (VRAP) – initiated in 1998 to focus on electric power and then expanded to all energy infrastructure and their interdependencies with other critical infrastructure – was designed to utilize DOE's expertise to enhance energy infrastructure security by creating awareness of the risks and providing assistance in conducting vulnerability assessments. The assessment process is used to develop a database to evaluate the identified vulnerabilities against, categorize key assets, and develop a plan for managing the risks and building internal expertise and security safeguards.⁵² The VRAP vulnerability assessment is based on six key vulnerability criteria:

- Susceptibility to physical attacks using readily available weapons
- Susceptibility to physical attack using difficult to acquire weapons
- Susceptibility to physical attacks from insiders
- Unprotected facilities
- Minimally protected facilities
- Susceptibility to cyber attack.

The DOE/Argonne VRAP model (outlined in Appendix 3) emphasizes a *system of systems* perspective for assessing the vast interdependencies between the energy infrastructure and the rest of the critical infrastructure, pointing out the challenges for ensuring security and reliability in circumstances of lost or degraded infrastructure, which would in turn adversely affect the performance under conditions of normal or distressed operations, disruptions, and repair/restoration. The VRAP model uses four criteria to quantify the extent to which the target is vulnerable: a) ability to detect threat; b) ability to respond to threat; c) the extent of its hardiness; and d) the complexity of attack.

The countermeasures selected to mitigate these vulnerabilities should prove cost effective with respect to these metrics. The Navy model describes the vulnerability of a potential

⁵¹ David Mussington, "Concepts for Enhancing Critical Infrastructure Protection: Relating Y2K to CIP Research and Development, RAND Corp. 2002.

⁵² Based on slide presentations by Ron Fisher and Jim Peerenboom, Argonne National Laboratory, "Lessons Learned from Industry Vulnerability Assessment and September 11th" prepared for DOE, Energy Assurance Conference, December 12-13, 2001, Arlington, VA, available at <http://www.anl.gov>.

target as follows: “Very High”: if an attack would be defeated or unsuccessful less than 10 out of 100 times; “High”: if an attack would be defeated or unsuccessful up to 1 out of 4 times, and so on to very low to medium vulnerability.

5-2 Risk Assessment and Information-Sharing as Core Components of Resiliency

As noted above, MTS adaptiveness, enhanced through capability to access real-time intelligence and risk-informed activity information, is a key component of resiliency as well as MDA. Risk assessment models and intelligence-sharing and data mining protocols are two key mechanisms for facilitating this process.

Maritime Security Risk Analysis Model (MSRAM)

Section 111 of the Security and Accountability for Every Port (SAFE Port) Act requires that the Maritime Security Risk Analysis Model (MSRAM) be used by the COTPs/ Federal Maritime Security Coordinators (FMSCs) and Area Maritime Security Committees (AMSC) to analyze and prioritize scenario-based risks within their areas of responsibility. The tool is also designed to measure risk reduction potential in the evaluation of port security grant program proposals. FMSC and AMSCs are required to validate the MSRAM data on annual basis.

MSRAM is designed as a risk based decision support tool to be used by COTPs, FMSCs, and AMSCs for identifying and prioritizing critical infrastructure and key resources (CIKR) and high consequence transits and events across sectors using a common risk methodology, taxonomy and metrics to measure security risk at the local, regional, and national levels.

MSRAM is used for preventing terrorist attacks, and to inform risk management plans in areas of reducing vulnerabilities, minimizing the resulting damages if prevention fails, and recovering from attacks that do occur:

- For prevention, MSRAM is used to assess terrorist intent and capability so that resources could be focused on *deterrence and interdiction*.
- For reduction of vulnerabilities, MSRAM is used to assess ability of owner/operator, local law enforcement and USCG forces to *protect* targets;
- For minimizing the consequences, MSRAM is used to assess ability of owner/operator, local first responders, and USCG to *respond* to attacks that do happen;
- For recovery from attacks, MSRAM estimates the primary and secondary economic impacts of the scenario considering the *recoverability* and *redundancy* of the system.

The MSRAM review process includes the following phases, with a feedback loop back process for reiterative assessment or risks:

Phase 1. Federal Maritime Security Coordinators (FMSC) and Sector Assessment (with AMSC input);

- Phase 2. District Review;
- Phase 3. Area Review;
- Phase 4. HQ Assessment, Review and Analysis.

Intelligence-Sharing and Data-Mining

The NIPP and National Maritime Strategy requirements for data sharing – e.g., formation of Area Maritime Security Committees and the Threat Analysis Center – rely on output from risk assessment, threat analysis, using systems such as ATS (as described in Section 2.0) and data mining.

Data mining is one element of an integrated process of risk analysis – i.e., Detection, prevention, mitigation – that could help link threat analysis to intelligence gathering, vulnerability assessment, and consequence management. Increasingly, data mining is incorporated in the process of analyzing data from sensors, detection devices, and video surveillance technologies. Increasingly, security technologies are deployed in tandem with data mining, pattern recognition, and decision-support software. Data mining has its origins in applied statistics. It has been defined as a tool for discovery of meaningful patterns in data. The sources of data can be past documents, sensors, biometrics, video, graphic, and audio data. The goal of any data mining exercise is to extract meaningful intelligence from the patterns that emerge within a database after it has been cleaned, sorted and processed.

What makes data mining – essentially a process for collection of information and intelligence – different from national security agency operations is the amorphous nature of the maritime threats and targets. Artificial intelligence (AI) and intelligent agents (IA) relate to some of the techniques deployed in data mining.⁵³ DOD’s DARPA has developed data mining tools as dual use technologies that have commercially viable applications for both defense and non-defense civilian purposes. In the late 1990s, the DOD stepped up acquisition programs in IT systems and technology; distributed training systems; affordable sensors; environmental monitoring; and advanced structural systems for high-speed ships. DARPA’s Video Surveillance and Monitoring (VSAM) program is another example of technologies available for making sense of security threat data. The goal of VSAM is to develop an “automated video understanding” technology for use in urban and battlefield surveillance applications. Through this technology, a single human operator would be able to monitor activities over a broad area using a distributed network of active video sensors. The sensor platforms are autonomous, designed to notify the operator only of salient information as it occurs.

Carnegie Mellon University Robotics Institute has been leading a team of researchers to develop a testbed system demonstrating a wide range of advanced surveillance techniques, including real-time moving object detection and tracking from stationary and moving camera platforms; recognition of generic object classes (e.g., human, sedan, truck); and real time data dissemination, data logging, and dynamic scene visualization. Ultimately, the goal of VSAM is go beyond the prevalent applications of video surveillance, which are used only as an “after the fact” forensic tool.

⁵³ Bruce Gabrielson, “Security Using Intelligent Agents and Data Mining,” Center for Information Security Technology, Science Applications International Corporation, Columbia, MD, June 29, 1999.

To conclude, the concept of smart infrastructure for securing marine terminals and facilities is not a futuristic vision. Today, embedded security is widespread, as facilities are becoming intelligent and adaptive, and “structural monitoring,” i.e., sensing buildings, bridges, marine terminals or railway tracks are able to detect structural changes with fiber optic and other data collection sensors are being built into facilities.

6.0 Progress, Lessons Learned and Implementation Challenges

This section concludes the MTS Security Task 5 Report capturing the progress made in enhancing MTS security, lessons-learned from efforts to meet strategic objectives, and implementation challenges faced.

6.1 Information-Sharing has Effectively Enhanced MDA

MTSA 2002 and SAFE Port Act of 2006 have several provisions for facilitating information sharing for risk assessment and prevention of security threats. MTSA 2002 called for Area Maritime Security Committee (AMSCs) to be formed as a vehicle for information sharing by using the USCG authority to create them at the port level. The Committees were to identify vulnerabilities and provide a forum for sharing threat information and developing Area Maritime Security Plans (AMSPs). The Homeport Internet portal is a helpful tool for developing AMSPs. By 2005, the USCG had organized 43 AMSCs covering the nation's 361 ports. Because some ports are located in close proximity of each other, some Committees cover multiple ports (for instance the Puget Sound AMSC includes ports of Seattle, Tacoma, Bremerton, Port Angeles, and Everett.) Other federal agencies such as the CBP, FBI, and MARAD are also part of the AMSCs. The USCG Homeport Internet portal is the official site for sharing information on AMSCs and development of AMSPs.

Formation of the Interagency Operational Centers (IOCs) is another key step towards improved information sharing and maritime domain awareness (MDA). IOCs bring together the intelligence and operational efficiencies of various agencies to collect intelligence and real-time operational data from sensors, radars and cameras. Three IOCs are presently operating in Charleston, SC, Norfolk, VA, and San Diego, CA. The Centers allow officials to receive 24/7 data on maritime activities and relay them to the command posts. The success of these Interagency Centers has led to the USCG efforts to develop its own operational center called Sector Command Center (SCC). SCC provides local port operations with a unified command, supporting the USCG reorganization efforts by consolidating the agency's marine safety office into unified sectors. The USCG has plans for developing SCC at 10 port locations, with potential expansion to as many as 40 port locations. The goal of the SCC is to deploy information and communications technologies to improve situational awareness and MDA by developing a Common Operating Picture (COP) for all AMSC.

CBP's *Enterprise Hubs* are proving an effective strategy for promoting greater domain awareness. The CBP is developing *Enterprise Hubs* within existing organizations for five key subject areas – vessels, cargo, people, infrastructure, and architecture management – with capabilities to make substantial contributions to MDA. Joint benefits from the USCG efforts at developing a COP to integrate and standardize disparate

maritime information sources have the potential to benefit from and add value to the *Enterprise Hub*. The USCG COP is designed as a computer software package that fuses data from different sources such as radar, sensors on aircraft, and existing information systems. In its FY06 budget request, the USCG requested \$5.7 million to continue developing the COP for a nationwide maritime monitoring system, in addition to funding for training personnel in COP for deployment at SCCs and for modifying facilities to enable implementation of the COP in the command centers. The USCG five-year Capital Investment Plan has estimated the capital costs of developing the COP at \$400 million, with plans for acquisition of the system starting in FY07.⁵⁴

CBP has been designated to lead the Cargo and People hubs, partly because CBP is the federal agency responsible for admissibility decisions regarding all international cargo, crew and passengers. The agency is familiar with and has access to data pertaining to the maritime supply chain, and has a history of establishing cooperative data sharing agreements with other agencies having requirements for collecting maritime supply chain data. Enterprise Hubs are intended to leverage their experience and expertise to provide leadership for the community in a particular area, not to be the exclusive federal provider of information and products for that subject area. Participating agencies' access to analytical tools to identify and respond to threats within the supply chain, and its responsibilities for operating the 24/7 National Targeting Center add to the chances that the hubs will be effective in enhancing MDA and supply chain resilience. Designation as an *Enterprise Hub* confers two primary responsibilities: coordinating information flows for the respective subject area both domestically and internationally, and facilitating the sharing of related intelligence, information, and data.⁵⁵

Recognizing the critical importance of access to accurate, real-time, and comprehensive cargo and vessel information, the USCG stressed the need for reliable cargo and vessel information both for MTS safety and security in its 2005 Federal Register Notice of Rulemaking for requesting 96-hour Notice of Arrival and Departure (NOA and NOAD) and making deployment of Automatic Information System (AIS) mandatory for commercial vessels of certain size:

“The lack of NOA information on this large and diverse population of vessels represents a substantial gap in our maritime domain awareness (MDA). We can minimize this gap and enhance MDA by expanding the applicability of the NOAD regulation beyond vessels greater than 300 GT, cover all foreign commercial vessels, more U.S. commercial vessels, and all U.S. commercial vessels coming from a foreign port; and enhance maritime domain awareness by tracking them (and others) with AIS.”⁵⁶

⁵⁴ GAO, “Maritime Security: New Structures have Improved Information Sharing, but Security Clearance Processing Requires Further Attention,” GAO-05-394, April 2005.

⁵⁵ <http://www.cbp.gov>

⁵⁶ U.S. Coast Guard, *Federal Register*, October 31, 2005, p. 64172

6.2 Layered Risk Control Strategies have Made Progress in Closing Visibility Gaps

Two main processes for assessment of compliance with maritime regulations enacted by MTS 2002 and the SAFE Port Act of 2006 – Container Security Initiative (CSI) and Secure Freight Initiative (SFI) – have made successful attempts to incorporate the layered *defense-in-depth* as their core strategy.

Container Security Initiative (CSI)

The core elements of CSI include:

- Developing criteria for identifying high-risk cargo and vessels through the ATS;
- Pre-screening processes at the port of origin, before the arrival of the container;
- Use of non-intrusive inspection (NII) devices to inspect cargo containers deemed high-risk before arrival in the U.S.; and
- Development of a Smart Containers and Electronic Seals for tracking containers.

As noted in Section 5.0, the CSI container security process is implemented within a framework for *layered defense*. It is based on the premise that no single layer or tool in a risk-based approach to MTS security is adequate. The layered security plan involves a process with continuous checks at multiple nodes in the supply chain, coupled with a distributed two-stage process involving 1) On-site inspections, review, approval of regulatory requirements and plans; and 2) Compliance assessment. The availability of layers of network of resources and information will allow greater focus on all threats and vulnerabilities, rather than allowing a single type of threat to overshadow all other potential vulnerable nodes. This includes cargo manifest, the 24-Hour Rule and 96-Hour NOA for cargo manifest and vessel information, the C-TPAT agreements with trusted shippers, the CSI inspections at points of container origin and container inspection; verification of reliability through screening with non-intrusive inspection (NII) technologies.

Secure Freight Initiative (SFI)

The Secure Freight Initiative (SFI), a key provision of the SAFE Port Act of 2006, is an outgrowth of the CSI scanning project. SFI is a joint effort of USCG, CBP, DOE, and the State Department, and builds on the current partnership between the CSI and the Megaports Initiative. Together, these three initiatives are designed to increase the security of U.S. ports while keeping legitimate trade flowing.

SFI was officially launched on December 7, 2006 to expand the use of scanning and imaging equipment to examine more U.S. bound containers, not just those determined to be high risk. It will test the feasibility of using integrated technology which includes radiation portal monitors, non-intrusive imaging equipment and optical character recognition. By using this technology to scan more cargo, SFI ports should achieve a higher level of security without impeding the flow of commerce. SFI is viewed as a preventive tool in the global war on terrorism by improving detection and deterrence, information sharing, and MDA.

SFI will be deployed in phases. Phase I will begin operating in six foreign ports within 18 months. Phase I ports deploying scanning technologies to capture data bound for the U.S. are Port Qasim in Pakistan, Puerto Cortes in Honduras, and Southampton in the U.K. The other three ports with limited initial deployment are Port Salalah in Oman, Port of Singapore, and Port Busan in Korea.⁵⁷ The operational testing of full scale radiation scanning and X-ray imaging at Port of Qasim, with near-real-time data transmission to the host governments and the U.S. partner agencies, represents a significant step towards developing the next-generation of technologies for border and supply chain security.

6.3 MSSIS and AIS System are Powerful Leveraging Forces that Generate Joint Safety and Security Benefits

Inherent joint security-safety USCG technologies allow leveraging of the benefits from the existing AIS systems. The USCG Maritime Safety and Security Information System (MSSIS) is among the federal technological capability that can be used to bolster maritime defense. MSSIS is a system developed by the Department of Transportation's Volpe Center at the behest of Commander United States Naval Forces in Europe to share Automatic Identification System (AIS) data in real-time with their European authorized users through a web-based Secure Socket Layer (SSL.)

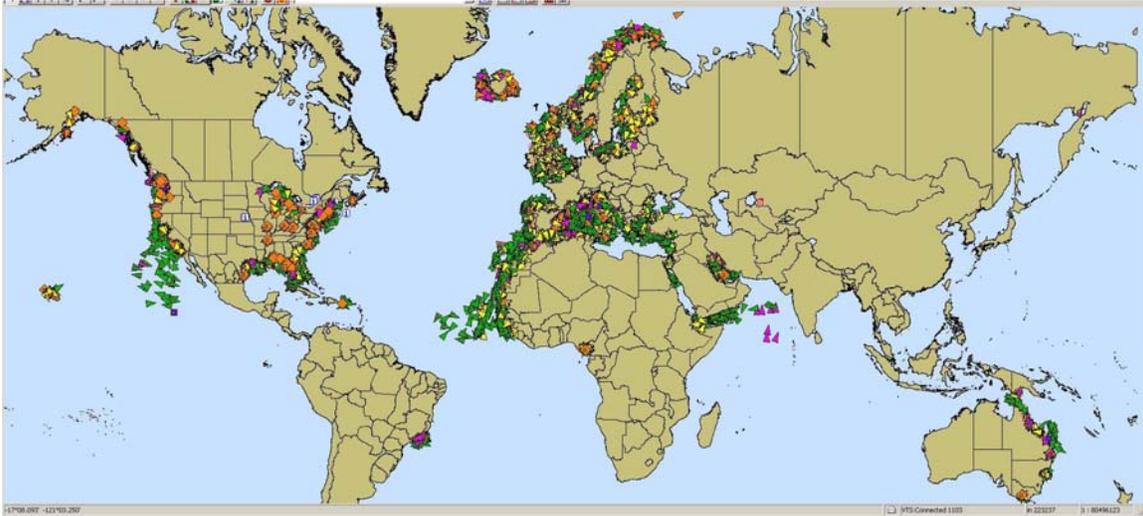
AIS is a system developed for safety at sea, collision avoidance purposes that provides a means for ships to electronically exchange ship data including, identification, position, course, and speed, with other nearby ships and Vessel Tracking System (VTS) stations. This information can be displayed on a screen or chart plotter. Though the underlying data are open-source and freely shared, the MSSIS system is password protected with multiple servers. The data on MSSIS though is *not* sensitive information, as it has not been fused or analyzed for intelligence purposes.

The equipment necessary to participate in MSSIS consists of commercially available AIS equipment: an Antenna, Transceiver, and GPS system; and a computer, required for map view. MSSIS users include US government interagency partners, Naval and Coast Guard agencies around the globe, law enforcement and border patrol agencies, and commercial shipping companies. Currently 47 countries are participating in MSSIS, with the rate anticipated to rise to 100 in 2009. International Association of Navigation Aids and Lighthouses (IALA) is one of the international sponsors of MSSIS.⁵⁸

⁵⁷ "Security Freight Initiative Begins Data Transmission for Radiation Scanning in Pakistan," May 2, 2007, <http://www.cbp.gov> and [Http://www.dhs.gov](http://www.dhs.gov)

⁵⁸ Lee Metcalf, Director, Office of Global Maritime Awareness (OGMSA), "Building the Global Maritime Picture," July 29, 2008.

Figure 4 - Participating Nations in the Maritime Safety and Security Information System (MSSIS)



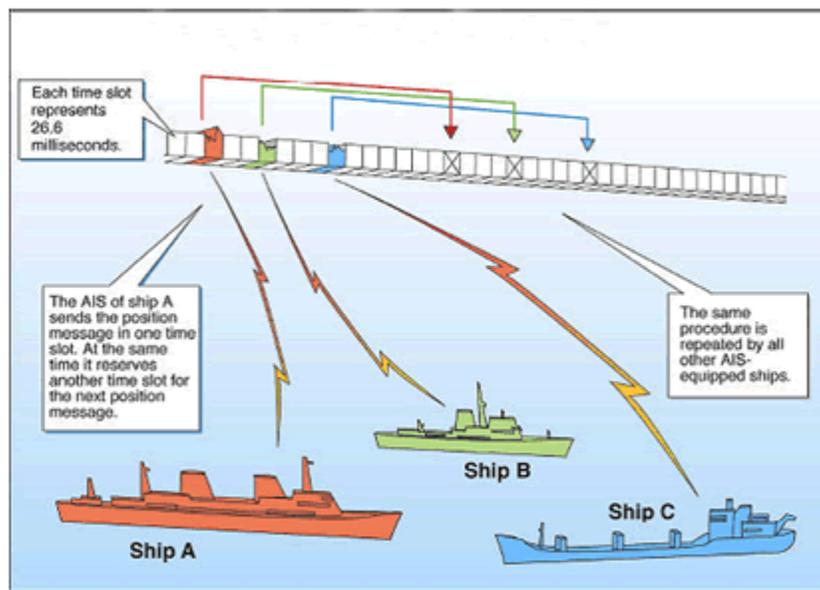
The USCG implementation of the AIS as part of a shipboard radar display with overlaid electronic chart data is designed primarily as a security that has significant safety benefits as well. The shipboard bridge system displays AIS signals as a mark for every eligible AIS-equipped ship within the radio range. Each “mark” has a velocity vector that indicates the vessel’s speed and heading. Each ship mark could reflect the actual size of the ships, along with an accurate position derived from GPS/DGPS. Officers, by clicking on a ship mark could learn the ship name, course, call-sign, speed, classification, and registration number. Other information to be obtained from AIS includes closest point of approach (CPA), time to closest point of approach (TCPA) and other navigation information. This information is more accurate and timely than information available from an automated radar plotting aid (ARPA). Display information previously available only to modern VTS operations centers are now available to every AIS-equipped ship.⁵⁹

The USCG rulemaking regarding the AIS carriage requirements expands the AIS coverage requirements to all commercial vessels identified in the MTSA 2002, and would include ≥ 65 vessels carrying 50 or more passengers, versus the current 150 or more passengers for hire, high speed for-hire ferries carrying over 12 passenger, vessels towing certain dangerous cargo, and certain dredges. The Federal Register USCG regulatory plan covers approximately 17,400 foreign and domestic vessels covered under the AIS regulations. The USCG estimates that approximately 20,000 vessels greater than 300 gross tons, with foreign vessels comprising nearly 17,000 of this amount, are currently submitting a Notice of Arrival (NOA), a Notice of Departure (NOD), or Notice of Arrival and Departure (NOAD). AIS compliance requirements are expected to a sub segment of

⁵⁹ USCS web-based information accessed on <http://www.navcen.uscg.gov/ais/AISFAQ.HTM>

these vessels currently required to submit NOAD, as identified in Table 2.⁶⁰ With the available information, the AIS provides the capability to: call any ship over VHF radiotelephone by name, rather than by "ship off my port bow" or some other imprecise means; dial it up directly using GMDSS equipment; or send to the ship, or receive from it, short safety-related email messages. Each AIS system consists of one VHF transmitter, two VHF STDMA receivers, one VHF DSC receiver, and standard marine electronic communications links to shipboard display and sensor systems (see the AIS Schematic in Figure 5). Position and timing information is normally derived from an integral or external global navigation satellite system (e.g. GPS) receiver, including a medium frequency differential GNSS receiver for precise position in coastal and inland waters. Other information broadcast by the AIS, if available, is electronically obtained from shipboard equipment through standard marine data connections.

Figure 5 – Schematic Depiction of the Automatic Identification System (AIS)



6-4 Challenges and Opportunities for Improvement

As we move towards completing the MTS Assessment and developing strategies to implement the recommendations of the MTS National Strategy, the following areas represent challenges as well as opportunities for future progress.

International Collaboration Still Faces Challenges

The ISPS and MTSA regulations require international cooperation in container inspection. The CSI process involves the ability of the USCG and CBP agents to inspect suspect containers deemed high-risk subsequent to an ATS screening. However, the ability of the U.S. federal agents to comply with the CSI requirements is hampered by the

⁶⁰ Federal Register, Vol. 70, No. 209, October 31, 2005, The Regulatory Plan, 51. Vessel Requirements for Notices of Arrival and Departure, and Carriage of Automatic Identification System (USCG-2005-21869)

host country rules. The GAO has reported on the challenges faced by the USCG visits to ports overseas when they were precluded from selecting the locations that were not in compliance with the CSI rules or the ISPS Codes for inspection. Instead, host countries would make available locations that were unlikely to be non-compliant. [GAO, Dec 2007⁶¹]

Information sharing and use of threat data for risk mitigation face challenges in the international as well as national arena. The GAO has designated information-sharing as a high-risk area because it saw the federal government as still facing formidable challenges in gathering, identifying, analyzing, and disseminating key information.⁶² An April 2005 GAO report found that information sharing can improve the leveraging of resources across jurisdictional boundaries for deterring, preventing, or responding to a possible terrorist threat at the nation's ports. The report concluded that maritime information sharing has improved as AMSC and Interagency Operational Centers grow and dissemination of security information expands, but identified lack of security clearance as a frequent barrier to effective information sharing among port stakeholders.

International information-sharing on maritime threats faces challenges relating to lack of standard protocols for threat assessment and communication. Interviews with the international trading partners conducted by a research team at the Lyndon B. Johnson School of Public Affairs suggest that information-sharing has been hampered by lack of standard protocols for data exchange among maritime security agencies. The U.S. international trading partners are concerned that a piece of information about a potential disruption could lead to officials deciding to halt marine traffic across the board (akin to what happened in the aftermath of the September 11, 2001 attacks that led to grounding of all flights.) The LBJ report noted that good intelligence from supply chain participants would allow accurate targeting of at-risk vessels and ports, thereby containing the search area to a small number of ports allowing precautionary steps to avert potential attacks without the need to close all ports.⁶³

The European RAND research office, having reviewed the efficacy of the CSI inspection cautioned that many technical and non-technical factors have been intermingled and created weak spots in the entire complex system of container security. One weak spot is that in Europe there is no public ownership of the container security problem as is in the US with the DHS ownership. The structure of the European cooperation is such that security remains a national issue and not an EU concern. National interests are protected through bilateral accords in the form of CSI or C-TPAT agreements. The agreement to seal the container before they arrive in the U.S. does not provide actual security as the

⁶¹ GAO, "Preventing and Responding to Terrorist Attacks on Energy Commodity Tankers," GAO-08-141, December 2007.

⁶² GAO, "Maritime Security: New Structures have Improved Information Sharing, but Security Clearance Processing Requires Further Attention," GAO-05-394, April 2005.

⁶³ Lyndon B. Johnson School of Public Affairs, *Port and Supply Chain Security Initiatives in the United States and Abroad*, Prepared for the Congressional Research Service, Policy Research Project Report Number 150, 2006.

container can now be sealed at the port of departure, but opened and left unsealed during part of the transport to the destination port.⁶⁴

The Great Lakes basin is governed by two nations, eight states, three Canadian provinces, several American and Canadian tribal nations, and hundreds of local communities. The Great Lakes MTS crosses the United States and Canada border at 22 points, which presents unique foreign policy and border security challenges. Great Lakes maritime borders are often delineated in bodies of water just hundreds of yards wide, which can be crossed by boat in minutes. The formation of “ice bridges” at the five major nexus areas (St. Lawrence Seaway, Niagara, Sault Ste. Marie, Detroit, and St. Clair) during the winter adds to existing challenges in controlling U.S./Canadian border security issues, such as terrorist networks, alien migrant interdiction, drug trafficking, gun trade, money laundering, and other criminal activity. On May 26, 2009, an international agreement called the “Integrated Cross-Border Maritime Law Enforcement was signed between U.S. and Canada. Coined the “Shiprider Program”, it allows the USCG and U.S. marine patrol police forces to work alongside Royal Canadian Mounted Police, including jointly-crewed vessels in shared waterways, in combating cross-border security issues.

Appendix 2 summarizes the existing practices for Port-Level Maritime Information Sharing and Interface with National-Level Intelligence Infrastructure

We Have Not Yet Been Able to Measure the Effectiveness of Security Countermeasures

A GAO report on the effectiveness of the 24-Hour Rule on has identified the following challenges:

- Measures so far include the number of companies signed up for participation. These measures are not enough, emphasizes the GAO report. The metrics must measure how CSI has improved targeting of high-risk containers beyond Customs’ existing capabilities, and how it has improved security.
- As a proxy measure, Customs has used the results of the Trade Compliance Audits to report that C-TPAT has improved security practices. The audit indicators for measuring Trade Compliance, notes the GAO, use select data elements derived from trade compliance data (e.g., if container seals indicate any possible tampering or if manifest data have discrepancies (e.g., discrepancy between cargo weight at export lading and arrival time.) Limitation of use these metrics as indicators of effectiveness are: compliance data compare two different populations by contrasting the behavior of C-TPAT member with that of Non-C-TPAT members. A more reliable measure of program impact would compare trade compliance before and after enactment of the agreement. For this purpose, baseline data would be needed.

⁶⁴ Rand Europe, “Seacurity”: Improving the security of the Global Sea-Container Shipping System,” Maarten van de Voort, Kevin A. O’Brien, 2003.

The GAO report also notes the poor strategic approach to development of program measures and poor communication with host ports. To correct these strategic weaknesses, GAO recommends that:

- Customs has to develop a human capital plan for recruitment, retention, and training, and better articulate a result-oriented container security strategy by creating a set of performance goals and means to address key dimensions of program performance such as outputs and intermediate outcomes.⁶⁵

USCG submission of data on the Crew Manifest and Cargo Manifest from the databases the two agencies have, including the ACE system (still at the beta development stage;

The Goal of 100% Screening of Cargo Containers Presents an Implementation Challenge

The CBP requirements for testing and implementing a new program to screen 100 percent of all incoming containers overseas represent implementation challenges. GAO has recommended that the DHS develop strategic plans and performance measures.⁶⁶ The agency considers the requirement for 100 percent screening in contravention of the ATS principles that call for using risk-informed analysis to reduce the number of container inspections at home and abroad. Risk-based analysis conducted for ATS incorporates intelligence information to target suspect or high-risk inbound or outbound shipments and select them for intensive examinations. NII inspections use large-scale radiation detection portals and hand-held technologies to detect nuclear or radiological materials.

Prioritizing MTS Security Risks and Determining how much to Spend on Security Remains a Challenge

The three goals for infrastructure protection outlined by the NIPP – Preventing and deterring acts of terrorism; Enhancing the resiliency of the MTS; and Maximizing cost-effectiveness for the limited resources of the MTS – represent significant challenges and tradeoffs. How are the needs prioritized? How can the finite resources be best allocated among potential countermeasures? Researchers have noted a fundamental tradeoff in layered defense: the tradeoff inherent in striking a balance between strategies that focus on preventing acts of terrorism and those that can substantially mitigate the consequences of such an act. As the RAND report cited above has noted, this set of tradeoffs involves a fundamental national strategy for reducing homeland security risks.⁶⁷ These issues are at the core of the political debate on how to allocate funding among competing preventive countermeasures for infrastructure protection. The RAND report has pointed out two sets of tradeoffs: one between prevention measures and consequence mitigation and the other between costs and the measure effectiveness. A layered-defense for reducing vulnerabilities has to be cost effective in order for them to be funded. They are the tradeoffs involved in selecting security countermeasures that represent an efficient use of

⁶⁵ GAO, *Container Security: Expansion of Key Customs Programs Will Require Greater Attention to Critical Success Factors*, GAO-03-770, July 2003.

⁶⁶ GAO, Correspondence, June 2008

⁶⁷ Larson, Eric V. and John E. Peters, *Preparing the U.S. Army for Homeland Security: Concepts, Issues, and Options*, RAND, ISBN: 0-8330-2919-3, 2001.

scarce resources. This means that we should select the options that produce a specified level of performance/ effectiveness – i.e., the preferred mix of prevention and consequence reduction – at lowest cost. It recognizes that the higher the performance level, the higher the costs. To make sure the programs are cost effective, one must assess the contributions of alternative mixes of local, state, and federal capabilities in terms of their cost effectiveness to craft an efficient program mix.

The Brookings Institution study reference earlier has emphasized that while protecting the targets of attack should be one of the options, there is always the potential for target shifting to less protected areas and the “displacement” problem. Preventive measures, the report concluded, tend to reduce the overall level of risk without having to know in advance what the targets are, though they are not a panacea. Prevention means the sources of threat should be interdicted before they materialize. This means tracking the movement of potential terrorists and dangerous goods – through data sharing, surveillance, entry and exist data analysis, tracking the transportation of hazardous cargo and securing hazardous material facilities. The study concluded:

“It is impossible to specify analytically how much risk we as a society should be prepared to run, and how much security is “enough” – that is a political decision, to be made by the political process. But this approach should lead to a cost-effective homeland security agenda, so that each additional dollar of spending is directed to achieving the greatest benefit in lives saved, costs averted, and so forth.”⁶⁸

Clearly, a layered defense-in-depth strategy does not simply deploy one countermeasure on top of the other as a safeguard. The key criteria for intervention decision are costs and effectiveness. Each intervention within the causal chain evaluated with respect to *efficiency* criterion – i.e., do the benefits exceed the costs? – as well as *cost-effectiveness* – i.e., does the selected option offer the best protection given all the other available countermeasures, given the price? Each criterion has merits in different circumstances, with higher weight assigned to one or the other, depending on the policy issues at hand and the amount of funding available. The RAND report has underscored the challenge of *efficiency* as a key cross-cutting issue in deterrence strategies crafted through a systems-based analysis of risk, pointing out:

“Although effectiveness, not efficiency, is most important in war, the United States could defeat itself economically by attempting to do everything everywhere and protect everything too well.”

Finally, a National Research Council (NRC) report has warned against putting too much faith in technologies, without taking into account the relevant human components. The June 2002 NRC report on *Making the Nation Safer: The Role of Science and Technology*

⁶⁸ Michael E. O’Hanlon, Peter R. Orszag, Ivo H. Daalder, I.M. Destler, David L. Gunter, Rober R. Litan, James B. Steinberg, *Protecting the American Homeland: A Preliminary Analysis*, Washington, D.C. Brookings Institution Press, 2002.

in *Countering Terrorism*,⁶⁹ has identified significant areas of R&D needs in prevention/deterrence rather than control/defense technologies. The report pointed out that eliminating – i.e. controlling and defending against – all vulnerabilities is improbable. This means that efforts to deter must be a key part of the national strategy. This makes deflection of threats, as well as sound intelligence information, critical components of the strategy. The report emphasized that: “The extent to which uncertainty can deter a terrorist from a specific target is a potentially important avenue of inquiry.” The NRC report identified prevention as the next line of defense when deterrence proves unsuccessful. Noting the myriad technologies available for preventing access and screening suspect cargo and passengers, the NRC report concludes:

“What is clear is that no single sensor technology can be expected to find all threats with acceptable accuracy, an array of sensor technologies will need to be developed and used together in a reliable, networked (“sensor fusion”) manner whereby each sensor can crosscheck the validity of others.”⁷⁰

We Need to use Risk Assessment Findings to Inform the Priorities of the MTS National Strategy

The July 2008 *National Strategy for the Marine Transportation System: A Framework for Action* stresses the National Defense functions of the MTS. Given that most supply movements are made by marine vessels, the MTS capabilities are critical for the rapid deployment of forces during a national emergency. The National Strategy emphasizes several security-related issues stemming from the nation’s Strategic Ports’ capacity, the growing oversight burden for inspection of vessels and crews and integrating the legacy computer systems into a single, integrated information system. The National Strategy concludes by stressing the need to address three key challenges:

- The Nation’s commercial and military strategic seaports need to have sufficient capability to support major military deployments. In addition to the 15 commercial strategic seaports, there are five DOD-owned terminals, supporting specific military “outload” requirements, such as ammunition. Access to these designated ports and their intermodal connections between the ports and military bases are vital to the transformed military envisioned in the Quadrennial Defense Review (QDR) of February 2005. The QDR calls for rapid global mobility to support a full range of operations, for which a robust and resilient MTS is essential.
- The burden of security and safety challenges resulting from the continued growth of inbound passengers and goods arriving by sea on government oversight services need to be addressed. The challenges include the need for tracking vessel, cargo, crew, passenger arrivals/entries; safety inspection requirements under Port State Control (PSC), and screening for illegal drugs, illegal immigration, bomb detection, terrorism, and invasive species. (The goal of the PSC program is to eliminate substandard

⁶⁹ NRC, *Making the Nation Safer: The Role of Science and Technology in Countering Terrorism*, National Academy Press, Prepublication Copy, June 2002, available on www.nap.edu

⁷⁰ NRC, *Making the Nation Safer: The Role of Science and Technology in Countering Terrorism*, National Academy Press, Prepublication Copy, June 2002, Ch. 7.

- The commendable efforts made to combine legacy customs, immigration, and other federal inspection services into a single, cross-trained officer corps should be recognized. However, meeting the added security requirements of the MTSA and the Safe Port Act of 2006, compounded by the growing demands on the security personnel arising from the escalating volume of cargo entering the U.S., is a significant challenge.

Appendix 1- Process Flow for Tracking Containers

Process Flow for Tracking Test Cargo Containers Northern Border E-Seal Pilot Project

HIGH RISK CONTAINER E-SEAL PILOT PROCESS FLOW	
<i>Step</i>	<i>Description</i>
[1]	Container is loaded onto ocean vessel at overseas port.
[2]	Prior to vessel's arrival, paper bills of lading are provided to Canada Customs. For vessels arriving in US ports, an electronic manifest is provided prior to arrival and is available to Customs officials using the Automated Manifest System (AMS), but in Canada this electronic information is not available.
[3]	Vessel arrives in port and Customs is notified.
[4]	Containers are offloaded to a portside terminal.
[5]	Canada Customs creates a preliminary list of high-risk containers based on a manual inspection of the paper bills of lading.
[6]	Based on the Canadian preliminary list, US Customs researches high-risk containers using ATS and prior knowledge of the inspector. Although US Customs in Vancouver does not receive an electronic manifest, they can manually enter the shipment data into ATS and run the targeting program to identify high-risk containers.
[7]	Canadian and US customs officials working at the Central Examination Station (CES) compare findings and jointly agree on which shipments require thorough examination via the "devanning" process.
[8]	Customs team at the CES sends a fax to the carrier identifying container(s) to be transported from the appropriate terminal. The CES is located 15 miles from the port of Vancouver; in Montreal, the CES is about 1 mile from the terminal. The carrier transports containers from the three container terminals, situated at various locations around the Vancouver metropolitan area.
[9]	After a targeted container(s) is removed from the vessel, the carrier transports the targeted container(s) to the CES. In Vancouver, Canada Customs contracts with a trucking company to provide the transport of containers between the terminals and the CES. This arrangement ensures control of the containers as they are transported back and forth.
[10]	Container arrives at the CES for devanning. This process involves removing all the contents of the container, performing gamma ray imaging of each box or bag, thoroughly examining loose components, drilling the sides of the container if appropriate and using a fiberscope to look at the structural components for secreted contraband, and then reloading the container.
[11]	After reloading, the container is placarded with the yellow reflective sticker and more recently the red envelope to identify it to U.S. border inspectors as a targeted shipment. The doors of the container are secured with two seals: a USCS high security seal and an eLogicity-Brooks e-seal. The USCS inspector sends an email containing the e-seal number to USCS Headquarters and to the expected border crossing.
[12]	The carrier is contacted and transports the container from the CES back to the terminal where it was originally picked up.
[13]	The container is subsequently placed on a truck, railcar or ocean vessel for transport to the US. Although movement by ocean vessel is unlikely, there was one such move noted during the e-seal pilot. However, since most containers go by either truck or rail, only those modes are shown in the flow diagram or discussed in the steps below.

[14]	Container arrives at a US border crossing and enters the normal queue for Customs processing.
[15]	The US Customs border inspector identifies targeted shipments based on visual observation of the yellow sticker on the side of the container or more recently the red envelope attached to the vehicle.
[16]	For truck shipments, the truck and container are diverted to “secondary” for examination.
[17]	If the inspector has a handheld reader, the e-seal is read electronically. If there is no reader available, the inspector records the e-seal identification manually. The identification number for the USCS high security seal is also recorded manually.
[18]	The border inspector transmits information, including the identification numbers for the e-seal and high security seal, the date of crossing, the e-seal status (intact/not intact) back to US Customs via email.
[19]	For rail shipments, the train is stopped and the container is inspected as described above.
[20]	The seals are electronically or visually inspected and data is recorded as described above.
[21]	Information on the container and its status is transmitted via email to US Customs as described above.

Appendix 2- Port-Level Maritime Information Sharing

Port-Level Maritime Information Sharing and Interface with National-Level Intelligence Infrastructure

Department of Homeland Security Agencies	
National-level Intelligence Organization	Regional or Field-level Intelligence Organization
<p><i>U.S. Coast Guard</i> USCG Intelligence Coordination Center (ICC), working in conjunction with the Navy’s Office of Naval Intelligence (ONI) at the National Maritime Intelligence Center (NMIC) to track the movement of vessels, cargoes, and crews, provide intelligence analysis and warning.</p>	<p>Two USCG Maritime Intelligence Fusion Centers (NMIFCs) located on each coast receive intelligence from, and provide intelligence to USCG commanders at the district and port levels, and share that analysis with Interagency partners. Field Intelligence Support Teams (FISTs) are also located at the port levels to collect, analyze and disseminate critical maritime threat information. FISTs can be collocated at Interagency Operational Centers or Sector Command Centers.</p>
<p><i>U.S. Customs and Border Protection (CBP)</i> The CBP Office of Intelligence for collecting, analyzing, and disseminating intelligence in support of tactical and operational maritime security mission. CBP’s National Targeting Center (NTC) conducts “sweep” operations of information on air, sea, and land passengers, vessels and cargo. The Center does 24-hour tactical targeting that coordinates CBPs field operation response to terrorist threats, develop raw intelligence into actionable targets, and serve as a liaison between other CBP officers and the USCG.</p>	<p>CBP Advanced Targeting Units (ATU) at the port level screen incoming cargo that poses a possible threat to the national security.</p>
<p><i>Immigration and Customs Enforcement (ICE)</i> ICE office of Intelligence evaluates and disseminates classified intelligence community and law enforcement reports. A central component of the ICE information sharing effort is</p>	<p>ICE has six Field Intelligence Units (FIUs) that provide geographic and regional intelligence and supervise Intelligence Collection and Analysis Teams (ICATs) that are also active in the field. In the maritime domain, ICE maintains Watchtower, a</p>

<p>ICE Intelligence Watch, which evaluates all tactical intelligence of terrorist threats to the homeland.</p>	<p>filed maritime operation providing detailed information on incoming vessels from targeted inspections of vessels and cargo. Over 20 Watchtower specialists are located at 17 seaports nationwide, providing Field Intelligence Reports (FIRs) covering all domestic seaports. Watchtower specialists meet and work with USCG and other state/federal agencies to provide information on vessels that may require an enforcement action such as boarding or interview of the vessel master.</p>
<p><i>Transportation Security Administration (TSA)</i> TSA is tasked to develop a maritime information system in accordance with the MTSA 2002 requirements. The TSA Transportation Security Intelligence Service (TSIS) disseminates intelligence and law enforcement information about threats to transportation security and serves as a liaison to the intelligence community. In this capacity, TSIS helps to coordinate domestic and international transport security activities with DHS and other federal agencies.</p>	<p>TSA has no domestic presence at the regional or field levels specifically related to maritime security.</p>
<p><i>Information Analysis and Infrastructure Protection (IAIP)</i> The mission of IAIP is to identify and assess current and future threats to the homeland, including the maritime system, map those threats against known vulnerabilities, develop protective measures, issue timely warnings, and take preventive and protective action. IAIP provides classified and unclassified information to federal, state and local agencies and conducts a daily Information Analysis Morning Executive Brief, whereby DHS components share and coordinate threat information.</p>	<p>No domestic presence at the regional or filed levels specifically related to marine security.</p>

Source: GAO, “Maritime Security: New Structures have Improved Information Sharing, but Security Clearance Processing Requires Further Attention,” Appendix III: “Port-Level Information-Sharing is Supported by, and Supports, national-Level Intelligence Infrastructure”; GAO-05-394, April 2005.

Appendix 3 – Vulnerability and Risk Analysis Program (VRAP)

Argonne National Laboratory’s VRAP process consists of three phases:

Pre-Assessment: Define scope and objectives; Identify and rank critical assets, where the “criticality” criteria typically include:

- Potential for immediate and significant local impacts
- Potential loss of energy supply to national security facilities or large civilian areas
- Potential for environmental impacts
- Extended time needed to repair
- Little or no redundant capacity
- Potential for cascading effects
- Potential for interdependency effects

- Assessment Phase:
 - *Analyze network architecture*: network topology and connectivity
 - *Assess threat environment*: individual background checks and organization threats.
 - *Conduct penetration testing*: scanning and penetrating network vulnerabilities, using security measures such as traffic filtering, authorized controls, and minimizing/disabling unnecessary services.
 - *Assess physical security*: identify the systems in place and compare operating procedures with best practices.
 - *Conduct physical asset analysis*: assess vulnerabilities of operational assets
 - *Assess operations security*: assess process and practices to deny adversary access to facility, using a 5-step process of identifying critical assets, analyzing threats, analyzing vulnerability indicators, assessing risk, and applying countermeasures to protect sensitive assets.
 - *Examine organizational policies and procedures*
 - *Conduct impact analysis*: estimates of the potential consequences, including economic, of not mitigating identified vulnerabilities or addressing security concerns, relying on quantitative analysis of disruption impacts.
 - *Assess infrastructure interdependencies*: Using a systemic perspective to develop contingency and response plan for responding to physical and cyber dependencies of energy on critical infrastructure. Interdependencies include *common-cause failures* due to simultaneous disruption of two or more infrastructures; *cascading failures* due to a disruption in one infrastructure leading to disruption in a second one; and *escalating failures* due a disruption in one infrastructure that exacerbates a disruption in a second one.
 - *Conduct risk characterization*: A risk management process for addressing security concerns are integrated into the corporate risk evaluation process for prioritizing countermeasures across all task areas.
- Post-Assessment:
 - Prioritize recommendations
 - Develop action plan
 - Capture lessons learned and best practices
 - Conduct training.

Appendix 4 – Small Vessel Security Program

Small Vessel Security Program

The DHS defines a small vessel as any watercraft less than 300 gross tons (GT), regardless of method of propulsion. A vessel of 300 GT is approximately 100 feet in length, although there is no exact correlation between a vessel's length and its gross tonnage. Small vessels can include commercial fishing vessels, recreational boats and

yachts, towing vessels, uninspected passenger vessels, or any other commercial vessels involved in foreign or U.S. voyages.⁷¹

In 2008, DHS developed a strategy to broaden the focus of federal interest to go beyond the recent U.S. maritime security efforts that have typically focused on regulating cargo containers and large vessels at official Ports of Entry (POE), through regulations such as the 96 Hour Notice of Arrival, 24-Hour Rule on transmission of cargo manifest and crew list, and the carriage requirement for the Automatic Identification System (AIS). The Small Vessel Security Strategy takes into account the security risks from terrorist exploitation of the small vessel community, including a wide range of vessels, from small commercial vessels, such as uninspected towing vessels and passenger vessels, to commercial fishing vessels and recreational boats, whether personal watercraft or large power and sail boats.

The small vessel community is comprised of a large and diverse group of operators, professional and casual users, with different backgrounds, training, and operating characteristics. Each geographic area has its own unique operating patterns and mix of small vessels. There are thousands of professional mariners who make their living on the waters every day—a considerable number of whom do so operating small vessels. These professional mariners range from charter vessel operators to small ferry or freight vessel operations, and include the majority of the domestic commercial fishing and towing vessel industries. In addition to these professional mariners, as many as 80 million people participate in recreational boating in a given year. The level of experience within the small vessel community varies from experts down to occasional renters of a recreational boat who have a widely varying range of training and experience.

The governance of the small vessel security is spread across multiple entities, with 18 Federal agencies and numerous state, local, tribal, and port authorities having roles ranging from vessel registration to operational safety enforcement. Therefore, this community has different expectations than more regulated large vessel operators.

Some security concerns presented by small vessels include:

- Small vessels operate in close proximity to critical infrastructure (CI) and key resources (KR), as well as major transportation channels and military ships, which may be potential high profile targets.
- There is a lack of a centralized access to hull identification and vessel registration/owner data.
- The ability to identify small vessel operators is limited because of uneven requirements for small vessel user certification and documentation.
- There are very limited Advance Notice of Arrival (ANOA) requirements for most recreational small vessels arriving from abroad.
- There is limited awareness among small vessel operators of arrival reporting requirements and limited resources to enforce requirements, making enforceability of the small vessel arrival reporting process difficult.

⁷¹ This section is based on DHS, *Small Vessel Security Strategy*, April 2008

- There is limited ability to screen for weapons of mass destruction (WMDs), especially chemical and biological agents.
- Among the large population of small vessel operators, there is a longstanding public expectation of totally unregulated access and use of U.S. waterways.

Risks and Vulnerabilities

Small vessels possess complex characteristics, which also present unique challenges in assessing risks related to their presence in the maritime domain. The most obvious is the vast exposure to potential threat due to the sheer number of the vessels in use nationwide. There are 13 million registered recreational vessels throughout the country and perhaps an additional 4 million unregistered recreational boats. Further, there are 110,000 commercial fishing vessels and thousands of towing vessels and uninspected passenger vessels operating within the maritime domain. Each of these disparate types of small vessels have different operating patterns, economic factors, and interested stakeholder groups.

Location of many sites of CIKR in marine locations easily accessible by water makes them vulnerable to small vessel attacks. Small vessels routinely operate within close proximity of high-profile targets such as passenger craft, large commercial or cargo vessels, military warships, major bridges, critical waterfront industries, and other maritime infrastructure. A key factor in CIKR vulnerability is the exact number of all small vessels operating in proximity of maritime infrastructure at any given time. In 2007, the US Coast Guard (USCG) Research and Development Center sponsored a study of nine U.S. ports and determined that there were approximately 3,000 small commercial vessels, 3,000 fishing vessels, and 400,000 recreational vessels that either must or are likely to operate in the vicinity of vulnerable maritime infrastructure within those ports.⁷²

Consequences and Potential Severity of Attacks

The consequences of a Transportation Security Incident (TSI) arising from a small vessel attack that lead to the damage to the CIKR or closure of the port could devastate the U.S. economy. Census data indicate that some 53% of Americans live in coastal watershed counties, and 85% live within 100 miles of the nation's coasts. In all, close to 75 million Americans were directly involved in on-the-water activities. The magnitude of damages would depend on whether the TSIs involve conventional weapons or WMD. A 2006 study examined the potential effects of a 15-day port closure at Los Angeles-Long Beach due to a radiological bomb at \$34 billion.⁷³

Four scenarios of terrorist-related attacks represent the gravest concern for the use of small vessels:

- a. Domestic Use of Waterborne Improvised Explosive Devices (WBIEDs);
- b. Conveyance for smuggling weapons (including WMDs) into the U.S.;

⁷² An Assessment of Small Vessel Population in U.S. Waters, prepared for the U.S. Coast Guard Research and Development Center by Potomac Management Group, Inc., June 2007.

⁷³ "The economic impact a terrorist attack on the twin ports of Los Angeles-Long Beach", in *The Economic Impacts of Terrorist Attacks*, 2006.

- c. Conveyance for smuggling terrorists into the United States; and
- d. Waterborne platform for conducting a stand-off attack (e.g. Man-Portable Air-Defense System (MANPADS) attacks).

Use of Small Vessels for Domestic Use of Waterborne Improvised Explosive Devices (WBIEDs)

In the past several years, there have been numerous examples overseas of the use of small vessels as a WBIED to attack maritime targets, including incidents in Turkey, in an Iraqi offshore oil terminal, on a French oil tanker off the coast of Yemen, on the USS COLE in 2000 in Yemen, and in Sri Lanka by the Tamil Tigers, as documented in the DHS *Small Vessel Security Strategy*, April 2008. The use of a small vessel as a WBIED also has potential consequences that would exceed the immediate casualties or damage caused by the attack. For instance the DOD relies on the availability of its 15 Strategic Seaports for military logistics support. A successful attack on one of these ports would drastically disrupt movement of supplies and military units.

Use of Small Vessels as a Conveyance for Smuggling Weapons (including WMD) into the U.S.

An attack involving a WMD represents one of the gravest maritime risks facing the nation. A 2007 national Intelligence Estimate (NIE) has documented the efforts of groups such as Al-Qaeda to acquire radiological and nuclear materials. A nuclear weapon could be concealed on many small vessels. A plausible scenario would be the use of a small vessel to transport an improvised nuclear device (IND), essentially a cruder version of a nuclear weapon fabricated by a terrorist organization or rogue nation. An IND would be smaller and less cumbersome than a nuclear weapon to assemble and transport, as the parts and equipment needed for assembling an IND could be well hidden on a small vessel. The vessel itself could also serve as a platform from which to detonate a nuclear weapon, IND, or radiological dispersal device (RDD), commonly referred to as a “Dirty Bomb.” The consequences of such attacks in terms of loss of life, direct and indirect economic losses, and environmental contamination have been estimated in several studies.⁷⁴ While an RDD would likely result in far less casualties than a nuclear weapon or INDS, the costs and disruptive effects on the economy and the nations could still be devastating.

Using Small Vessels as a Conveyance for Smuggling Terrorists into the United States

The number of people entering the country illegally between ports of entry, and the concomitant proliferation of human and drug smuggling networks present clear risks to the nation. Since 1980, the USCG, working with other Federal, state, and local law enforcement authorities, has interdicted over 320,000 illegal maritime migrants from 47 different countries. The concern is that terrorist organizations could leverage the illicit networks for human and drug smuggling and allow them to provide cover for terrorists. Small vessels could also be used to circumvent the more stringent land border security

⁷⁴ Clark Abt, “The Economic Impact of Nuclear Terrorist Attacks on Freight Systems in an Age of Seaport Vulnerability,” Cambridge, MA, 2003.

measures. Such was the case in the 2008 terrorist attack on Mumbai, India, which killed over 160 victims.

Using Small Vessels as a Waterborne Platform for Conducting a Stand-off Attack (e.g. a Man-Portable Air-Defense System (MANPADS) Attack)

The use of a small vessel as a platform for conducting a stand-off attack has been established as a viable attempt. In November 2005, a cruise ship 100 miles off the coast of Somalia was attacked by two 25-foot rigid hull inflatable boats. The pirates used rocket-propelled grenades and automatic weapons at a distance of no more than 25 yards from the cruise ship. The pirates were ultimately repelled by the ship's crew using a device that generated disabling sonic blasts. It is technically feasible to launch a ballistic missile from a ship as small as 200 tons. However, for the attack to succeed the ship's crew and the missile launch personnel would need to engage in a substantial collaborative effort.

Resiliency and Mitigation

Offsetting the concerns about the small vessel threats and security risks are the inherent attributes of the small vessel community that could prove significant contributions to security, add to the resiliency of the Marine Transportation System, and provide solutions for mitigating the threats:

- The population of small vessel owners in the U.S. represents an abundance of geographically dispersed user groups providing a large number of “eyes on the water” that would be impossible to replace using only government assets.
- The presence of the immense population of small vessel operators on U.S. waters can serve as a deterrent by identifying suspicious activities, given their adequate education and training.
- Small vessel users could potentially serve as willing volunteer partners to assist in providing the initial response capability for maritime incidents.
- Small vessel users represent a wealth of knowledge by professional mariners and recreational boaters who understand the local waterways and are willing to assist in developing methods to reduce risk in the maritime domain.

These attributes allow successful implementation of strategies to deter, prevent, protect and respond to incidents, including strategies that:

- A. Develop and leverage a strong partnership with the small vessel community and public and private sectors in order to enhance maritime domain awareness (MDA). For instance the educational and outreach programs conducted by the USCG Boating Safety Division, USCG Auxiliary and the U.S. Power Squadrons are effective sources of both security and safety training. Two effective means for the public to report suspicious activities are to telephone America's Waterway Watch (AWW) or the National Response Center.

- B. Offer the potential to enhance maritime security and safety based on a coherent plan with a layered, innovative approach. Data provided from sources such as Pleasure Boat Reporting System (PBRs), the Marine Information for Safety and Law Enforcement (MISLE), and the Vessel Identification System (VIS) could be used as sources of information. Furthermore, the NOAA Office of Law Enforcement maintains a Vessel Monitoring System (VMS) that tracks over 5,900 small vessels with an anticipated expansion to another 2,500 vessel. In addition, NOAA maintains law enforcement information on small vessels through its Law Enforcement Accessible Database System (LEADS) that tracks investigations, incidents and marine activities.
- C. Have the potential to leverage technology to enhance the ability to detect, determine intent, and interdict small vessels when necessary. This strategy would not necessitate the surveillance and tracking of the entire maritime domain, but would focus efforts on deployment of effective existing technologies such as GPS, RFID, AIS and cell phones, and conduct research on advanced detection technologies for WIEBD, WMD, and MANPADS.
- D. Have the potential to enhance coordination and collaboration among Federal agencies. For instance, the strategies could involve the use of the Maritime Operational Threat Response (MOTR) Plan in accordance with current directives to optimize employment of all appropriate responses in order to interdict threats as far from U.S. shores as practicable. The MOTR Plan directs coordination between the lead and supporting Federal agencies. This strategy encourages the integration of officers and intelligence analysts from USCG, CBP, and Immigration and Customs Enforcement (ICE) into local fusion centers. It calls for updating the Area Maritime Security (AMS) processes to ensure that small vessels are addressed when conducting AMS assessments and developing AMS Plans (AMSPs.)

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ACRONYMS

AEO	Authorized Economic Operator
AI	Artificial Intelligence
AIS	Automatic Identification System
AMS	Automated Manual Solution
AMSC	Area Maritime Security Committee
AMSP	Area Maritime Security Plan
AMSTEP	Area Maritime Security Training and Exercise Program
ANOA	Advance Notice of Arrival
APEC	Asia Pacific Economic Cooperation
ARPA	Automatic Radar Plotting Aid
ATS	Automated Targeting System
AWW	America's Waterway Watch
BIMCO	Baltic & International Maritime Council
CBO	Congressional Budget Office
CBP	Customs and Border Protection
CI	Critical Infrastructure
CIKR	Critical Infrastructure/Key Resources
COE	Condition of Entry
COP	Common Operating Picture
CPA	Closest Point of Approach
CSI	Container Security Initiative (CSI)
C-TPAT	Customs-Trade Partnership Against Terrorism
CMTS	Committee on the Maritime Transportation System
COE	Condition of Entry
COTP	Captain of the Port
DARPA	Defense Advanced Research Projects Agency
DHS	Department of Homeland Security
DOE	Department of Energy
DNDO	Domestic Nuclear Detection Office
DSC	Digital Selective Calling
DWT	Deadweight tons
EEZ	Exclusive Economic Zone
EO	Executive Order
EOSO	Extended Offshore Security Operation
EPA	Environmental Protection Agency
EPIRB	Emergency Position Indicating Radio Beacons
ER	Emergency Response
ERDC	Engineering Research and Development Center
FIR	Field Intelligence Report
FMSP	Federal Maritime Security Coordinator
GDMSS	Global Marine Distress and Safety System
GEOSS	Global Earth Observation System of Systems
GPS	Global Positioning System

GT	Gross Tons
HSPD	Homeland Security Presidential Directive
IALA	Marine Aides to Navigation and Lighthouse
IAIP	Information Analysis and Infrastructure Protection
IAT	Integrated Action Team
IBS	Integrated Bridge System
ICW	Intra-Coastal Waterways
IMO	International Maritime Organization
IOC	Interagency Operational Center
IPS	International Port Security
IRIS	Intelligent Robust Infrastructure System
ISPS	International Ship and Port Facility Security
ISF	Importer Security Filing
ITS	Intelligent Transportation System
ITV	In-Transit Visibility
IWR	Institute for Water Resources
LEADS	Law Enforcement Accessible Data System
LRIT	Long Range Identification and Tracking
MANPADS	Man Portable Air Defense System
MARAD	Maritime Administration
MARPOL	International Convention on Prevention of Pollution from Ships
MDA	Maritime Domain Awareness
MISLES	Marine Information for Safety and Law Enforcement System
MOTR	Maritime Operations Threat Response
MOU	Memorandum of Understanding
MRO	Mass Rescue Operations
MSC	Military Sealift Command
MSI	Maritime Safety Information
MSP	Maritime Security Program
MSRAM	Maritime Security Risk Analysis Model
MSSIS	Marine Safety and Security Information System
MSTS	Maritime Sea Transportation Service
MTS	Marine Transportation System
MTSA	Maritime Transportation Security Act of 2002
MTSNAC	MTS National Advisory Council
NDNS	National Dredging Needs Study
NDRF	National Defense Reserve Fleet
NDRS	National Distress and Response System
NDU	National Defense University
NHS	National Highway System
NII	Non-Intrusive Inspection
NIPP	National Infrastructure Protection Plan
NMTSP	National Maritime Transportation Security Plan
NOA	Notice of Arrival
NOAA	National Oceanic and Atmospheric Administration
NOAD	Notice of Arrival and Departure

NOD	Notice of Departure
NPOESS	National Polar-Orbiting Operational Environmental Satellite
NPRM	Notice of Proposed Rule Making
NPRN	National Port Readiness Network
NRC	National Research Council
NRF	National Response Framework
NSA	National Shipping Authority
NSMS	National Strategy for Maritime Security
NSPD	National Security Presidential Directive
NTC	National Targeting Center
OCS	Outer Continental Shelf
OOW	Officer of the Watch
OSC	Operation Safe Commerce
OSV	Offshore Supply Vessel
PANY/NJ	Port Authority New York/New Jersey
PAWSA	Port and Waterway Safety Assessment
PAWSS	Port and Waterway Safety System
PBRs	Pleasure Boat Response System
PCNS	Portable Communications, Navigation, and Surveillance
PortSTEP	Port Security Training Exercise Program
PSC	Port State Control
PSPG	Port Security Grant Program
PWSA	Ports and Waterways Safety Act
RITA	Research and Innovative Technology Administration
RFID	Radio Frequency Identification
RRF	Ready Reserve Force
SAIC	Science Application International Corporation
SAFE Port	Security and Accountability for Every Port Act
SARSAT	Search and Rescue Satellite Aided Tracking
SAROPS	Search and Rescue Optimal Planning System
SART	Search and Rescue Transponder
SBI	Secure Border Initiative
SFI	Secure Freight Initiative
SOLAS	Safety of Life at Sea Convention
SOW	Scope of Work
SSA	Sector Specific Agency
SSL	Secure Socket Layer
SSS	Short Sea Shipping
SST	Smart and Secure Tradelanes
STDMA	Self-Organized Time Division Multiple Access
TCPA	Time to Closest Point of Approach
TRB	Transportation Research Board
TSI	Transportation Security Incident
TWIC	Transportation Worker Identification and Credential
ULCC	Ultra Large Crude Carriers
USACE	United States Army Corps of Engineers

USCG	United States Coast Guard
USDA	United States Department of Agriculture
USDOD	United States Department of Defense
USDOT	United States Department of Transportation
VACIS	Vehicle and Cargo Inspection System
VDR	Voyage Data Recorder
VHF	Very High Frequency
VIS	Vessel Identification System
VISA	Voluntary Intermodal Sealift Agreement
VRAP	Vulnerability and Risk Analysis Program
VSAM	Video Surveillance and Monitoring
VTA	Voluntary Tanker Agreement
VTS	Vessel Traffic Services
WBIED	Waterborne Improvised Explosives Device
WMD	Weapons of Mass Destruction



Appendix F

Assessment of the Marine Transportation System (MTS) Challenges

Task 6: MTS Institutional Challenges

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Preface

This Draft report is Task 6 deliverable for the Volpe Center Reimbursable Agreement (RA) VH-99 with the United States Army Corps of Engineers (USACE) in support to the Committee on Marine Transportation System (CMTS) in its mission to conduct an assessment of the Maritime Transportation System (MTS) challenges. The report has been prepared by Dr. Bahar Barami, the Volpe Center project manager, and revised to reflect the comments and inputs received from LCDR Ellis Moose (and his colleagues), U.S. Coast Guard (USCG), CG-54121, Safra Altman, National Oceanic and Atmospheric Administration (NOAA), and Richard Lulich, Maritime Administration (MARAD). At the Volpe Center, Nathan Grace, MacroSys, LLC, provided editorial assistance, and Rod Cook, Chief, Intermodal Infrastructure Security and Operations Division, provided peer review and quality control input.

Background

This MTS task report is the last of the original six task reports on MTS challenges. A 7th task has been added to the scope of the MTS Needs Assessment since the original scope of work (SOW) was developed. Task 7 will develop a Summary Report that integrates the findings of the Needs Assessment and aligns them with the MTS National Strategy and the Implementation Plan.

Task 1 of this study examined the MTS physical infrastructure and conducted an assessment of the baseline MTS characteristics within a risk and reliability assessment framework. It analyzed the present and projected threats to the continued performance of the infrastructure, and identified system vulnerabilities and potential countermeasures for enhancing system resiliency.

Task 2 Report built on the risk and resiliency analysis framework developed in Task 1 and conducted an analysis of the economic impacts and risks of MTS. Within this framework, the study estimated the magnitude of the global economic impacts of a disruption in system operations, identified the vulnerabilities relating to the dependence of the nation's trade system on MTS, and assessed system resiliency with respect to the flexibility of the MTS-dependent supply chains, users and vessel operators.

Task 3 Report addressed the environmental challenges arising from systemic risks and vulnerabilities inherent in MTS, including the threats to the Nation's environmental stewardship mission and the associated challenges of meeting the performance demands of a global transportation network. The report focused on the environmental and safety risks arising from the marine vessel engine emissions, oil spills and hazardous cargo incidents, contaminated dredged materials, and invasive non-indigenous species introduced by ballast water. Task 3 also identified measures for preventing pollution and addressed issues relating to sustainable environmental practices, the resilience of the marine ecology, and the ability of MTS to return to normal conditions after an environmental disaster.

Task 4 addressed the MTS safety challenges within the risk and resiliency framework created and used in other three task reports. The report identified the threats, vulnerabilities and exposure levels that contribute to vessel and navigational risks, evaluated the trends in marine accidents and safety threats, the adequacy of the existing safeguards, and the factors that enhance system resiliency.

Task 5 addressed the challenges arising from the federal requirements for security inspection and status reports for ensuring cargo and vessel security, their impacts on MTS operations, and opportunities for enhanced MTS security and efficiency. The report identified the components of a resilient transportation system, including redundant layered security systems and backup provisions that would serve as a buffer against catastrophic disruptions in the MTS.

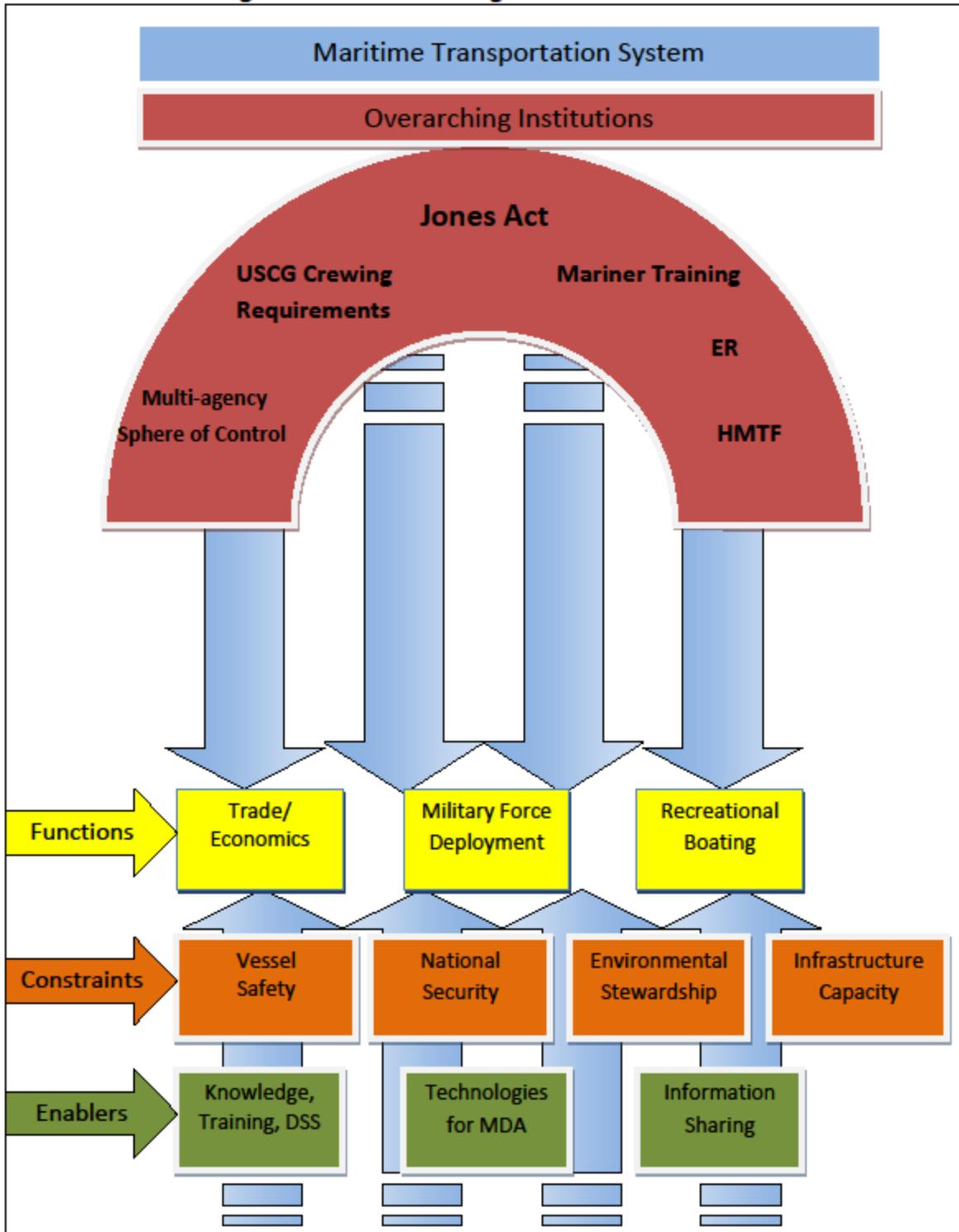
Task 6 will assess the MTS institutional challenges by reviewing a number of overarching influences that enable the MTS to operate to the full extent of its capabilities, or conversely, prevent it from meeting its intended functions. These overarching factors are the institutional determinants of the MTS and include statutory and legislative forces that determine:

- a) How MTS operations and infrastructure improvements are funded;
- b) How the existing regulatory guidelines governing MTS operations shape the nature and boundaries of domestic and international operations (vessels, routes, ports, crewing, ownership, etc.);
- c) How mariners, crew members, enforcement agencies, and other users of the marine resources are trained, and what quality of data and decision-support systems they have access to in order to achieve maritime domain awareness (MDA);
- d) How MTS agencies work together, or fail to work together, to ensure continuity of operations and system resiliency in response to emergencies.

Figure 1 depicts the constellation of institutional forces influencing how well the MTS functions are performed given the constraints imposed by the national security, vessel safety and environmental stewardship priorities, and the capabilities made available by access to advanced enabling technologies for decision support system (DSS), maritime domain awareness (MDA) and data sharing.

Figure 1 - Overarching Institutional Influences

Figure 1 MTS Overarching Institutional Influences



These overarching institutional influences determine how well the military and civilian functions of the MTS are performed and the missions of the participating agencies are fulfilled. This Task 6 Report conducts an assessment of these institutional challenges by reviewing them in the context of the risk and resiliency framework developed in previous tasks. The task report reviews the literature on these challenges and recommends potential solutions in the following sections:

- Section 1.0 Gaps in MTS funding for port development and dredging;
- Section 2.0 Regulatory constraints and legislative issues relating to domestic shipping cabotage laws, the Jones Act, financing of shipbuilding, and the crewing requirements;
- Section 3.0 Gaps in adequate operational data, decision-support systems, and mariner training;
- Section 4.0 Gaps in interagency coordination, information-sharing, network integration, and emergency response (ER);
- Section 5.0 Closing the gaps: potential solutions for creating a resilient MTS.

Section 1.0 MTS Funding

This section reviews the status of the two key sources of MTS funding, as authorized under the Water Resources Development Act (WRDA) of 1986 (Public Law No. 99-662): the Inland Waterways Trust Fund (IWTF) and Harbor Maintenance Trust Fund (HMTF), and evaluates the issues relating to the fund balances and how they impact the MTS.

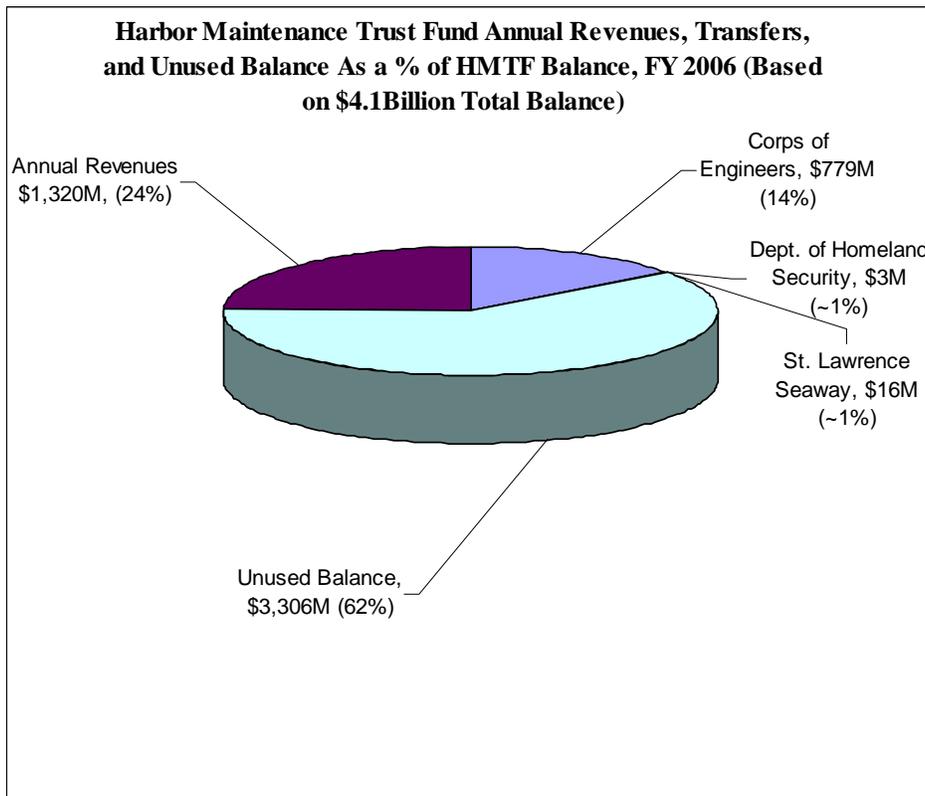
Harbor Maintenance Tax (HMT) and the Harbor Maintenance Trust Fund (HMTF) Congress enacted the Harbor Maintenance Tax (HMT) in the 1986 WRDA as a general *ad valorem* tax on the cargo value (0.125 percent) levied on the value of all waterborne cargo loaded or unloaded at a port (§26 U.S.C. 4461 and 19 C.F.R. §24.24.) The tax is paid by the shipper or the product importer. Exports have been exempted by the Supreme Court ruling from paying the tax. Cargo entering at ports in Alaska, Hawaii, and Puerto Rico is also exempt from the fee. For domestic shipments, the fee is levied at only one port – either the port of departure or the port of entry, but not both – and it does not normally apply to movements of tugs and barges along the inland waterways as long as the ship moving the goods is subject to the Inland Waterways Fuel Tax (19 C.F.R. §24.24 (C0 (5) and 25 U.S.C. § 4042) and collected in the IWTF.¹

The HMT is intended to pay for harbor dredging. The proceeds of the HMT go into the Harbor Maintenance Trust Fund (HMTF), which is used to reimburse the cost of maintenance dredging for federal channels, cover the costs of the St. Lawrence Seaway Development Corporation, and reimburse the Customs and Border Protection (CBP) for the costs of fee collection. Figure 2 shows the uses and balances of the HMTF in 2006. In 2006, of the total annual revenue of \$1.3 billion, the fund authorized expenditure of \$779 million to pay for Corps of Engineers waterway projects and \$19 million for the St. Lawrence Seaway and CBP expenses. The remaining HMTF balance of \$3.3 billion was used for reducing the government budget deficit.

The HMT is likely to discourage domestic waterborne movement of import containers since equivalent truck transportation of a container load does not involve similar fees. The tax adversely impacts domestic short sea operations because the fee, imposed on each leg of the movement of an import container, taxes the same load twice: once at the arrival port and again at the inland destination port when unloaded for domestic distribution or feeder. An import container pays the tax when it is offloaded at the arrival port and again when loaded on a domestic vessel for the inland leg of the journey.

¹ Government Accountability Office (GAO), “Freight Transportation: Short Sea Shipping Option Shows Importance of Systematic Approach to Public Investment Decisions,” GAO-05-768, July 2005.

Figure 2 – HMTF 2006 Fund Revenues, Expenditures, and Ending Balance



Source: Volpe generated chart based on *Annual Report to Congress on the Status of the Harbor Maintenance Trust Fund for Fiscal Years 2005 and 2006*, released by IWR

Inland Waterway Trust Fund (IWTF)

The Water Resources Development Act (WRDA) of 1986 also authorized a fuel tax collected as part of the IWTF. The fee consists of a 20-cent per gallon tax levied on diesel fuel purchased by tugs and towboats operating in the inland waterways. The IWTF funds are intended for paying for half the cost of lock and dam maintenance. The other half of the cost is paid for from general revenues, to account for non-transportation benefits, including the uses of the waterways for national defense, water supply, flood control and recreation. Only 195 lock sites out of the existing 230 lock sites have received maintenance funding from the IWTF.

By some projections, the IWTF balance was to be exhausted by 2009. The Fiscal Year (FY) 2008 IWTF had a positive end-balance of \$130.8 million. Though the balance was lower compared to the balance of \$209.4 million for the previous year, it is not expected to be exhausted by 2009.² The USACE Institute for Water Resources (IWR) has estimated that at current levels of income, the IWTF could not meet projected

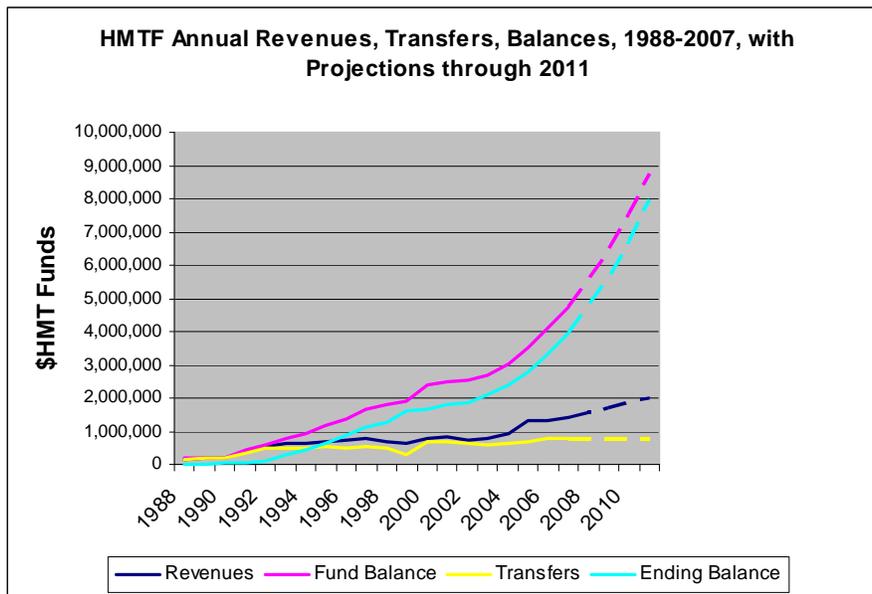
² Inland Waterways Trust Fund Status Report, prepared for Inland Waterways Users Board Meeting, No. 60, February 20, 2009. www.iwr.usace.army.mil/newusersboard/StatusofTrustFund.htm

infrastructure needs without significantly curtailing outlays or seeking alternative methods for increasing revenues.³

Impacts of the HMT on Equity and Economic Efficiency

The HMTF collections far exceed funds appropriated for harbor maintenance. However, the USACE and port development agencies have maintained that many federally-managed waterway channels are under-maintained and point to a backlog of improvement projects. A 2008 Government Accountability Office (GAO) report has stressed that the sizable HMTF surplus is inconsistent with principles of equity as well as efficiency, warning that the “misalignment between fee collection and expenditures has undermined the credibility of the HMTF.” The reason for the rising HMTF balance is that the fees are *ad valorem* and that the receipts grow with both volume and value of shipments. The GAO report underscores the fact that in 2001 HMTF collections exceeded expenditures by about \$44 million, and by 2007 that gap had grown to over \$506 million, with total collections growing by over 100 percent from \$704 million to \$1.4 billion from 2001 to 2007.⁴ By 2011, according to the USACE *Annual Report to Congress*, the surplus will reach \$8 billion, as shown in Figure 3.

Figure 3 – Harbor Maintenance Trust Fund Annual Revenues, Expenditures and Balances, 1988-2007, with Projections through 2011



Source: Volpe generated chart based on IWR, *Annual Report to Congress on the Status of the Harbor Maintenance Trust Fund for Fiscal Years 2005 and 2006*.

The growing balance of the HMTF has given rise to concerns over equity, economic efficiency, and “revenue adequacy” – i.e., the extent to which the fee collections cover

³ “Assessment of Alternative Assumptions of Outlays and Revenues for the Inland Waterways Trust Fund,” (IWTF) dated July 13, 2006

⁴ Government Accountability Office, *Federal User Fees: Substantive Reviews Needed to Align Port-related Fees with the Programs they Support*, GAO-08-321, February 2008.

the intended share of the costs – as expressed in a February 2008 GAO report on port-related user fees.⁵ GAO reported that since 2003, HMF collections have significantly exceeded funds appropriated for harbor maintenance, resulting in a large and growing surplus in the trust fund. The surplus is currently being used to lower the federal budget deficit. GAO noted that this surplus may be inconsistent with users’ expectations of the fee’s purpose as laid out in statute and the principles of effective user fee design. The report pointed out that the authorizing legislation has generally designated the use of the HMT collections for harbor maintenance activities and associated expenses and not for other uses.

Another reason for the growing gap between revenues and expenditures is that the harbor maintenance project expenditures are subject to annual appropriation. These project expenditures have grown more slowly—from \$660 million in 2001 to \$910 million in 2007, reflecting a 38 percent increase. The GAO report recommended that Congress review the link between the HMT fee and expenditures and establish an HMTF stakeholder advisory. GAO made eight recommendations to the Secretaries of Homeland Security, Agriculture, and the U.S. Department of Defense/Army to better align the fees with the activities they support, and to improve collections, oversight, and reporting.

Underscoring the importance of using the HMTF funds for improvements to the nation’s marine infrastructure is a January 2006 National Academy of Science (NAS) report on challenges of infrastructure financing that views inadequate maritime funding mechanisms for system maintenance as an alarming concern. The report states:

“Lack of system preservation and rehabilitation produces a downward spiral... The price of short-term savings from deferred maintenance... is proportionately greater rehabilitation cost later.... Raising the visibility and developing support for system preservation is critical to the 21st century transportation system.”⁶

Misalignment of Funding for projects

USACE authorizes projects through a formal process but that does not guarantee funds are appropriated for the completion of the project. Similarly, many waterway projects need funding from several agencies. In most cases the funding mechanisms are not linked. For example, USACE funds a channel widening project but the completion of the project may be contingent on the rebuilding of some components of the Aids to Navigation (AtoN) infrastructure assets by USCG; it may be as long as 10 years before the USCG receives funding to rebuild the navigation ranges. This reflects a generally low level of funding from Congress for AtoN, particularly Acquisition, Construction and Improvement (AC&I.) Currently there is approximately a projected backlog of \$13.4 Million in value of AC&I assets for AtoN for FY2010.⁷

⁵ Government Accountability Office, *Federal User Fees: Substantive Reviews Needed to Align Port-related Fees with the Programs they Support*, GAO-08-321, February 2008.

⁶ Nation Academy of Science, (NAS), *Critical Issues in Transportation*, 2006.

⁷ The text for this paragraph was suggested by LCDR Ellis Moose, USCG, CG-54121.

Section 2.0 Regulatory Constraints

This section reviews regulatory issues that may have potentially adverse impacts on the MTS operations.

Cabotage Laws and the Jones Act

The Merchant Marine Act (MMA) of 1920 (46 U.S.C. App. § 883), one of the federal laws commonly referred to as the Jones Act, is a US federal statute that regulates maritime commerce in U.S. waters and between U.S. ports. The MMA, among other things, was intended to protect domestic shipbuilding industry through enactment of a cabotage law and enforcement of provisions regarding seafarer's rights and cargo preference.

The MMA cabotage provisions restrict the carriage of goods or passengers between United States ports to U.S.-built- and flagged-vessels. The only ships allowed to call on two or more consecutive American ports are required to be built in the U.S. shipyards, owned by American companies, fly the American flag and be operated by American crews (at least 75 percent of the crewmembers must be U.S. citizens.)

The MMA seafarer's protection allows injured sailors to obtain damages from their employers for the negligence of the ship owner, the captain, or fellow members of the crew.

The Cargo Preference component of the MMA requires that certain portion of the U.S. government cargo be shipped on U.S. flag-vessels. For instance, Cargo Preference provisions state that under Titles I, II, and III of the Agricultural Trade Development and Assistance Act of 1954 (Food for Peace Act), at least 75% of food aid provided to foreign countries be shipped on U.S. flag vessels.

A waiver process can be put in effect to neutralize certain Jones Act provisions. The waiver process is intended to correct for insufficient supply of Jones Act vessels at times of emergency. The Maritime Administration (MARAD) has the authority to review requests for waivers of certain provisions of the act on a case by case basis. Waivers have been granted in cases of national emergencies or in cases of strategic interest. In the wake of hurricane Katrina, MARAD temporarily waived the U.S. Shipping Act for foreign vessels carrying oil and natural gas from September 1 to 19, 2005. During the Persian Gulf War, the Jones Act was suspended because there were not enough U.S. built ships to transport supplies. MARAD has also granted a waiver to the operators of the 512-foot Chinese vessel *Tai An Kou* to tow an oil rig from the Gulf of Mexico to Alaska. The two-year contract granted to the Chinese vessel for setting up a "jack up" rig to drill in the Alaska's Cook Inlet Basin, the first of its kind granted to an independent oil-and-gas company, was prompted in response to Alaska's declining oil production levels.

Impacts on Vessel Size and Propulsion

Federal regulations guiding the design, operation and manning of vessels for domestic use have generated unintended consequences for domestic navigation. Guidelines on construction and crewing standards may have stifled the development of markets for construction of more efficient, higher performance self-propelled ships and encouraged excessive reliance on tug-barge vessels. Current federal regulations treat tug-barge combinations differently, with an unintended detrimental effect on self-propelled vessels. Differential manning is often a key factor in the choice between self-propelled and tug-barge combinations. The USCG applies crew size determination rules on the basis of the size of the vessel's propulsion unit. As a consequence of these manning requirements, an articulated tug-barge (ATB) requires a crew of 10 persons, while a tanker of the same capacity would require a crew size of 20. This is because crew standards are based on the size of the vessel's propulsion engine and not its carrying capacity or operational risks. The tug is treated as a small vessel with lower crew requirements (the size of the barge is not relevant to crew size determination) whereas a tanker with a capacity similar to an ATB is treated as a large ship. The labor cost advantages can thus favor ATBs over self-propelled ships with similar construction costs despite ATBs' disadvantages in maneuverability and reliability.

Some observers have maintained that the differential treatment afforded the tug-barge combination vessels has led to a sub-optimal choice of vessels for domestic shipping because self-propelled ships have higher fuel efficiency and better maneuverability than tug-barge vessels and ATBs. This view has been expressed in a recent IHS Global Insight report on the regulatory advantages enjoyed by ATBs in manning, concluding that the outcome has been poor design choices by shipbuilders. The report has maintained that federal programs in support of shipbuilding for the domestic Jones Act fleet have adversely affected domestic marine transport, because the protection afforded through the cabotage regime has generated a backlash from the differential treatment of the domestic and foreign-trade sectors and adversely impacted efforts to promote short sea shipping for domestic cargo movement. Because the current manning requirements have raised the operating costs of more efficient self-propelled vessels, the IHS report has concluded:

“...current crewing laws are not optimal from the standpoint of commerce. They distort ship choice and cause the market to choose less efficient ships were it not for the crewing regulation.”⁸

Regulatory incentives and disincentives have also created an excessive reliance on the barge-tow and articulated tug-barge (ATB) vessels and prevented the expansion of the fleet of medium-speed small ships that could effectively compete in the domestic freight markets. According to the MARAD Fleet Report on the inventory and traffic volumes for coastal tank vessels, the volume of trade carried on crude carriers and product tankers, measured by metric tons carried, declined moderately between 2002 and 2007, while the

⁸ IHS Global Insight, Inc., *An Evaluation of Maritime Policy in Meeting the Commercial and Security Needs of the United States*, Prepared for the USDOT, MARAD, January 7, 2009.

volume of trade on tank barges stayed relatively stable. Table 1 shows the extent to which the fleet of the Jones Act fleet is dominated by tugs and barges.

Table 1 – Number of Jones Act Compliant Self-Propelled and Barge Vessels with Potential Application for SSS Service

US Flag Vessels (Based on County of Registry Fleet Data)	# of Jones Act Vessels
Self Propelled Tankers	95
Self-Propelled Freight Ships (Container, Dry-bulk, RoRo, General Cargo)	200
Tug/Tow boats	4,560
Dry Bulk Barges	28,000
Liquid Bulk barges	4,200
Total Jones Act Fleet	37,055

Source: MARAD, based on data from the United States Army Corps of Engineers.

Industry advocacy groups such as the Coastwise Coalition have recommended removing this significant disincentive to coastal waterborne traffic.⁹

Impacts on Vessel Construction Costs

The MMA regulations have also raised the construction costs for the U.S. flag fleets. Many domestic marine shipping stakeholders have maintained that the Jones Act adversely affects domestic operations because it increases the startup costs since ships built in the U.S. tend to be more expensive than those constructed abroad. Industry observers have noted that U.S. cabotage policies governing the coastal trade and navigation influence the cost structure of the domestic waterborne shipping, and that the Jones Act’s restrictions have handicapped coastal shipping within the American waters and opened the way for the growth of the trucking and freight-rail industries. They maintain that privately-owned domestic shipyards in the United States operate with high cost structures, building vessels that are not always competitively priced. Because of these higher vessel purchase costs, businesses may find it harder to start and sustain a domestic short sea shipping (SSS) operation.

The higher cost of shipping cargo on U.S.-built vessels raises the price to the shipper and leads to the loss of consumer benefit from trade. For instance, a 1990 GAO report estimated that cargo preference for food assistance (instead of shipping on lower priced foreign ships) incurred additional costs estimated at about \$150 million per year. The economic losses from these higher costs include smaller volumes of food shipment, since given the government’s fixed budget for food purchase, farmers can sell less grain for food assistance.¹⁰ Jones Act provisions have also been considered responsible for raising the cost of feed for poultry, pork, and cattle farmers in North Carolina who have to import feed from abroad when adequate capacity for shipment of Midwest grain on U.S. flag barges has not been available.

⁹ *Coastwise Coalition*, Paul Bea, pbea@phbpa.com and <http://www.maritimeadvisors.com>

¹⁰ GAO, “Cargo Preference Requirements: Their Impacts on U.S. Food Aid Programs and the U.S. Merchant Marine,” Report to Chairman, Committee on Agriculture, June 1990.

In a U.S. Department of Agriculture (USDA) study conducted in 1986 to estimate the impacts of the Jones Act on the Alaska forest products, the analysis of freight differentials indicated that the Jones Act protection of domestic shipping had an adverse effect on the trade flows, though on the whole the effects appeared small relative to the wholesale value of producing and shipping spruce and hemlock logs and export lumber. The Act was not seen a major factor in market determination, although low-value products and longer trade routes were more sensitive to rate changes.¹¹ Pacific Rim countries typically purchase 95 percent of the products produced by the Alaska forest products industry, with another 4 percent shipped to the Pacific Northwest. Alaska depends on waterborne transportation to conduct foreign and domestic trade. The study estimated the extent to which compliance with the Jones Act raises shipping costs for Alaskan forest products by estimating the difference in freight rates for equivalent vessels under U.S. and foreign flags. The study estimated the direct effect of the Jones Act to be a reduction in income for Alaska forest resource owners and consumers of forest products. Relaxing the Jones Act would generate the greatest potential for cost savings for the domestic movement of logs and lumber from the Pacific Northwest.

Other industry experts, however, have maintained that given the long operating life of a ship, higher construction costs would add little to the cost of each shipment. A July 2005 GAO report asked a domestic marine operator whether the Jones Act requirements for the vessels to be U.S.-built were a potential obstacle to expanding service, given that U.S. construction costs may be more expensive than foreign-built vessels. The operator responded that these higher construction costs did not pose a burden, but that the USCG crewing requirements that mandate unnecessarily large crews for short sea operations significantly increase the operating costs.¹² The USCG has maintained that the safety benefits of the larger crewing requirements exceed the cost burden, given the adverse consequences of crew error on vessel accidents, as noted in Section 3.¹³

Impacts on Viability of Hub & Spoke Feeder Port System

Currently there is no viable feeder port system in the U.S. operating within a well-integrated, interconnected network, partly because of the higher costs of deploying U.S.-built self-propelled vessels for domestic feeding service. In the marine shipping industry, “feeder” is defined as the practice of using smaller self-propelled ships for local or coastal transport to carry bulk cargo or containers to and from ports not scheduled to be called by the ocean vessels serving international trade, and to connect smaller ports to major ocean ports.¹⁴ In its 2006 *Report to Congress*, MARAD pointed out that there is a scarcity of small feeder vessels and short sea shipping services in the

¹¹ Kristine C. Jackson and Charles W. McKetta, *Impacts of the Jones Act on the Alaska Forest Products Trade*, USDA, Forest Service, Pacific Northwest Research Station, General Technical Report PNW-196, September 1986.

¹² GAO, “Freight Transportation: Short Sea Shipping Option Shows Importance of Systematic Approach to Public Investment Decisions,” GAO-05-768, July 2005.

¹³ This point was raised by LCDR Ellis Moose, CG-54121.

¹⁴ P&O Nedlloyd 2005, quoted in Mark Yonge, “The Development of Short Sea Shipping in the United States,” Testimony before Subcommittee on Coast Guard and Maritime Transportation Committee on Transportation and Infrastructure, House of Representatives, February 15, 2007.

U.S., and attributed the growing channel capacity constraints and the inability of the existing infrastructure to meet the vessel draft needs to this deficiency. The report noted that the average size of containerships calling at U.S. ports is 17 percent larger than the size of vessels calling at ports elsewhere in the world. The size of an average feeder ship is less than 3,000 TEU, compared to the 6,000-plus TEU vessels routinely calling on coastal ports. The report explained that one reason for the larger average size of the vessels calling at U.S. ports is the absence of a robust feeder port system in the U.S. In Europe and Asia, the report pointed out, short sea services rely in smaller feeder vessel to handle most of the intra-European and intra-Asian trade.¹⁵ It is also possible that the larger size of the vessels calling at the U.S. ports is driven by the need to achieve economies of scale for transoceanic voyages from Asia, and that the availability of European feeder vessels is not due to different cabotage laws but to transportation policies in the European Union (EU) that favor short sea shipping.¹⁶

Vessel Crewing and Manning Requirements

Crewing regulations may have more of an adverse impact on the growth of domestic waterborne shipping than vessel construction costs. Industry observers have maintained that given the long operating life of a ship, higher construction costs would add little to the cost of each trip; but that crewing costs make up a large share of a vessel's daily operating costs. The July 2005 GAO report cited above found that the Jones Act requirements had a relatively small impact on a vessel's operating costs, but that the USCG crewing requirements that mandate large crews for short sea shipping operations were likely to increase the operating costs significantly.¹⁷

It should be pointed out that while at the domestic level crewing regulations may raise the operating costs of a vessel, at the international level crewing levels have been declining, pointing to an emerging safety risk area not related to the U.S. crewing requirements, as addressed in detail in section 3.0 on gaps in crew training and operator error. This report recognizes the tradeoffs of trade facilitation and navigation safety, and addresses the underlying elements of the complex MTS operational challenges is their entirety and with respect to all risks.

Requirements for Advance Notice of Arrival (ANOA)

DHS requirements for Advance Notice of Arrival (ANOA), the 24-Hour Rule for transmitting container manifest and the 96-Hour Vessel Arrival Notice, may also present potential barriers to domestic shipping in the Great Lakes and St. Lawrence Seaway. The 24-Hour Rule is enforced by CBP to receive advance cargo manifest in compliance with the Container Security Initiative (CSI) implementation process. The implementation of the rule has allowed the CBP to directly receive cargo manifest information from carriers

¹⁵ Maritime Administration, *Annual Report to Congress*, Fiscal Year 2006.

¹⁶ This point was raised by LCDR Ellis Moose, CG-54121.

¹⁷ GAO, "Freight Transportation: Short Sea Shipping Option Shows Importance of Systematic Approach to Public Investment Decisions," July 2005, GAO-05-768.

and provide necessary data for determining which containers should be scanned and inspected overseas.

The USCG 96-Hour ANOA requires all vessels scheduled to call at U.S. ports to report their arrival to the USCG. The rule also requires submission of information on passengers, crew, and cargo manifest. The USCG reviews and analyzes the ANOA to determine the vessel and crew's risk levels and determine if additional security precautions entailing boarding the ship while it is still at sea and/or armed escort during transit to and from certain ports are necessary. The USCG, CBP and Immigration and Customs Enforcement (ICE) jointly implement the ANOA requirements. Maritime Security Risk Analysis Model (MSRAM) and High Interest Vessel (HIV) data could also be used to determine the appropriate security risk level from terrorism for vessel transits to U.S. waterways.¹⁸

¹⁸ The last point in the paragraph was made by LCDR Ellis Moose, CG-54121.

Section 3.0 Gaps in Data, Information Systems, and Mariner Training

The CMTS Data Collection and Information Management Integrated Action Team (IAT), led by MARAD, has developed a comprehensive inventory of the existing sources of MTS data. The MTS data inventory contains an overview of available marine transportation-related information that is either used or produced by the Federal Government. This inventory is made available to provide analysts, managers, and decision makers with data and information useful for statistical and performance measurement.¹⁹

While recognizing the value of the vast inventory of data and the associated advanced-technology assets, certain gaps remain. This section identifies several gaps in the available risk data, software systems and technologies for controlling marine traffic, and training programs for educating professional and recreational mariners.

Gaps in Maritime Risk Data

Tools for Waterway Traffic Control

For the MTS to attain a high level of control on network traffic and navigation safety, more rigorous centralized control of waterway traffic would be needed in some locations. In its seminal 1994 report on *Minding the Helm: Navigation and Marine Piloting*, the Marine Board/National Research Council commented on the state of marine navigation control:

“The loosely integrated management of U.S. waterways systems needs to be tightened in the face of regional and global economic competition and the safety and environmental concerns of the public and Congress. Centralized management by a single authority is not necessarily essential if components of the marine navigation and piloting can be effectively and systematically coordinated through cooperative working relationships.”²⁰

¹⁹ The members of the Data IAT include representatives from the Department of Transportation (Maritime Administration, Saint Lawrence Seaway Development Corporation, Federal Highway Administration, Research and Innovative Technology Administration, Bureau of Transportation Statistics, Federal Railroad Administration, and Pipeline and Hazardous Materials Safety Administration), Department of Defense (U.S. Army Corps of Engineers, U.S. Transportation Command), Department of Homeland Security (U.S. Coast Guard, U.S. Customs and Border Protection), Department of Commerce (National Oceanic and Atmospheric Administration, U.S. Census Bureau, International Trade Administration), Department of Energy, Department of Labor, Department of the Interior, Department of Agriculture, Department of State, Environmental Protection Agency, and the Federal Maritime Commission.

²⁰ National Research Council (NRC), National Research Council (NRC), *Minding the Helm: Marine Navigation and Piloting*, Committee on Advances in Navigation and Piloting, Marine Board, Commission on Engineering and Technical Systems, 1994.

The Marine Board did not find the national airspace system as a suitable alternative model for marine traffic control, given the fundamental operational differences between aviation and marine operating models. However, the Board recommended that the air traffic control model for control of approaches to marine pilots' boarding areas would be a good model for maritime navigation because both modes require a similar systemic approach. Such an approach would consist of a system-wide operating concept, high-reliability systems, universal procedures and protocols, universal operating language, real-time precision navigation capability, adherence to preplanned routes, availability of real-time environmental data, professional controller staff, technology-based decision aids, vigorous training requirements for pilots and controllers, and a near-miss reporting system.

Risk-Based Accident Data

Better risk-based accident data are needed for calibrating decision-support tools to help mariners during adverse navigation conditions and hazardous situations. One such gap in maritime risk analysis is lack of data on near miss incidents. The USCG computerized safety risk assessment models have advanced capabilities for efficient Search and Rescue (SAR), as extensively discussed in Task 4 report of the CMTS Assessment on Safety Challenges. However, little data on near-misses are available for marine incidents. Compared to aviation industry, where near-miss data are used extensively for risk analysis, no such data exist for maritime incidents. Reporting near misses would be a positive step towards providing insight into actual and potential causes of accidents. These reports would include data on unusual events such as loss of propulsion, steering, failure and near-miss that do not qualify as reportable, and fires and facility malfunctions that could provide valuable insight into root causes of accidents. The NRC/Marine Board report has recommended processing these near-miss data by software systems that conduct automated tracking of marine incidents and feed into risk analysis models that identify high-accident conditions. These data could be either integrated with computer-based operating systems that support the USCG vessel traffic service (VTS) systems or used for planning and computerized risk assessment purposes. The reporting system would allow development of an Exposure Database to facilitate risk identification, and would enable better maritime risk assessment programs.²¹

Experts have pointed out that the USCG led an effort in the late 1990s to report near-miss events, but had little success. They have observed that the lack of success had to do with differences between the maritime culture and aviation. Simply creating a reporting mechanism does not necessarily entice the mariners and operators to report near-miss events.²²

²¹ National Research Council (NRC), *Minding the Helm: Marine Navigation and Piloting*, Committee on Advances in Navigation and Piloting, Marine Board, Commission on Engineering and Technical Systems, 1994.

²² LCDR Ellis Moose, CG-54121, has pointed out the USCG developed a near-miss reporting database named NMSIRS, with information documented in <http://www.dot.gov/affairs/1998/cg0398.htm>. MARAD is reported to be still working on such a system; point of contact: Pradeep.Nayyar@dot.gov

Better risk-based data would also include collecting data to reflect the influence of new navigation technologies. Such data would allow analysis of trend data over several decades to identify navigation errors and incidents that have been introduced due to changes in ship building practices and navigation technologies. Currently there are no data sources for systematic monitoring of the performance of new navigation systems and bridge technologies. Many safety studies have to rely on incomplete and faulty casualty data. Furthermore, there is no accepted method for normalizing data or a systematic performance monitoring program to accommodate vast difference among ports and waterway systems to allow comparative safety performance assessment. The 1994 NRC report on adequacy of data and tools for addressing navigational risks found:

“Underlying causes of marine accidents have not been addressed methodically or effectively by most shipping companies, marine safety authorities, or other interested parties. Furthermore, the available marine safety data are not adequate to support this objective. No public agency in the U.S. is systematically monitoring to detect problem ships, inadequate operating and management practices, and substandard crews. Some proprietary monitoring is conducted, but these data are usually not available. When accidents occur, pilotage is frequently an early target for blame. The overall result is that risk management in the marine operating environment depends to a great extent on perceptions of risk and personal judgment. Thus symptoms of problems rather than underlying causes are often treated.”²³

The USCG created the Marine Information for Safety and Law Enforcement System (MISLES) in 2000 and has changed its data collection system and approach to reporting marine casualties.

In an attempt to improve accident data, MARAD is currently co-sponsoring the Ship Owners Cooperative Program (SOCP) to enable ship owners to engage in Research Development (R&D) projects to enhance maritime safety, security, and environment. The program will assess the benefits to the U.S. maritime industry of an effective marine safety information network for accident prevention and identify the challenges faced in developing such a network.²⁴

Gaps in Mariner Training

The U.S. MTS is comprised of an immense knowledge base for supporting a safe and efficient maritime system. The MTS training institutions represent a vast reservoir of knowledge that is embodied in several sources: the MTS knowledge may be embodied in the expertise of its people – mariners, vessel operators, SAR officers, educators and

²³ National Research Council (NRC), *Minding the Helm: Marine Navigation and Piloting*, Committee on Advances in Navigation and Piloting, Marine Board, Commission on Engineering and Technical Systems, 1994.

²⁴ Information on the MARAD SOCP was provided by Richard Lolich in an email to CMTS dated November 20, 2009.

researchers – or in the capabilities offered by the technological tools and devices – vessel propulsion system and hardware/ software technologies for navigation, control, and communications. These capabilities have allowed the MTS mariners, regulatory personnel and vessels to operate efficiently and safely and remain competitive.

Access to educational and professional training provided by the Merchant Marine colleges, universities, and academies for training and R&D has generated immense benefits. The nation’s federally-supported maritime service academies – U.S. Merchant Marine Academy, Kings Point, NY; California Maritime Academy, Vallejo, CA; Great Lakes Maritime Academy, Traverse City, MI; Maine Maritime Academy, Castine, ME; Massachusetts Maritime Academy, Buzzards Bay, MA; State University of New York Maritime College, Bronx, NY; and Texas Maritime Academy, Galveston, TX – provide state-of-the-art mariner training, with programs that provide a reservoir of knowledge for basic professional mariner training. These academic programs train mariners on all components of maritime know-how: *core knowledge* relating to fundamental principles of science and navigation system, *enabling capabilities* derived from technology-based enhancements, and *supplemental* skills relating to learning how to perform specific tasks. Other mariner training programs include the union run schools and the recreational boating classes run by the Coast Guard Auxiliary and the U.S. Power Squadron.²⁵ While for students at these institutions the key components of mariner training are adequately addressed, for many untrained crew-members (foreign and domestic), and millions of casual boaters training on these skills has been inadequate.

In the institutional context of the MTS, three key training-related issues, all of which are interrelated, need to be addressed: operator error/lack of training, moral hazard, and technology-assisted collisions.

Operator and Crew Error

Collision- and grounding-accidents are often caused by operator error. Studies have shown that key causes of collision accidents are poor bridge management resulting from inadequate crew skill and knowledge, including poor lookout, infractions of collision regulations (COLREGS), crew fatigue, and officer of the watch (OOW) falling asleep.²⁶ Many of these operator errors, often found to be the “immediate” or “triggering” causes of marine accidents, stem from “human factors” relating to communication failures, misunderstanding, ignoring hazard warnings, making errors in navigation, or operating in adverse conditions without adequate monitoring. However, in complex waterway systems, the immediate and triggering causes of accidents are often different from the root causes. The propensity of vessels to get involved in an accident may stem from diverse roots causes such as the inherent risks of the cargo or facility operations, mechanical failure, chart flaws, or vessel scheduling and shipping practices that ignore safe navigation principles.²⁷ Accident studies have indicated that human error is responsible for the majority of navigation accidents. However, human error is often not

²⁵ Point raised by LCDR Ellis Moose, CG-54121.

²⁶ Marine Accident Investigation Branch (MAIB), “Bridge Watchkeeping Safety Study,” July 2004.

²⁷ Based on John R. Harrald and Martha Grabowski, “Risk Mitigation in Passenger Vessel Operations,” Originally appeared in Disaster Recovery Journal (Vol. 7. No. 3, circa 2003).

the real cause of accidents, but the symptom of other failures in managing a vessel's navigation.

Studies have indicated that nearly all human errors associated with marine accidents are caused by lack of knowledge, skill, instruction, or motivation. A recent report by the Norwegian classification society, Det Norske Veritas (DNV) has warned about recent trends in accident rates that point to certain underlying failures in vessel crew skills that have led to an increasing rate of serious marine accidents, cautioning that the "accident numbers are going in the wrong direction" despite improved inspection, auditing, and standards of technical excellence and transparency. It warns that there is more stress and fatigues relating to the people and organizations both on board and on shore, to keep up with the growth in commercial shipping, partly because:

"the general level of experience on board vessels has been reduced. There are more new recruits, less retention and faster promotion....The workload onboard with respect to paperwork and inspections has increased while the crew size is stable. [At the same time] the loss of experience is also a stress factor for those on board who continuously have to train new crew members."²⁸ [The DNV article calls for greater focus on the crew on board and the management on shore, recommending that] the management has to demonstrate more commitment to safety, and learn more from practices in offshore and aviation industry with intense focus on human and organizational factors for more 25 years."²⁹

The need for more rigorous training was emphasized by Captain Gregg Farmer, Boston Pilots Association, at an Expert Panel meeting held at the Volpe Center. Captain Farmer stressed the need for training, pointing out that there are currently no international requirements for equipment training, and that while crossover licensing from another country is accepted, no training requirements are associated with the use of the equipment, adding:

"The IMO comes out with the equipment, but there is no training. They've got a salesman trying to sell the product, but he has no knowledge of the unit...The IMO needs to be more user-specific and get back to training. It should be required and it is not. Reps don't spend the time to teach the system."³⁰

Moral Hazard Issues

Operator-error causes of recreational boating accidents account for some 80 percent of all navigation accidents. Some of these errors have their roots in what is referred to as the "moral hazard" arising from increased risky behavior caused by excessive confidence in the protection afforded by an electronic product. Access to electronic navigation charts (ENC), GPS, and real-time data on weather/tide & current conditions could be effective

²⁸ Safety at Sea International, "Manpower strains linked to accidents", <http://www.safetyatsea.net/>

²⁹ DNV, "Increasing incidence of serious accidents", Stamford, Connecticut, October 9, 2007. <http://www.dnv.com/industry/maritime/publicationsanddownloads>

³⁰ Expert Panel meetings held at the Volpe Center for a NOAA Study on Valuation of the NOS Navigation Data, in Cambridge, MA, on May 7, 2008.

in reducing maritime accidents when used properly. However, the extent to which the products have proven efficacious at the present is limited because boaters often do not use the products according to usage standards. The findings of a recent report on recreational boating and the capability of electronic navigation data to reduce boating accidents highlight the contribution of boater error and moral hazard to boating accidents, warning that:

“... the full scope of the benefits from these electronic devices has not yet been realized because recreational boaters presume that the data they can zoom in and out of are as accurate as the GPS system the users have in their cars.”³¹

Arthur Allen, Office of Search and Rescue, USCG, has characterized the role of moral hazard in reducing risks of navigation in the context of the systemic tendency for *conservation of risk*:

“I’d like to take the 100-year view. Going to sea has gotten safer and there have been improvements in positioning and navigation. There have been huge improvements in letting the world know you are in trouble. It has reduced the number of SAR cases. We have a better understanding of the weather and environmental factors. Vessels themselves are getting safer as well. This means these things have worked over time, but that there is also the issue of “*conservation of risk*”: that is to say, improved technology has encouraged more risky behavior. *Technology allows people to go to sea without any training*. No apprenticeship is required any longer; no open ocean experience is needed to use a boat. *We have made the vessels and navigation safer, but we haven’t made people safer.*”³²

Training gaps for professional mariners are distinctly different from risks arising from untrained recreational boaters. Mariner training requirements enforced by the USCG and the International Maritime Organization (IMO) Standards of Training, Certification & Watchkeeping for Seafarers (STCW) Convention have established strict codes for crew training and ship bridge management on board commercial vessels. Moral hazard issues and lack of training for recreational boaters, however, remain a daunting challenge.³³

Computer-Assisted Collisions

Closely related to the moral hazard associated with excessive reliance on advanced technologies is the paradoxical role advanced navigation technologies have played in increasing risks of accidents. Terms such as Radar Assisted Collision or Computer-Assisted Groundings have for some time been used to refer to this contradictory outcome of the availability of electronic aids to navigation (AtoN.) The 1991 Port Needs Study (PNS) first pointed out this problem by noting that the role of AtoN in navigation safety

³¹The Hydrographic Services Review Panel (HSRP, “HSRP Most Wanted Hydrographic Services Improvements,” the HSRP Federal Advisory Committee Special Report, 2007

³² Expert Panel meetings held at the Volpe Center for the NOAA Study on Valuation of the NOS Navigation Data, in Cambridge, MA on May 7, 2008.

³³ Point raised by LCDR Ellis Moose, CG-54121.

is uncertain and that AtoNs have at times been known to increase the risks. The report noted that radar is widely indicated for reducing stranding and collisions, but that in numerous cases “radar-assisted collisions” have occurred because mariners focused too much attention on the radar picture or incorrectly interpreted radar information. The PNS pointed out that while technology advances can ameliorate some marine risks they can also introduce new ones.

Though empirical data are still lacking in support of the extent and frequency of these computer-assisted collisions, industry experts consider the risks significant. Here is how Captain Dave MacFarland of NOAA has described the inadvertent role electronic navigation (e-charts) play in vessel grounding:

“When e-charts first became popular, people were overusing the charts and using them for things they were never intended for. We’ve seen cases of what has been facetiously called Computer-Assisted Groundings. The e-charts were not adequate for what people wanted to do with them; they led to grounding because of the user over confidence.”³⁴

Emphasizing the moral hazard associated with access to electronic devices are the comments made by Captain Craig Dalton, Massachusetts Merchant Marine Academy:

“Our guys have to take a 4-year course on electronic chart display and information system (ECDIS). The more you use ECDIS the less you can navigate. They are not able to navigate without using the electronic system because they rely on it so much. When there is no positioning data coming in, what do you do? It is important to continue to stress education using paper charts. Kids can embrace this technology because they love video games. The old timers will learn to use it over time. What do you do when you rely solely on ECDIS and the data is wrong? There is also a problem of liability there. How do you maintain navigation skills when using state of the art technologies? The cruise ship industry uses ECDIS a lot, but they have had a lot of problems; running aground because of a huge dependence on electronic technology.”³⁵

Responding to panel discussion questions about the risks of over-reliance on electronic devices and how marine academies and educators should use new technologies without reinforcing the associated moral hazard risks, Captain Craig Dalton, pointed out:

“There needs to be a way to use this new technology without losing your safety net. There needs to be another mode of monitoring.”

Similar comments on the moral hazard introduced by new electronic technologies were made by Captain Gregg Farmer, Boston Pilots Association:

³⁴ Comments made at the Expert Panel meetings held for the NOAA Study on Valuation of the NOS Navigation Data, held in Cambridge, MA on May 7, 2008.

³⁵ Comments made at the Expert Panel meeting held at the Volpe Center on May 7, 2008.

“Sailors are not using their eyes. When gyros were used, you became accustomed to the older technology. The newer systems are taking that away.”

In response to the question on whether we should we have a layered system with some redundancy and continue the legacy of older technology and skills, Captain Farmer responded:

“How many kids today can pick up a sextant and do a one-off? I get worried when people start talking about situational awareness with Automatic Identification System (AIS). Anyone is able to mask his ID by looking up an IMO number. AIS is great, it just depends on how you use it.”³⁶

When AIS was deployed originally, the system was linked to data showing improved navigation security and safety. However, more recent data have not shown that deployment of the technology has reduced accident rates. Part of the reason is that many mariners assume that all vessels are displayed on their screens. However, only vessels of ≥ 300 gt are required to carry AIS; smaller boats and fishing vessels are not covered. The possibility of a computer-assisted collision has been investigated by several studies conducted by the United Kingdom (U.K.)-based Marine Accident Investigation Branch (MAIB). In one study, the MAIB found that the officers of the watch (OOWs) place excessive reliance on radar and ARPA to maintain lookout and assess the risks of collision in contravention of the IMO Standards of Training, Certification, and Watchkeeping (STCW) guideline. The study warned that:

“...indeed, many newer vessels are not even equipped with a gyro pelorus on the bridge with which to take a visual bearing.... [The study concluded that] it is therefore disturbing that the OOWs on 73 percent of the vessels involved in collision potentially contravened the [STCW] Rules 7(b) or 7(c) regarding proper use of radar equipment, ...[and that] assumptions shall not be made on the basis of scanty information....”³⁷

In June 2004, a collision occurred between a UK-flagged *Yudais Dominion* and the Hong Kong flagged *Sky Hope* in the Pacific Ocean. The OOW of *Hyundai Dominion* had sent an AIS text message to *Sky Hope* warning it of its presence, assuming that the text message was received despite receiving no audible sign that the message has been delivered. The MAIB investigation found that AIS alone will never give full awareness of all the vessels in the vicinity.³⁸

³⁶ Comments made at the Expert Panel meeting held at the Volpe Center on May 7, 2008.

³⁷ Marine Accident Investigation Branch (MAIB), *Bridge Watchkeeping Safety Study*, Safety Study 1/2004, July 2004.

³⁸ MAIB, *Report on the Investigation of the Collision between Hyundai Dominion and Sky Hope in the East China Sea*, 21 June 2004, http://www.maib.gov.uk/cms_resources.cfm?file=/Hyundai_Sky%20Hope.pdf

Gaps in Port Recovery Baseline Data

Among the gaps identified by the Implementation Plan for the MTS National Strategy is availability of detailed harbor survey data that would reduce post-incident recovery time. CMTS has proposed funding for Domestic Port Recovery and Security Survey Baseline.

Section 4.0 Gaps in Interagency Emergency Response Coordination, Information-Sharing, Equipment Interoperability, and Intermodal Integration

With respect to the institutional challenges arising from lack of interagency coordination and information sharing, the most critical problems are encountered under Emergency Response (ER) conditions. Ensuring coordination and information-sharing among myriad MTS safety and security agencies and availability of interoperable equipment and communications devices is a high priority objective. Collaborative response and decision-support when dealing with complex incidents involving chemical, biological, radioactive or nuclear (CBRN) threats determine and test the adequacy of MTS institutional resources.

Scale and Scope of the MTS Interagency Coordination Needs

The National Response Plan (NRP), developed for the management of the Nation's domestic incident management, as authorized by the Homeland Security Act of 2002 and the Homeland Security Presidential Directive-5 (HSPD-5), defines the scope of the emergencies addressed in the NRP as follows:

“Today's threat environment includes not only the traditional spectrum of manmade and natural hazards – wildland and urban fires, floods, oil spills, hazardous materials releases, transportation accidents, earthquakes, hurricanes, tornadoes, pandemics, and disruptions to the Nation's energy and information technology infrastructure – but also the deadly and devastating terrorist arsenal of chemical, biological, radiological, nuclear, and high-yield explosive weapons.”³⁹

The implementation of the NRP is predicated on the development of a National Incident Management System (NIMS) that is designed to provide a “nationwide template that would enable federal, state, and local governments and private-sector/nongovernmental organizations to work together effectively to prevent, prepare for, respond to, and recover from domestic incidents regardless of cause, size or complexity.”

Included in the scope of the DHS ER responsibility is the Homeland Security Presidential Directive-7 (HSPD-7) that provides the framework for the overarching goal of the National Infrastructure Protection Plan (NIPP) to provide a unifying structure for the integration of existing and future critical infrastructure and key resources (CIKR) of the nation. The partners in managing the CIKR, in addition to the DHS and Federal/state agencies in charge of managing the risks of the 17-plus infrastructure sectors, are numerous regional, commercial, sector-specific agencies, boards, commissions, councils and academic agencies that need to be coordinated and unified when an ER is required.⁴⁰ Coordinating the diverse number of CIKR risk management plans developed by the array of public and private partners represents a daunting challenge. Task 5 Report on the

³⁹ Department of Homeland Security, *National Response Plan*, December 2004.

⁴⁰ DHS, *National Infrastructure Protection Plan: Partnering to Enhance Protection and Resiliency*, 2009.

Assessment of the MTS Security Challenges has addressed many dimensions of these ER challenges.

In a large-scale incident, e.g., blockage of a major port with disabled vessels, ER response typically requires an array of marine salvage services, including salvage and towing vessels, heavy lift assets, lightering ships, divers and underwater robotic devices. Continual need to evaluate myriad legal, regulatory, economic transportation and political considerations may significantly impede the execution of a timely response. The goal of minimizing the economic costs and safety and environmental damages from such events could thus be thwarted.

The U.S. Navy's Office of the Supervisor of Salvage and Diving (SupSalv), established primarily to meet military needs for search and salvage, maintains a Marine Salvage capability for marine recovery and salvage. By statute and through agreements with other federal agencies, SupSalv also provides services to meet certain non-military emergency salvage needs, given its recognized expertise in the field. Under the Salvage Facilities Act, the U.S. Navy has oversight responsibility for monitoring the nation's overall marine salvage capability.

Gaps in Coordinating Emergency Response (ER), Preparedness and Recovery Strategies

At a National Academy's Transportation Research Board workshop held on September 4-5, 2008 on marine ER and salvage needs, a number of institutional challenges relating to coordination of ER and vessel salvage procedures were addressed, including: How are the diverse missions of the federal agencies with military, security, marine safety, environmental protection, trade, facilitation, immigration, economic costs prioritized and reconciled? ⁴¹ The requirements for completing the "Due Process" before the vessel removal is initiated, the Workshop participants indicated, often introduce complications in the response process. Working closely with the Navy are USCG, USACE, NOAA, MARAD, and other DOT agencies, FEMA, and FBI. ⁴² The Due Process for salvage involves participation and input from the following parties before vessel removal:

- Private vessel owner, operator or lessee is responsible for the vessel and must be given notice;
- Insurance companies and underwriters of the policy holders must be notified;
- USACE requires reimbursement for any removal activities;
- Notices to Mariners need to be coordinated with USCG;
- Hazard-to-navigation notices need to be coordinated with NOAA Hydrographic Survey agencies;
- Hazards to navigation need to be identified for consideration by USACE dredging operators;
- Environmental compliance and wetland permits need to be obtained;

⁴¹ *U.S. Marine Salvage Assets and Capabilities in a Maritime Disaster*, Conference Proceedings 45, Transportation Research Board, September 4-5, 2008

⁴² *National Response Plan*, Department of Homeland Security, 2004, a 426-page report available on www.nmfi.org/natlresp/files/NRPallpages.pdf

- FEMA needs to approve the removal and disposal of “wet debris” by USACE, as required by the National Response Framework (NRF);
- USCG Captain of the Port (COTP) is responsible for certain salvage operations;⁴³ these are operations that fall outside the USACE policy concerning Federal Channels;⁴⁴
- Debris disposal must be in compliance with local, state, and federal laws and recycling requirements as much as possible, with each incident requiring a coordinated debris removal and disposal plan.⁴⁵

In the event of declaration of an Incident of National Significance (in response to a request by state/states for federal assistance) a team consisting of multiple federal agencies is assembled for Incident Response. The Presidential Declaration authorizes DHS/FEMA to oversee assistance under the Stafford Act. The DOD/USACE is the primary agency providing technical assistance, engineering and construction management under the Emergency Support Function (ESF) that is triggered for all hazard types and emergencies, not just natural disasters.⁴⁶

In January 2008, the National Response Plan was revised and replaced with the National Response Framework (NRF), which became effective in March 2008. The Framework maintains FEMA’s responsibility for coordinating human services, and specifically includes disaster case management as one of several categories of human services. The NRF recognizes the need for collaboration among the myriad of entities and personnel involved in response efforts at all levels of government and the nonprofit and private sectors and places increased responsibility on FEMA for coordinating with voluntary organizations. Moreover, the Framework requires federal agencies involved in mass care, housing, and human services to coordinate federal response efforts with the efforts of state, local, private, nongovernmental, and faith-based organizations.⁴⁷

The NRF provides the guidelines for prioritization of actions needed to ensure continuity of MTS operations. The NRF requires availability of lock and channel and connections to terminals and landside transportation links in the event of anticipated threats such as floods, hurricanes and ice storms, as well as unanticipated earthquakes, vessel sinking, bridge collapses and spills.

⁴³ LCDR Ellis Moose, CG-54121, has pointed out that the COTP does not have blanket authority in reference to salvage vessels, noting that the USCG can remove abandoned vessels if: 1) they contain oil or hazardous substances and pose a threat to the environment; or 2) are an abandoned barge covered by the Abandoned Barge Act of 1992.

⁴⁴ LCDR Ellis Moose, CG-54121, has pointed out that the Secretary of the Army has the authority to remove or dispose of obstructions “whenever the navigation of any river, lake, harbor, sound, bay, canal, or other navigable waters of the U.S. shall be obstructed...”(33 U.S. C Section 414). USACE limits the application of this authority to the Federal Channel by policy.

⁴⁵ Michael F. Kidby, “Hazards to Navigation: How to Manage the Removal/Disposal of Debris” HQ. USACE, presentation at the Maritime Disaster Workshop, TRB, September 4-5, 2008.

⁴⁶ Michael Kidby, September 4-5, 2008.

⁴⁷ GAO, Disaster Assistance: Greater Coordination and an Evaluation of Programs’ Outcome Could Improve Disaster Case Management, GAO-09-561, July 2009.

Lack of Interagency Coordination for Fee Collection

One example of the lack of interagency coordination and collaborative decision-making, is provided by a recent report on Federal User Fees collected by the USACE (the Corps) and the Customs and Border Protection (CBP), in which the GAO points to a:

“lack of coordination between the Corps and CBP [that] inhibits oversight of the Harbor Maintenance Tax (HMT) payments made by passenger vessel owners/operators, domestic shippers, and imports shipping into Foreign Trade Zones.... The misalignment between fees and the services for which they are charged reduces both equity and economic efficiency and does not provide policy makers with information on the level of service for which users are willing to pay.”⁴⁸

As an example of the CBP failure to coordinate the fee collection processes, the GAO reports that “of the over 200 value and classification of goods audits conducted between 2004 and 2007, the importer had paid the HMF incorrectly more than 60 percent of the time;” noting that:

“the CBP cannot reliably project future MPF [Merchandise Processing Fee] collection because the agency has not estimated the effects of exemptions, entries made through foreign trade zones, the decline in the constant dollar value of the minimum and maximum fees, or changes in import demographics on total MPF collections. CBP data on MPF collections and program costs indicate that since fiscal year 2004 collections have increased relative to program costs and in fiscal years 2006 and 2007 collections exceeded cost by a total of approximately \$221 million.”⁴⁹

Decentralization Challenges

Decentralization of the MTS CIKR resources for prevention, deterrence, response, and recovery has been cited as a key impediment to implementing a cohesive MTS strategy. A recent report prepared for MARAD on maritime policy challenges has noted that:

“there is no cohesive, nationally adopted Federal policy that notes the critical interface between the world ocean transportation system and the U.S. inland transportation represented by the Nation’s ports.”⁵⁰

The IHS Global Insight report has acknowledged that the CMTS has begun this process, noting that CMTS, directed to be created by the 2004 Ocean Action Plan and formally established in August 2005, has delivered its initial report on July 10, 2008. It notes that CMTS has identified several action items “with a broad range of words such as propose,

⁴⁸ Government Accountability Office, Federal User Fees: Substantive Reviews Needed to Align Port-Related Fees with Programs they Support,” GAO-08-321, February 2008.

⁴⁹ Government Accountability Office, Federal User Fees: Substantive Reviews Needed to Align Port-Related Fees with Programs they Support,” GAO-08-321, February 2008, p. 32.

⁵⁰ IHS Global Insight, “An Evaluation of Maritime Policy in Meeting the Commercial and Security Needs of the United States,” January 7, 2009.

work collaboratively, facilitate,” but that it has “no inherent legislative authority.” The report concluded:

“It is unclear if the forecast seaborne trade can be accommodated by the current infrastructure: this means that some sort of change must be forthcoming.... The current decentralized structure of maritime policy-making in the U.S does not have one clear leader to coordinate all the functions that can assume the realization of this goal. Responsibilities for commerce facilitation, safety, national security, finance, and environmental integrity in the maritime domain are spread across many agencies and departments, with overlapping and at times contradictory missions. Having a central authority among these various interests could help to remove the obstacles to reform.”⁵¹

The IHS Global Insight report has recommended that policy makers align the multi-modal transportation system with the needs of the U.S. economy:

“Current maritime policy remains narrowly focused on vessels, rather than on the transportation system as a whole. While the desired outcome is a seamless intermodal system from end to end, this can only be achieved when each component – the U.S.-flag fleet, the marine highway, ports and intermodal connectors, shipbuilding and repair, a highly trained workforce, and related services – are fully integrated into the overall transport system.”⁵²

The IHS Report also notes the non-complementary goals of federal agencies, noting that with 11 cabinet-level departments and 4 independent agencies involved in the development of policies for ocean, coastal and inland waterways, inevitable conflicts are generated, noting that with over 18 agencies, strategic goals are often secondary relative to the particular agency mission. The report also identifies a lack of Federal leadership in formulating consistent maritime regulations and policies, noting that lack of a coherent structure of regulation increases the cost of compliance. It also notes that the lack of a singular authoritative oversight body for establishment and furtherance of the national maritime domain limits the prioritization of policy and implementation.

Gaps in Equipment Interoperability and Data Standards

Interoperability among myriad devices for communicating information about maritime hazards is not always established. For instance, SAR experts have maintained that less than 10% of the radios on recreational boats are hooked up correctly and that the radios do not have GPS properly locked into them. Also, distress signals sent by cell phones do not often have adequate location information. SAR officers have commented that they receive many distress signals from boaters, but that the signals don’t help with identifying the search area. One SAR officer, LT Bob Griffin, USCG, SAR Sector SE New England,

⁵¹ IHS Global Insight, “An Evaluation of Maritime Policy in Meeting the Commercial and Security Needs of the United States,” January 7, 2009, p. 54.

⁵² IHS Global Insight, “An Evaluation of Maritime Policy in Meeting the Commercial and Security Needs of the United States,” January 7, 2009.

commented at an Expert Panel meeting, put it this way: “pushing the technology is good, but the education is still lacking and needs to be improved.”⁵³

Need for standardization of electronic navigation data elements and display formats has been stressed by many navigation experts. During Expert Panel held on mariner’s use of electronic navigation charts (ENC) discussions on how the USACE and NOAA display hydrographic data elements for the two agencies’ electronic charts differ, and how information on channel depth and location are displayed showed the extent of the gap in uniform data standards. The participants noted that not all different sensors and data sources are synchronized. Because navigation charts and real-time tide and currents data require precise timing and vessel location information, synchronization of the electronic chart plotter with the vessel navigation and propulsion system is critical. The IMO requirements for installation of a voyage data recorder (VDR) in all SOLAS vessels, for instance, would require precise time and location information from the vessel GPS and ENC. However, when sensors are not synchronized the VDR data cannot be reliable.⁵⁴

Incompatibility of data standards for electronic charts also arises from the different layers of hydrographic data displayed and what elements are filtered out in the charts. Many participants expressed the need for a standard navigation chart display system, with international standards supporting them similar to efforts with respect to AIS and GPS standards.

Need for a standardized device for port pilots has also been noted. There was a consensus among the participants at the Expert Panel that the portable pilot devices such as the Portable communication, Navigation, and Surveillance (PCNS) are essential tools for pilots and that they should be standardized. Currently there are many different options and the devices are highly complicated. Depending on the ship and whether or not the vessel owners pay for the devices, pilots may obtain a PCNS or have to otherwise pay for it themselves. The harbor pilots participating at the Expert Panel noted that the reason there are no standard pilots units available is that the regulatory agencies have no requirements for it.

Lack of Infrastructure Integration

The nation’s vast inland waterway system is not integrated with the nation’s intermodal freight system. This means that planning and investment decisions for waterborne transportation projects and operations are not conducted at the same high level (Federal and state) as investment decisions on projects for highway, freight rail, or transit are made. The decisions are routinely made piecemeal at the local level, with no integrated approach to planning for the needs of the MTS users. In a 2005 feasibility study prepared by the University of Virginia the study team explored alternative means for augmenting intermodal transportation capacity at the inland waterways to alleviate capacity shortfalls and highway congestion facing the US intermodal system. The report noted that the

⁵³ Expert Panel meeting, held at the Volpe Center in Cambridge, MA, May 7 2008. LCDR Ellis Moose has pointed out that this comment applies only to recreational boaters, and that most radios on commercial ships are property installed and the crew trained.

⁵⁴ Volpe Center-organized Expert Panel meeting, held in Norfolk, VA, June 25, 2008.

inland river container services are underutilized resources because they are not fully integrated with the intermodal system, thus depriving the nation of the potential benefits of a low-cost and efficient transportation mode.⁵⁵

Lack of integration of the inland waterway system is further exacerbated because adequate access infrastructure for the cargo terminals serving inland waterway traffic is not available. This gap has created significant competitive barriers to the development of a viable short sea shipping system for moving containers as well as bulk and break bulk cargo. Currently about 85 percent of the domestic waterborne commerce, and 72 percent of the foreign waterborne trade is for moving bulk cargo. (See Appendix B, Task 2 MTS Assessment Report.) Lacking cargo handling and intermodal access infrastructure, for both bulk and containerized cargo has created high concentration levels at the nation's top 10 to 25 ports, adding to the system's congestion and capacity constraints. For processing bulk cargo, adequate equipment for efficient movement of commodities on barges is available only at a limited number of facilities. For handling containers and trailers, lack of lift and cargo handling infrastructure is even more pronounced. Access-infrastructure for roll-on/roll-off (RoRo) trailers and container lift equipment is not in place for handling more containerized cargo onto the inland waterway system. Building wharves, container marshalling areas, high capacity cranes and other container handling equipment, and providing access connectors to the inland transportation network will be essential if domestic short sea shipping operations are to be expanded.

Lack of Interagency Collaboration on Safe Vessel Mooring

The CMTS Implementation Plan for the MTS National Strategy has identified gaps in interagency consensus on how to address the threats to safe moorings of vessels to prevent barge breakaways and minimize debris accumulation in the waterways and threats to structures. The Plan has proposed interagency strategies to address this gap.

⁵⁵ "Inland Waterways Intermodal Transportation System Design and Feasibility Analysis" prepared by the University of Virginia for MARAD in May 2005.

Section 5.0 Closing the Gaps: Potential Solutions for Creating a Resilient MTS

This section reviews several proposed solutions to the current MTS institutional impediments in the context of the risk and resiliency assessment framework created in previous task reports. The resiliency framework was built on four pillars that characterize a resilient system, i.e., a system that can withstand disruption to its functions and resume operations because the system has the following built-in attributes:

- a) System conditions that serve as preventive measures, make the system *robust* and *fault tolerant*, and reduce the totality of the events that can go wrong;
- b) Layered monitoring capabilities with *built-in redundant components* that mitigate the vulnerabilities;
- c) Access to research, planning and preparedness information and intelligence to make the system *adaptive* to disruption; and
- d) *Response, intervention, mitigation, and recovery* capabilities that *reduce severity* of the consequences of an accident.

Actions taken to promote MTS resiliency rely on a number of countermeasures, including technologies for detection, deterrence, and prevention of threats. As noted in previous MTS Assessment task reports, a number of “decision variables” corresponding to eight risk management phases in a national MTS strategy – detection, prevention, protection, interdiction, containment, attribution, analysis, intervention — can be deployed along with strategies such as reengineering and realignment of civilian and military institutions and infrastructure to enhance system resiliency. These layers of risk mitigation measures can be used as the conceptual framework for aligning the MTS institutional forces that meet the objectives of a resilient MTS. The following *institutional reform* measures could potentially address the MTS resiliency needs:

- 5-1 Making MTS more *robust and fault tolerant* by efficient use of the HMTF funds for modernizing the waterway system and improving the infrastructure;
- 5-2 Building *layers of redundancy* by providing uniform crewing and operating requirements across vessel types, e.g., ATB versus self-propelled vessels, in support of short sea shipping operations;
- 5-3 Enhancing the system *adaptive capabilities* by improving mariner and recreational boating training and conducting R&D to promote efficient decision-support systems;
- 5-4 Improving interagency coordination to enhance system capability to respond to and *intervene in incidents, mitigate the consequences, and recover rapidly*.

5-1 Make MTS more Robust and Fault-Tolerant by Improving the Use of the HMT

Two major areas of improvement for the HMTF are in promoting a dedicated use of the HMTF for modernizing the waterway operations and supporting the initiatives for exempting domestic container shipments from double payment of the HMT.

Promote a Dedicated Use of the HMTF for Modernizing the Waterway System

Currently the HMTF shows a surplus of over \$4 billion, with the unused balance being used for reducing the federal budget deficits. As noted in Section 2.0, the sizable HMTF surplus is inconsistent with principles of equity as well as efficiency. The surplus represents a “misalignment between fee collection and expenditures” that is likely to “undermine the credibility of the HMTF,” as the GAO has warned. Promoting a dedicated use of the fund balance for completing the maintenance and dredging of the inland waterways would be a positive step towards improving the MTS operational efficiency. Currently, many federally-managed waterway channels are under-maintained and there is a backlog of improvement projects. Promoting a more efficient use of the funds would be a step towards greater financial accountability and avoiding what the NAS has called a “downward spiral” precipitated by “lack of system preservation.”

Exempt Domestic Cargo from Double Payment of HMT

As noted in Section 2.0, the HMTF is taking in much more revenue than is being appropriated. The requirement for the shippers and importers to pay the HMT for the domestic leg of shipping a container has been a major obstacle to expansion of domestic short-sea-shipping. The current unused fund balance is \$4.7 billion; by 2011, the surplus is projected to reach \$8 billion. Maritime industry stakeholders have maintained that HMT may not be the best method of financing waterway improvements and that domestic container shipments should be exempted from the tax payment.

Current efforts in support of the exemption include H.R. 3319 to amend the IRS code to exempt domestic intermodal cargo containers from the HMT. The American Association of Port Authorities (AAPA) has drafted several position papers and supported legislative initiatives in support of the waiver, maintaining that only a small fraction of the HMT collection on domestic shipments comes from the intermodal cargo. After the Supreme Court found in 1998 that imposing HMT on the U.S. exports was unconstitutional, the remaining cargo base subject to the HMT consisted of imports, domestic cargo, cargo processed and fabricated at Free Trade Zones (FTZ), and cruise ships using the coastal and inland waterways. The AAPA document advocating the removal of the HMT shows that domestic cargo accounts for only 4.3 percent of the annual HMT revenues. The exemption would have negligible effects on the HMT revenues.⁵⁶

⁵⁶ The American Association of Port Authorities, The Harbor Maintenance Tax and Congestion Relief (v.9.1.05) http://aapa.cms-plus.com/files/PDFs/HMT_Coastwise_Paper_01Sept05.pdf

Other advocates of exempting domestic cargo containers from the HMT have maintained that the waiver would most likely be revenue-neutral for the region, as any foregone tax revenue would be offset by funds saved in highway construction and repair as trailers are removed from the highway.⁵⁷

HMT represents an additional cost to domestic short-sea shippers that is not borne by their over-the-road counterparts. The majority of these short sea service providers operate shallow draft vessels that do not require deep channels. HMT is first applied to containers arriving at the initial U.S. port from overseas, and then again, when they arrive at the final destination port by transshipment. This double taxation of short-sea moves restricts the ability of these carriers to expand their services and can put them at a potential disadvantage when competing against trucking carriers.

Lending support to the argument exempting domestic moves of import containers from the HMT is a study by the University of New Orleans estimated that domestic movements of containers contribute only about \$1.7-1.9 million to the \$880 million of HMT collected in 2004 (0.2% of the total.) Balancing this loss of \$1.9 million, the researches suggest, is \$61 million in benefits resulting from savings in highway infrastructure maintenance costs and external costs of traffic congestion and air pollution if the HMT were waived for the domestic shipping industry.⁵⁸ The study proposed exemption from Harbor Maintenance Tax as a key strategy for promoting expanded cargo service on inland waterways. One tradeoff to consider is that such exemption might be subject to a PAYGO fiscal discipline – i.e., the pay-as-you-go rule that in the 1990s served to promote a balance budgets. The discipline may be imposed by Congress in order to offset a decrease in revenue by increases elsewhere.⁵⁹

5-2 Build Layers of Redundancy by Easing Regulatory Restrictions on Domestic Shipping

Regulatory rigidities that have restricted deployment of appropriate vessels, ports, and routes for domestic shipping have stifled the growth of domestic markets for marine transportation. Allowing greater flexibility in building Jones Act self-propelled vessels, facilitating landside infrastructure, and reducing the inequities in crew size requirements for tug-barge and self-propelled vessels would be positive steps towards enhancing the resiliency of the nation's marine transportation network by promoting domestic short sea shipping.

⁵⁷ Reeves & Associates, "Analysis of the Potential Market for Short-Sea Shipping Services over the Ports of Fall River and New Bedford," March 29, 2006.

⁵⁸ University of New Orleans: National Ports and Waterways Institute, *Short-Sea Vessel Service and Harbor Maintenance Tax*, October 2005.

⁵⁹ This last point was made by LCDR Ellis Moose, CG-54121.

Support Construction of an Efficient Fleet of Small Self-Propelled Jones Act Vessels

As noted in Section 2.0, current regulatory disincentives for the construction and use of Jones Act fleets have created an excessive reliance on the barge-tow vessels and prevented the expansion of the fleet of medium-speed small ships that could effectively compete in the domestic freight markets. In the past decades, the fleet of the Jones Act fleet has been dominated by tugs and barges. Increasing the fleet of the higher-speed self-propelled vessels and correcting the inequities in the USCG manning requirements would be important steps towards closing this gap.

As noted above, currently there is no viable feeder port system in the U.S. partly because of the higher costs of deploying U.S.- built self-propelled vessels for domestic feeding service. The average size of containerships calling at U.S. ports is 17 percent larger than the size of vessels calling at ports elsewhere in the world. The growing channel capacity constraints and the inability of the existing infrastructure to meet the vessel draft needs is to some extent attributed to this scarcity of smaller vessels.

Ease Regulatory Restrictions on Short-Sea Shipping and Hub-&-Spoke Container Shipments

Several proposals are currently offered for easing regulatory restrictions and disincentives for expansion of waterborne transportation. One proposal relates to promoting the construction of self-propelled Jones Act vessels for domestic cargo shipment, as documented above. While Title XI grants would be the first step in this process, market analysis data would suggest that the expansion of markets for small self-propelled vessels would be likely to generate significant economies of scale that would reduce construction costs. As the scale of production for these vessels grows, the need for Title XI grants would decline.

A recent application by the I-95 Corridor Coalition to MARAD for designation as a Marine Highway Corridor captures the extent of the barriers to successful short sea shipping operations, also called Marine Highway (MH). The proposal lists the following barriers to promotion of short sea shipping/MH operations:

- Vessel availability. There are very few vessels suitable for transporting goods over the MH, and those that are available require substantial carrier investments. Trucking industry in this respect has significant advantage since barriers to entry are low.
- Labor and regulatory costs. Labor costs and regulatory constraints (including HMT and restrictions on non-U.S. flag vessels calling at more than one U.S. port sequentially) drive up the cost of short-sea operations, making them a less viable option compared to truck and rail.
- Availability of suitable MH access points and waterway channels. An inventory of potential access points needs to be developed and performance measures and criteria to screen out candidates are needed.

- Landside access. Many ports do not have the landside access or waterside equipment and infrastructure to support MH services. Connector studies (e.g., those prepared by the Delaware Valley Regional Planning Commission (DVRPC) have identified candidate projects.⁶⁰

Among other regulatory initiatives to promote domestic shipping are the easing of the requirements for Advance Notice of Arrival (ANOVA) for coastal and short-sea services on the Great Lakes and the St. Lawrence Seaway, as proposed by the MTS National Strategy Implementation Plan.

5-3 Improve System Adaptiveness through Improved R&D, Training, and Access to Risk Data

Key institutional barriers to a more resilient MTS are gaps in training and access to efficient risk analysis and decision-support data that enhance system adaptiveness. To close these gaps, research and development (R&D) programs and improved data compilation efforts are proposed.

Support Oceanic and Marine R&D Efforts

The CMTS R&D Integrated Action Team (IAT) has identified R&D activities for each of the six components of the MTS Assessment, as follows:⁶¹

To improve the physical infrastructure, the following R&D efforts are proposed:

- Investigate new construction materials and methodologies to repair, rehabilitate and replace aging infrastructure;
- Develop an electronic information infrastructure to track cargo, provide better real time information on lock operations;
- Explore alternative pricing strategies (i.e. differential pricing based on commodity value) to bring new commodities on the waterways (inland and at ports);
- Develop infrastructure performance metrics for mariners, economists, researchers to help with operational planning and identifying failure risks;

To meet the MTS economic and productivity challenges:

- Develop risk-informed decision models to improve economic and engineering decision and help prioritize pricing models, routes and cargo;
- Develop decision support models that integrate economic, safety, environmental and security constraints;
- Investigate the impacts of economic downturn and energy supplies on MTS;

⁶⁰ I-95 Corridor Coalition, *Application for Designation of the I-95 Marine Highway Corridor*, e-mail communication dated May 28, 2009 with Mr. Michael Gordon, Acting Director, Office of Marine Highways and Passenger Service, May 2009.

⁶¹ This section is based on recommendations sent by Safra Altman, NOAA, on October 20, 2009.

- Develop a risk-informed decision framework that incorporates asset management issues with potential infrastructure failure risks and assesses the economic risks associated with factors such as port closings, oil spills, climate change, sea-level rise, sedimentation, and severe storms.

To meet the MTS environmental challenges:

- Support development of systems for Marine Spatial Planning (MSP) and Coastal Zone Management;
- Promote MTS sustainability by evaluating impacts of climate change, planning green routes, and developing pricing models to identify the economic constraints;
- Develop research models on the effects of climate change on port infrastructure management, susceptibility to inundation, and effects on channel drafts, air gaps, bridges and general adaptability of MTS infrastructure;
- Investigate the issues relating to the “greening” of the MTS to identify the cross-cutting R&D issues that a new green MTS would represent with respect to meeting the infrastructure, economic, environmental, safety and security challenges;
- Address ship life cycle management to determine how vessel design, next generation fleet, ballast free designs, new technologies, and re-usable recycled parts would improve the MTS operations and alleviate environmental challenges;
- Conduct R&D on impacts of fisheries on the MTS (e.g., interference from salmon spawning, dredging windows, turtle takes, etc.);
- Investigate the potential effects of climate change on MTS;
- Link research/researchers to policy/policy makers to better address environmental challenges.

To meet the MTS safety and security challenges:

- Identify the impacts of hazardous materials on the waterways and the associated effects of the growing congestion at ports and intermodal connectors;
- Support R&D on E-navigation, including safety benefits of Electronic Navigation Charts (ENCs) and Automatic Identification System (AIS), and the safety impacts of facility/fleet maintenance and moored vessels;
- Investigate the congestion benefits of electronic devices to support navigation at locks, and determine how alternate channels may be used for recreational and commercial vessels;
- Investigate how ENCs, tied to hydrodynamics, real-time data and underkeel clearance data, can predict current and future conditions and improve safety;
- Support R&D on better utilization of under-keel clearance to address navigable depth, improve trip efficiency, and reduce berthing accidents;
- Promote geospatial tools to support decision makers by scanning containers and vessels without impeding the movement of commerce;
- Conduct research on accidents involving recreational vessels, better define reporting requirements and data gaps to correct for the existing USCG data

To meet the MTS institutional challenges:

- Promote operations research, R&D test beds for emergency models, and facilitate transition from research to application.

Improve Risk Data Compilation and Mariner Training to Avert Technology Induced Risks

A number of strategies have been proposed for reducing training gaps relating to technology-assisted collisions and the moral hazard associated with access to electronic navigation technologies. These strategies would help create and disseminate core technical capabilities that would instill the needed maritime skills for navigating the seas and managing maritime risks.

These training programs would reverse the existing rigidities and gaps in mariner knowledge. A complex system's core capabilities could often be inhibited by rigidities that weaken the system's adaptive ability. These rigidities, dubbed "*path dependency*," refer to conditions prevailing in the past could potentially solidify into routines and restrict change.⁶² In economics, *path dependency* is commonly defined as the rigidities of the system reflecting the footprints of the past; referring to conditions prevailing in the past that solidify into rigid structures and prevent ability of the system to learn, adapt, survive, and be resilient. Adoption of new approaches to managing and mitigating risks and reducing vulnerabilities would potentially have a transformative effect on the MTS safety and efficiency, creating a new path dependency that lock in improvements, and reinforce their effects through cross-cutting dual-use technologies that generate increasing returns to any improvement. This beneficial path dependency would be characterized as a system showing *increasing returns* from a given increment of output – in safety, MDA, operating efficiency, environmental monitoring, etc. – that enhance system survival. These increments are self-reinforcing, with effects that can be highly beneficial when designed as such. However, self-reinforcing path dependency can be detrimental to system survival and resiliency if charted on a path that reinforces system vulnerabilities and destructive elements.⁶³

The existing MTS core capabilities could be enhanced through support for a transformative knowledge-base that would create a beneficial, self-reinforcing path-dependency by:

- a) Drawing upon *cross-functional expertise* and technical knowledge of the marine community for enhanced MDA across all agencies ensuring MTS safety, security, commerce, infrastructure capacity, and environmental integrity;

⁶² Dorothy Leonard, *Wellsprings of Knowledge: Building and Sustaining the Sources of Innovation*, Harvard Business School Press, 1995.

⁶³ W. Brian Arthur, *Increasing Returns and Path Dependence in the Economy*, with a Forward from Kenneth J. Arrow, University of Michigan Press, 1994.

- b) *Integrated decision-support tools* that augment the functionalities of the ship bridge through integrated monitoring, surveillance, control and traffic management systems that rely on the existing Integrated Bridge System (IBS), AIS, ECDIS, radar and Physical Oceanographic Real-Time Systems (PORTS[®]) technologies;
- c) Enhancing MTS knowledge-base by *learning lessons* from outside agencies such as aviation and offshore-drilling industries in their attempt to deal with air traffic separation and control, analysis of near misses, ocean and weather hazards, and allocation of scarce capacity.

Among new information sources that could deal with some of these challenges is the proposed funding for a Domestic Port Recovery and Security Survey Baseline by the CMTS Implementation Plan. Access to this database would enable response personnel to conduct Mine Countermeasures (MCM) in the event of a domestic mining threat and respond to incidents in a timely manner.

5-4 Improve Interagency Coordination to enhance system Capability to Respond and Recover

Institutional elements of the MTS emergency response (ER) operations present a new dimension of challenge distinct from the challenges addressed with respect to the MTS safety, security, or environmental-protection objectives. These institutional challenges arise from the complexities involved in a large-scale maritime incident. The diversity of organizational entities concerned with the maritime ER mission suggests that prevention alone is not sufficient, and that regardless of the effectiveness of individual preventive measures, when multiple institutions are involved the outcomes could be quite unpredictable. One implication of this is that for all the institutional forces to work together two types of control will be needed:

- Centralized coordination of the strategies and standard operating procedures; and a
- Distributed network of mechanisms for conducting preventive and response operations.

The seeming contradiction between having a centralized sphere of control guided by a distributed set of information and communications systems is explained when the capabilities and objectives of such a system are reviewed. A well integrated MTS ER system would consist of a system consisting of the array of surveillance and threat detection devices as well as technologies and decision-support systems that enable intervention, response, mitigation and recovery operations. In this respect, improved interagency coordination is paramount in ensuring the success of ER operation and system resiliency.

Centralizing interagency coordination is a key element of improved MTS ER. Several MTS analysts have maintained that an efficient maritime policy must begin with a

paradigm shift away from decentralized policy-making. Improving interagency coordination would require centralized strategic planning and integration of planning and investment for the multimodal freight. Better coordination would also require improved interoperability among disparate technology systems and greater coordination for infrastructure and port investment decisions. For instance, currently the needs of individual ports are assessed separately from the needs of having adequate port capacity that maximizes efficiency in shipping at the national level. Ports planning within the broader purview of the MTS would view ports as key entry and exit points for a broader intermodal network, with communication and coordination among the agencies involved reflecting the objective of making MTS an integral part of the nation's transportation system.

Steps to promote safe vessel mooring are among initiative currently underway. The CMTS has proposed drafting a sample memorandum of agreement between USCG and USACE to serve as a template for local and regional collaboration for addressing this gap. The CMTS has taken the first steps in improving interagency coordination by identifying twelve key MTS-related federal multi-agency organizations. Text Box 1 summarizes the twelve teams, commissions and task forces identified in the Draft Implementation Plan for the MTS National Strategy, June 2009.

To conclude, large-scale marine disasters and incidents entail a “threat to the commons”; i.e., they generate losses that far exceed direct losses of private assets owned by individuals directly involved in the incident. The scale and scope of these threats may far exceed the direct commercial losses to private sector participants in the MTS resulting from port disruption and capacity shortfalls, as documented in the evidence on the magnitude of the losses – economic, environmental, and safety/security – presented in previous task reports for the MTS Needs Assessment. In this respect, the role of a national coordinating body to serve in a countervailing institutional role is of fundamental urgency.

Text Box 1
MTS-Related Federal Interagency Organizations

- *Aquatic Nuisance Species (ANS) Task Force*, an intergovernmental organization dedicated to preventing and controlling ANS and implementing the Non-indigenous Aquatic Nuisance Prevention and Control Act (NANPCA) of 1990.
- *Arctic Research Commission (ARC)*, established by the Arctic Research and Policy Act of 1984.
- *Committee on Ocean Policy (COP)*, formed to enhance the use, conservation and management of oceans, coastal, and Great Lakes resources.
- *Federal Geographic Data Committee (FGDC)*, chaired by the Secretary of the Interior to look at the spatial activities and develop a national digital spatial information resource, linked by criteria and standards that will enable data sharing and efficient transfer of spatial data between producers and users.
- *Integrated Ocean Observing System (IOOS)*, a multidisciplinary system designed to enhance the federal government's ability to collect, deliver, and use ocean information.
- *Interagency Arctic Research Policy Committee (IARPC)*, established by Congress through the Arctic Research and Policy Act (ARPA), and chaired by the National Science Foundation (NSF) to coordinate arctic research among more than 15 federal agencies.
- *Interagency Committee on Ocean Science and Resource Management Integration (ICOSRMI)*, an interagency committee serving under Committee on Ocean Policy (COP), and co-chaired by the Office of Science and Technology Policy (OSTP) to incorporate the activities of the National Ocean Research Leadership Council's current mandate.
- *Interagency Marine Debris Coordinating Committee (IMDCC)*, responsible for developing and recommending comprehensive and multi-disciplinary approaches to reduce the sources and impacts of marine debris.
- *Joint Subcommittee on Ocean Science and Technology (JSOST)*, established by the National Science and Technology Council (NSTC) as a joint subcommittee serving under COP.
- *Marine Mammal Commission (MMC)*, created by the Marine Mammal Protection Act of 1972 for protection and conservation of marine mammals.
- *National Dredging Team (NDT)*, established in 1995 to implement the recommendations in the Dredging Processes in the United States: An Action Plan for Improvements.
- *Office of Global Maritime Situational Awareness (OGMSA)*, and interagency office co-led by the U.S. Navy and the USCG to facilitate the creation of a collaborative global maritime information-sharing environment through unity of efforts across entities with maritime interests.

ACRONYMS

AAPA	American Association of Port Authorities
AIS	Automatic Identification System
AMS	Automated Manual Solution
AMSC	Area Maritime Security Committee
AMSP	Area Maritime Security Plan
ANA	Advance Notice of Arrival
APEC	Asia Pacific Economic Cooperation
ATB	Articulated Tug Barge
AtoN	Aids to Navigation
ATS	Automated Targeting System
CBP	Customs and Border Protection
CBRN	Chemical, Biological, Radioactive or Nuclear
CSI	Container Security Initiative
CIKR	Critical Infrastructure and Key Resources
C-TPAT	Customs-Trade Partnership Against Terrorism
CMTS	Committee on the Marine Transportation System
COLREGS	Collision Regulations
COTP	Captain of the Port
DHS	Department of Homeland Security
DNV	Del Norske Veritas
DOE	Department of Energy
DNDO	Domestic Nuclear Detection Office
DSC	Digital Selective Calling
DWT	Deadweight
ECDIS	Electronic Chart Display and Information System
EEZ	Exclusive Economic Zone
ENC	Electronic Navigation Chart
EPIRB	Emergency Position Indicating Radio Beacons

EPA	Environmental Protection Agency
ER	Emergency Response
ERDC	Engineering Research and Development Center
ESF	Emergency Support Services
FEMA	Federal Emergency Management Agency
FTZ	Free Trade Zone
GAO	Government Accountability Office
GDMSS	Global Marine Distress and Safety System
GEOSS	Global Earth Observation System of Systems
GPS	Global Positioning System
HIV	High Interest Vessel
HMT	Harbor Maintenance Tax
HMTF	Harbor Maintenance Trust Fund
HSPD	Homeland Security Presidential Directive
HSRP	Hydrographic Services Review Panel
IALA	Marine Aides to Navigation and Lighthouse
IAT	Integrated Action Team
IBS	Integrated Bridge System
ICE	Immigration and Customs Enforcement
IMO	International Maritime Organization
ISPS	International Ship and Port Facility Security
ITS	Intelligent Transportation System
ITV	In-Transit Visibility
IWR	Institute for Water Resources
IWTF	Inland Waterway Trust Fund
LRIT	Long Range Identification and Tracking
MAIB	Marine Accident Investigation Board
MARAD	Maritime Administration
MARPOL	International Convention on Prevention of Pollution from Ships
MCM	Mine Countermeasures
MDA	Maritime Domain Awareness

MSIS	Marine Safety Information System
MISLES	Marine Information for Safety and Law Enforcement System
MSP	Maritime Security Program
MSRAM	Maritime Security Risk Analysis Model
MTS	Marine Transportation System
MTSA	Maritime Transportation Security Act of 2002
MTSNAC	MTS National Advisory Council
NDNS	National Dredging Needs Study
NDRF	National Defense Reserve Fleet
NDRS	National Distress and Response System
NHS	National Highway System
NIMS	National Incident Management System
NIPP	National Infrastructure Protection Plan
NOAA	National Oceanic and Atmospheric Administration
NRC	National Research Council
NRP	National Response Plan
OOW	Officer of the Watch
OSV	Offshore Supply Vessel
PANY/NJ	Port Authority New York/New Jersey
PCNS	Portable Communications, Navigation, and Surveillance
PORTS [®]	Physical Oceanographic Real-Time System
PWSA	Ports and Waterways Safety Act
RITA	Research and Innovative Technology Administration
RFID	Radio Frequency Identification
RoRo	Roll-on/Roll-off trailer
SAR	Search and Rescue
SOLAS	Safety of Life at Sea Convention
SOCP	Ship Owners Cooperative Program
SOW	Scope of Work
SSA	Sector Specific Agency
SSS	Short Sea Shipping

SST	Smart and Secure Tradelanes
STCW	Standards of Training, Certification, and Watchkeeping for Seafarers
SupSalv	Supervisor of Salvage and Diving
TRB	Transportation Research Board
TSI	Transportation Security Incident
TWIC	Transportation Worker Identification and Credential
ULCC	Ultra Large Crude Carriers
USACE	United States Army Corps of Engineers
USCG	United States Coast Guard
USDA	United States Department of Agriculture
USDOD	United States Department of Defense
USDOT	United States Department of Transportation
VDR	Voyage Data Recorder
VISA	Voluntary Intermodal Sealift Agreement
VTS	Vessel Traffic Service
WMD	Weapons of Mass Destruction
WRDA	Water Resources Development Act

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