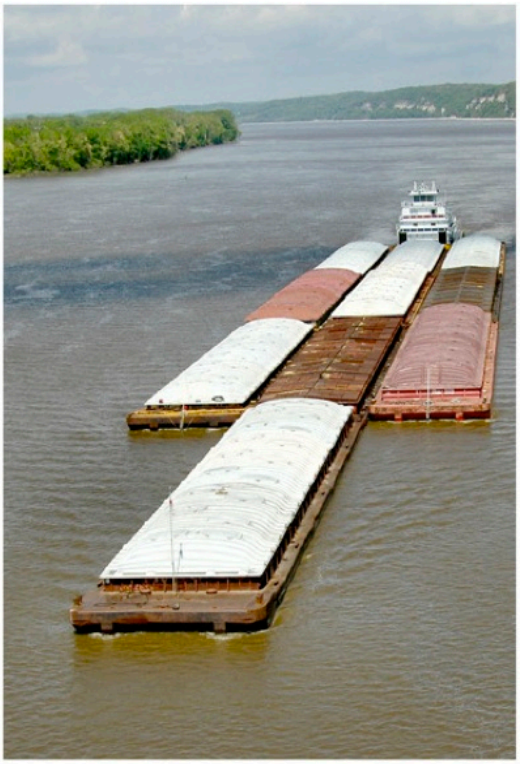
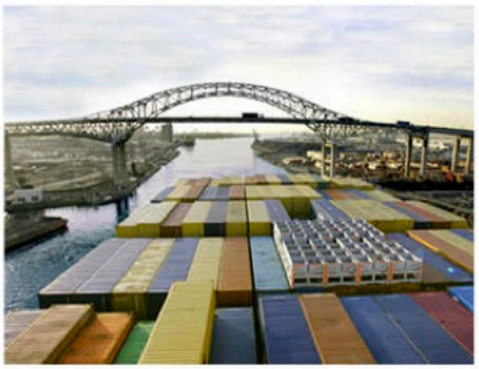
Strategic Action Plan for

Research and Development in the Marine Transportation System

Committee on the Marine Transportation System





January 2011

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Preface

The Committee on the Marine Transportation System (CMTS) established a Research and Development (R&D) Integrated Action Team (IAT) in March 2009 to provide a strategic capability to identify, develop, and implement innovative research and technology to address the pressing challenges identified in the CMTS *National Strategy for the Marine Transportation System: A Framework for Action* (July 2008, www.cmts.gov). The R&D IAT also serves to re-establish previous collaborative interagency activities and develop a robust research agenda to improve the Marine Transportation System (MTS). This report provides an Action Plan for short-term and long-term R&D based on the needs identified by the CMTS and stakeholders from State agencies, Industry, and Academia. The R&D Plan is built on collaboration among Federal agencies, leveraging multiagency programs, and execution of multi-party studies, projects, and demonstrations. The R&D IAT serves as a crosscutting function along all the CMTS IATs[1], and in particular, coordinates with the Navigation Technology Coordination and Integration IAT by transitioning navigation services and products for national deployment.

Valuable input to this R&D Strategic Action Plan was provided through panel discussions and breakout sessions at the joint Transportation Research Board and CMTS conference. *Transforming the Marine Transportation System: A Vision for Research and Development*, held June 29 – July 1, 2010, at the Beckman Center, Irvine, CA, with over 100 registrants from academia, industry, State, Federal and international agencies. Federal participation in the R&D IAT was provided by the following agencies:

- National Transportation Safety Board
- U.S. Department of Commerce
    - National Oceanic and Atmospheric Administration (co-lead agency from March 2009 to July 2010)
- U.S. Department of Defense
    - U.S. Army Corps of Engineers (lead agency)
    - Office of the Oceanographer of the Navy
- U.S. Department of Energy
    - Oak Ridge National Laboratory
    - Sandia Laboratory
- U.S. Department of Homeland Security
    - U.S. Coast Guard
- U.S. Department of Transportation
    - Maritime Administration
        - U.S. Merchant Marine Academy
    - Research and Innovative Technology Administration
        - Volpe Center
    - Saint Lawrence Seaway Development Corporation
- U.S. Environmental Protection Agency

[1] A list of CMTS integrated action teams can be found at www.cmts.gov.

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Executive Summary

The Committee on the Marine Transportation System (CMTS) Coordinating Board established a Research and Development Integrated Action Team (R&D IAT) in March 2009 as part of an overall work plan to implement the *National Strategy for the Marine Transportation System: A Framework for Action* (July 2009) by addressing challenges affecting the Marine Transportation System (MTS). This Strategic Action Plan for Research and Development in the MTS was developed with participation by many CMTS member agencies and with strong non-Federal stakeholder involvement. The Plan identifies research requirements and gaps in existing Federal MTS R&D programs and lays out a framework and specific short- and long-term actions to address these gaps.

The R&D Strategic Action Plan responds to recommendations within the five priority areas in the *National Strategy* for the MTS that include capacity, safety and security, environmental stewardship, resilience and reliability, and finance and economics. Additionally, the R&D Strategic Action Plan includes two additional priority areas. These are intermodal linkages and coastal and marine spatial planning. The R&D IAT developed an inventory of Federal research programs as well as organized a joint conference attended by academia, port and harbor representatives, interested stakeholders, and Federal agencies with the Transportation Research Board from which priorities were established and actions identified.

The R&D IAT identified the following primary gaps:

- The need for better integration of the MTS with other modes of transportation in the U.S. and with other MTS systems globally;
- The need for the MTS to be more adaptable to change on short- and long-term time scales;
- The inefficient access to MTS research opportunities, programs, and research results;
- The need for real-time operational information of the MTS use; and
- The need for MTS performance metrics that assess the national freight movement system.

The resulting primary research and development focus areas for action are:

- Research into resiliency from all hazard types and to climate change
- Develop a framework for R&D pilot projects that enable effective transition to operations
- Create an MTS-wide data access and sharing capability
- Expand and deploy e-Navigation concepts and enabling technologies
- Create a framework and system-wide performance metrics
- Develop and inventory system-scale numerical models and capabilities
- Create a model of supply chain dependencies
- Address technological gaps for a systems approach to national freight movement
- Integrate alternative fuels into use
- Improve port automation
- Incorporate social science and human factors into the MTS
- Increase tools for risk-based adaptive management
- Create tools and capabilities for a holistic approach to global freight movement

The R&D IAT will develop a yearly work plan to address these priorities with periodic reports back to the CMTS and seek to organize a biennial R&D conference from which current and emergency issues can be honed and developed.

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In the middle of difficulty lies opportunity….Albert Einstein

Introduction

America's Marine Transportation System (MTS) moves people and goods through U.S. ports utilizing a system of harbor channels and waterways to final delivery points or connections to highways, railways, and pipelines[2]. The MTS allows the worldwide distribution of our Nation's agricultural and manufactured products. The MTS carries 44.9 percent by value and 77.7 percent by weight of all U.S. international trade totaling over $1 trillion[3]. In his January 2010 State of the Union address, President Obama set a goal of doubling exports in the next five years, a goal that cannot be achieved without a reliable, safe, and efficient MTS. However, the MTS is at a crossroad. MTS infrastructure is showing signs of strain, which will intensify as cargo and passenger traffic increases[1]. The MTS is at a crossroads from which the challenges to meet increasing export trade are growing. Ports are in need of more capacity and efficient throughput, our inland locks on average are ten years beyond their fifty year life cycle, most coastal channels are not deep enough for the next generation Panama Canal ships, and intermodal connections are not adequately efficient. U.S. history shows that in transformational times our country has turned to technology to solve daunting problems and keep us globally competitive and secure.

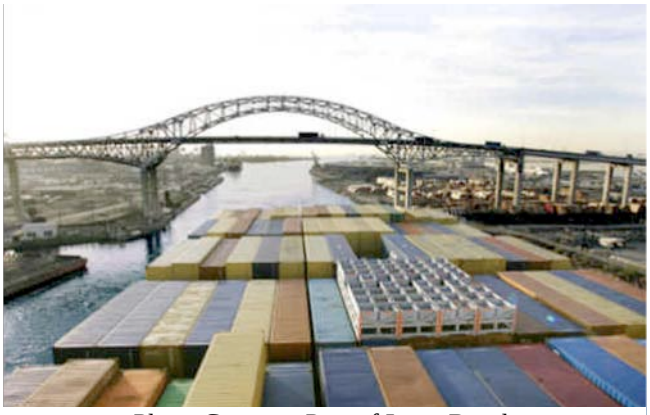


Photo Courtesy Port of Long Beach

Research and development of technology is a critical component in the national framework for addressing issues of the MTS to create new ways of solving or leapfrogging challenges. With this in mind, the Committee on the Marine Transportation System (CMTS) created a Research and Development (R&D) initiative to provide the CMTS Federal agency partnership with a strategic capability to identify, develop, and implement innovative research and technology to address the pressing challenges identified in the *National Strategy for the Marine Transportation System: A Framework for Action*[1]. The goal of the R&D initiative is to develop a deliberate, integrated, interagency R&D strategy that supports actions identified in the framework. The initiative also serves to re-establish previous collaborative interagency research activities and to develop a robust research agenda to improve the MTS. A key product of the R&D initiative is this Research and Development Strategic Action Plan. The Action Plan lays out requirements and specific short- and long-term actions to

[2] National Strategy for the Marine Transportation System: *A Framework for Action*, July 2008, by the Committee on the Marine Transportation System

[3] U.S. Department of Transportation, Research and Innovative Technology Administration, Bureau of Transportation Statistics, America's Freight Transportation Gateway 2009 (Washington DC, 2009). Figure 3.

address MTS challenges that increase national R&D capabilities, leverages existing programs and addresses gaps in existing programs in the MTS.

The R&D Strategic Action Plan for the MTS was developed through a two-tiered process linking CMTS priority requirements from the *National Strategy* with member agency research programs, followed with feedback and input from the broader non-Federal MTS stakeholders. The Transportation Research Board of the National Academies of Science and the CMTS held a joint conference in June 2010 titled “Transforming the Marine Transportation System: A Vision for Research and Development.” The conference was organized into a workshop format by which participants could express independent views on the priority needs or issues for research and development in support of the U.S. marine transportation system.

An inventory of Federal MTS programs identified 44 research programs with approximately $75M in annual expenditures and a range of on-going research, development and technology integration among the CMTS agencies. The five priority areas in the *National Strategy* and these existing programs were matched to identify research and development gaps. The result is a research action plan linking existing programs with both short- and long-term actions supporting the five National Strategic areas.

The Strategic Action Plan includes a coordinated research framework or process aimed at leveraging and linking existing Federal R&D programs and infrastructure to address the MTS R&D as a whole. It lays out the need to disseminate and communicate information and research results widely among engineers and scientists as well as policy makers, academia, industry and the public to harmonize standards, regulations, and solutions with new technologies. Several critical framework components are presented, such as effectively moving research to operations, creating incentives for innovation, and establishing performance metrics.

National research needs are examined and organized within the five *National Strategy* themes. For each theme the problem is defined, objectives specified, and specific opportunities developed to address gaps. For example, some identified gaps include a lack of National MTS performance metrics and quantification of system risk and improving methods to integrate intermodal operations. In the final report section, specific near-term and long-term actions are identified that are not currently addressed in existing R&D programs according to the CMTS research program inventory. Actions, such as development of real-time river system-scale hydrodynamic modeling with coupled vessel interactions, are identified. Most importantly, these actions require multiagency involvement and expertise.

The CMTS will review this action plan annually as new MTS requirements emerge, technologies advance, challenges are addressed, and research programs evolve. Additionally, a biennial MTS R&D conference will be held, pursuant to funding, inclusive of the U.S. and international MTS community to raise public awareness, present and share the latest R&D, and identify collaborative opportunities.

Background

In the *Coast Guard Authorization Act of 1998* the U.S. Congress directed the Secretary of Transportation to form a task force to assess the adequacy of the Nation's Marine Transportation System (MTS) to operate in a safe, efficient, secure, and environmentally sound manner. The MTS

Task Force was made up of industry associations, shipper groups, and other stakeholders. Through cooperative efforts between government and private sector partners, the MTS assessment was completed and transmitted to Congress in September 1999. That report, *An Assessment of the U.S. Marine Transportation System*, called for the creation of a coordinating body, and the new Interagency Committee on the Marine Transportation System (ICMTS) was established in 2000.

The President's *U.S. Ocean Action Plan of 2004* called for the elevation of the ICMTS to a cabinet-level committee, and the Committee on the Marine Transportation System (CMTS) was formally established by charter in August 2005. CMTS members are the Cabinet secretaries and administrators, including DOT, whose Secretary serves as CMTS Chair, the Department of Homeland Security, the Department of Defense, the Department of Commerce, the Environmental Protection Agency, the Department of the Interior, and the Chairman of the Federal Maritime Commission, among others. The CMTS reports directly to the President. It is supported by the following four sub-organizations.

- A Coordinating Board of many Federal agency stakeholders with direct and indirect MTS interests, including the U.S. Coast Guard (USCG), the Maritime Administration (MARAD), the National Oceanic and Atmospheric Administration (NOAA), and the United States Army Corps of Engineers (USACE);
- An Executive Secretariat who are permanent or detailed CMTS staff charged with CMTS coordination;
- Integrated Action Teams (IATs) that are established and approved by the Coordinating Board. The IATs are composed of various agencies tasked with cooperatively addressing key MTS issues; and
- A Working Group of member agency staff that coordinate, integrate, and provide support to the IAT's and Executive Secretariat; and

Currently, 27 Federal agencies and offices participate in the CMTS. All have shared interests and needs for a safe, efficient, and secure MTS as well as specific goals guided by their individual missions. Part of the function of the CMTS is to provide a coordinated platform for all these entities to interact and improve the MTS while simultaneously meeting their individual missions.

Photo Courtesy USACE St. Louis District

The President, through Executive Order also established an Interagency Ocean Policy Task Force (OPTF) on Stewardship of the Ocean, Our Coasts, and the Great Lakes. The OPTF was charged with developing recommendations to enhance our ability to maintain healthy, resilient, and sustainable ocean, coasts, and Great Lakes resources for the benefit of present and future generations. The CMTS and its research and development needs have strong links with the new National policy, including using the best science and knowledge to inform decisions, improving our understanding and awareness of changing environmental conditions, and increasing our understanding of ocean,

coastal, and Great Lakes ecosystems. All nine National Priority Objectives have connections with CMTS requirements, but Coastal and Marin Spatial Planning (CMSP), changing conditions in the Arctic, and ocean, coastal and Great Lakes observations, mapping and infrastructure are closest.

The National Strategy for the Marine Transportation System: A Framework for Action was developed by the CMTS, and approved by the Cabinet members of the CMTS in July 2008. The *National Strategy* (www.cmts.gov) is the policy framework for the MTS for five years, through 2013, with a view to addressing issues 20 years and more into the future. It presented the most pressing challenges to marine transportation at the time, and called for Federal action and leadership in five priority areas: capacity, safety and security, environmental stewardship, resilience and reliability, and finance and economics. This *Research & Development (R&D) Strategic Plan* was developed in support of the *National Strategy* and focuses on R&D needs for each of the five priority areas. The priority areas are briefly described below.

Capacity. The MTS consists of ocean, coastal, and inland waterways, ports, intermodal connections (connecting points for changes in modes of transportation), vessels, and commercial, military, and recreational users. Growth in use of the MTS and projected increases in total freight volumes and international container traffic brings with it the demand for additional staging areas, expanded landside access, and improved logistics technologies. To accommodate all projected growth[4], additional infrastructure is needed. Capacity expansion in key cargo ports is critical for the nation's economic growth and requires significant collaboration among stakeholders, the formation of public-private partnerships, and efforts to improve the efficiency of the system.

Safety and Security. The expected increase of commercial and recreational vessel traffic, continued ocean and inland water research from vessels, and the operation of U.S. military vessel traffic will place burdens on waterway and port safety and security services, and raise the risk of accidents. The challenge is to ensure that the business, recreational, safety, military, and security needs of vessels on our oceans, harbors, ports, Great Lakes, and inland waterways are met. Security mandates, including the *Maritime Transportation Security Act of 2002* and the *SAFE Port Act of 2006* among other legislative initiatives, have created additional pressures on the MTS to balance operational requirements and security needs with limited public and private resources.

Environmental Stewardship. The economic health of the MTS and the natural health of the Nation's ocean, coastal, and freshwater ecosystems must co-exist in a way that supports transportation while protecting and sustaining human health and the environment. The MTS intersects with, and is in close proximity to, sensitive and valuable natural resources, including wetlands, estuaries, drinking water sources, recreational waters, watersheds, critical habitats, fisheries, coral reefs, and marine life habitats. To support a dynamic and synergistic program of

Sandusky Harbor, OH, photo courtesy of USACE

[4] National Strategy for the Marine Transportation System: *A Framework for Action*, July 2008, by the Committee on the Marine Transportation System

environmental stewardship, the CMTS *National Strategy* promotes ecosystem-based management in alignment with the new National Ocean Policy and provides for effective implementation of environmental regulations.

Resilience and Reliability. Natural and human-caused disruptions to ports and waterways not only threaten the continuity of operations on the MTS but also have an adverse ripple effect throughout the U.S. economy. New streamlined supply-chain networks with strong links to providers, suppliers, and customers have minimized inefficiencies, but simultaneously increased vulnerability. The challenge is to reduce the risk of disruption and plan for an orderly recovery. Disruptions may be local, such as waterway closures resulting from a barge hitting a bridge, or may be regional, such as the shutdown of Gulf Coast ports from hurricanes. Impacts from these disruptions can have national ramifications because the MTS is a critical component in the national supply chain. The MTS must have the capability to respond quickly to disruptions of varying scales in order to return to normal operations.

Finance and Economics. Collaborative action between the Federal government and State, local, and private interests is necessary for preserving and enhancing the MTS. The Federal role in managing the MTS includes public infrastructure, mobility, channels, navigational systems, charting, weather and real-time navigational information, environmental oversight, marine safety and security, and incident response. State and local agencies address the demands of their geographic areas. The private sector invests in vessel, port, and transfer assets. The *National Strategy* envisions a coordinated and detailed exploration of specific options for increasing the efficiency of the existing MTS system, developing better methods for prioritizing investments, and developing ways of attracting more private sector investments.

Federal Research Program Inventory

In order to assess the state of current Federal research in the MTS, the CMTS R&D IAT compiled an inventory of related research and development programs being conducted by the member agencies and offices. Funding information for each program was requested in 2010 as part of the inventory and each agency provided a dollar range associated with each research program. Details such as whether funding was committed to R&D dollars or if funds were appropriated were asked and agencies provided a value for each research program based on binned funding ranges (<$50K, <$500K, <$1M, <$10M, >$10M). For this reason, details of the reported spending are most likely defined differently across agencies. Table 1 presents the cumulative total R&D expenditures, based on binned ranges, by agency.

The current inventory consists of 44 MTS R&D programs being conducted in six agencies or offices. These include the Research and Innovative Technology Administration, Environmental Protection Agency, Federal Maritime Commission, Maritime Administration, National Oceanic and Atmospheric Administration, U.S. Army Corps of Engineers, and U.S. Coast Guard. The distribution of programs is listed in Table 1. The various programs focus on many research topics including, but not limited to, dredging, navigation, coastal mapping, maritime security, emissions, and ballast water management. Most research programs address multiple themes. Of the 44 programs, 30 address Safety and Security, 24 have a Capacity component, 28 deal with Environmental Stewardship, 21 include a Resilience and Reliability focus, and 15 contribute to Finance and Economic research. In addition to programs that addressed multiple priorities, multiple

programs in different agencies addressed similar research problems. This highlights areas of potential collaboration. Some examples are listed below.

- Air emissions research conducted by MARAD, NOAA and EPA.
- Fix facility hydrogen powered research by RITA, MARAD, and Navy.
- Coastal mapping and lidar programs conducted by NOAA, Navy, USGS, and USACE.
- Work on aquatic invasive species conducted by the USCG and MARAD.

The inventory also identified areas of opportunity for a coordinated approach. For example, while the National Transportation Safety Board (NTSB) does not conduct maritime safety and security research, coordination between NTSB and the safety programs run by USACE (navigation safety), USCG (maritime security), and MARAD (safety reporting) may be very useful.

Research programs varied in their duration, with 8 expected to conclude within one year, 13 expected to expire in 2-5 years, 2 expected to expire in 6-10 years and 26 continuing for longer than ten years. In terms of expended dollars per fiscal year, the entire portfolio was approximately $75M. The distribution of this funding by Federal agency is also listed in Table 1.

Table 1 MTS Research and Development Programs, Fiscal Year 2010

Agency or Office	No. R&D Programs	Expended Funds
Customs and Border Protection	-	
Environmental Protection Agency	8	< $32 M
Federal Maritime Commission	3	
International Trade Administration	0	
National Oceanic and Atmospheric Administration	14	< $7.2 M
National Transportation Safety Board	0	
Oceanographer of the Navy	-	
Oak Ridge National Laboratory	-	
St. Lawrence Seaway Development Corporation	0	
Transportation Security Administration	-	
U.S. Army Corps of Engineers	10	< $30 M
U.S. Coast Guard	5	< $2.5 M
U.S. Department of Agriculture	0	
U.S. Department of Energy	0	
U.S. Department of Interior, Office of Policy	0	
U.S. Department of Justice, Office of the Attorney General	0	
U.S. Department of Labor	0	
U.S. Department of State, Office of Oceans and Polar Affairs	0	
U.S. Department of Transportation, Maritime Administration	3	< $4 M
U.S. Department of Transportation, Research and Innovative Technology Administration	1	< $0.05 M
U.S. Department of Transportation, Office of Policy	0	
U.S. Department of Treasury, Office of Economic Policy	0	
U.S. Transportation Command	0	

Source: R&D IAT Survey to CMTS member agencies, 2010.

Research and Development Framework

Research and development in the MTS, regardless of subject matter, must be addressed with a systems approach. A necessary first step is an accurate baseline analysis of current conditions. From the baseline, it is possible to determine the weak points, vulnerabilities, surpluses and gaps, and then to focus MTS research and development efforts effectively. Integrated analyses and modeling are necessary to better understand research and development needs and demands. Using a coordinated approach that leverages existing programs, funding sources, and infrastructure, and addresses international efforts for developing new technologies will allow for significant improvement in the system as a whole. Federal and non-Federal, public and private access to data will be needed to develop robust, fully articulated systemic simulations and models of the MTS. Research and development efforts will require openly shared information in collaboration with Federal partners, stakeholders, and academic representatives. We must improve dissemination and communication of information and research results among Federal agencies, policy makers, academia, industry and the public. Additionally, it must be recognized that there are short- and long-term time horizons to consider when developing the coordinated approach, and that ongoing research and development should be linked and included into the national strategy.

In addition to these general considerations, several critical overarching themes serve as foundations to a useful research and development framework.

1) Research and Development to Operations

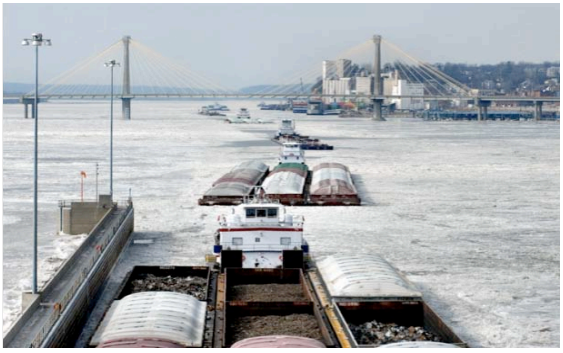


Photo Courtesy USACE St. Louis District

While there is challenging dynamic between research and operational requirements, there is also a need to balance basic (transformational) and applied (incremental) research. In some cases, rapid solutions for technology transfer and innovative technologies can quickly transform the MTS and solve problems of the future. A focus on using test-beds, "living labs," innovative approaches such as adopting ports as research and development laboratories, and other cooperative partnerships to implement research programs may help achieve an effective balance of basic and applied research and development.

To effectively transition research and development to operations also requires open communication and collaboration. Peer-reviewed publications, participation in workshops and symposia, and conferences are common vehicles to share knowledge and speed the transition of ideas and research and development to operational practice. To this end, the CMTS will convene, pursuant to funding, a biennial conference focused on R&D in the MTS, ensuring that these conference agendas are aligned with other National-level data integration efforts such as development of the National Information Management System and portal support to CMSP.

2) Policy and Governance

It is critical that research objectives align with current Federal policies and legislation as well as with industry priorities and needs. To this end, research and development initiatives should

support transparent and strong governance and maintain a centralized vision. R&D programs should be conducted within a context that includes ongoing review of Federal policies and recommendations. Continuing the R&D initiative under the CMTS umbrella will ensure Federal and National research and policy alignment, while also facilitating coordination with other key National-level R&D efforts, such as those led by the National Ocean Council's Interagency Policy Committee.

3) Incentives for Innovation

Incentives need to be created to encourage transformative solutions that will attract and retain entrepreneurs and researchers, and to prepare future generations of MTS professionals. Recommendations for incentivizing behavior include creating rewards for best research and development, providing funding for fellowships, internships and grants to students and universities, and educating the public about the MTS starting at an early age (grade school). Supporting collaborative programs, providing access to data and facilities/project sites, and developing a Critical R&D Needs Clearinghouse will also provide incentives.

Large Federal investments in MTS research and development have focused on engineering and scientific solutions. However, the inclusion of social science research, including economics, is needed to evaluate human factors, such as corporate and individual behavior in accepting and implementing new technologies. A social science perspective could also change the paradigm of environmental costs-to-benefits and improve public communications and engagement.

The Administration has an Innovation Strategy that may be leveraged to support this framework component. The Innovation Strategy has three major focus areas; 1) invest in the building blocks of American innovation; 2) promote competitive markets that spur productive entrepreneurship, and 3) catalyze breakthroughs for National priorities. The CMTS research and development strategy aligns well with this last one that includes the objective of harnessing science and technology to address the "grand challenges" of the 21st century.

4) Decision Support

To evaluate complex systems, optimize new technologies, aggregate disparate data and make good investment decisions, tools are needed to help decision makers and operators. To be effective, decision support tools must integrate aspects of risk assessment, management and communication. These tools should be available to the MTS community and rely on input data from authoritative sources so that results are transparent. Facilitating the linking of data and information from across the Federal sector and among all stakeholders will be the National Information Management System and CMSP portal.

5) Performance Metrics

Metrics for measuring success (or failure) of research and development programs should be identified for the MTS and associated modes, as well as system performance indicators. Development of performance metrics should be an integral component in the design of effective research programs. Targets should be defined (e.g., zero accidents, 50% reduction in emissions in 5 years, 10% improvement throughput), and research should be focused on meeting these

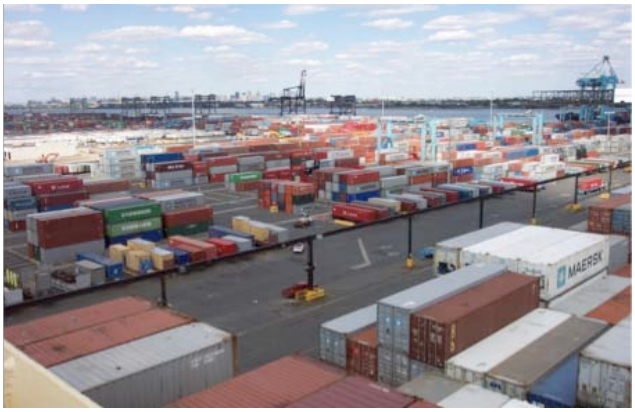
targets. Performance metrics should be used to evaluate the efficacy of research programs and transitions to operations. Meeting performance targets could also be used as a research incentive.

National Research and Development Needs

This section reviews each of the five areas from the *National Strategy* plus two additional areas that are of significant importance, discussing challenges in terms of the research and development required to address solutions. Specific R&D priorities for each area are identified, some unique and some that begin to recur between the seven different themes. These recurring themes are combined in subsequent sections of the report as research themes (RT) and used to identify actions for research. Following each research and development priority below is an identifier in parentheses ranging from RT1 to RT5, that crosswalk it to a research theme and a specific research and development action.

Capacity

Challenges: Many factors contribute to providing sufficient and reliable capacity for the MTS. They range from maintaining navigational channels, maintaining and rehabilitating locks and associated dams, making infrastructure improvements, encouraging growth in trade and travel, and accommodating changes in distribution operations, to providing accurate and timely maritime data. Each of these factors can impact both existing and future capacities.



Container Terminal, Port of Elizabeth, NJ, Photo courtesy of NOAA

As a critical component of the global and domestic transportation system, the MTS is experiencing the same capacity challenges that the aviation, highway, and rail systems are experiencing, such as increasing congestion and stressed infrastructure. Transportation freight and logistics planners must be certain that reliable MTS infrastructure can meet today's demands and tomorrow's projected growth. The challenge is to find ways that ports can expand their operations within available land and financial constraints to better handle increased volume and accommodate growth. Additionally, growth and new development must be done within an eco-system framework and socially conscious manner that addresses the needs of both the community and the transportation system. There are many parts of the MTS where reliability is the key challenge given aging infrastructure and increased costs of maintenance.

Priorities: The capacity of the MTS must be adequate, reliable, accessible, and economical. Impacts to any one of these attributes can result in diminished capacity of the system, in a decline in usage, or in significant cost increases, any of which would seriously impact the Nation's economy and security. Maintaining and sustaining existing capacity must be a priority to ensure the MTS remains a thriving and viable entity. Research and development priorities to provide sufficient and reliable capacity are:

- Develop infrastructure and operational technologies to make the MTS more efficient for existing and future needs (RT1).
- Develop standardized terminologies, interpretations, and flow-through models to foster increased productivity (RT1).
- Develop performance measures to assess the productivity of the MTS and the risk of potential infrastructure failures to the MTS (RT5).
- Identify and develop solutions to chokepoints in the system at intermodal connectors (RT4).
- Develop tools for robust economic analyses of the impact of capacity changes on the MTS and surrounding communities (RT1).
- Integrate security concerns and develop mutually beneficial solutions to increase capacity in an economically favorable way without compromising national security (RT1).
- Develop smarter marine observation and monitoring systems and expanded long-range marine forecasting (RT4).

Safety and Security

Photo Courtesy Port of Los Angeles

Challenges: The vision for the U.S. MTS, as approved by the CMTS in the *National Strategy*, is to be "safe, secure and globally integrated network that, in harmony with the environment, ensures a free-flowing, seamless, and reliable movement of people and commerce along its waterways, sea lanes and intermodal connections." The challenge is to ensure that commercial, recreational, and military safety and security needs are simultaneously met for vessels, harbors, ports, and waterways. We must look for opportunities in which the MTS Federal partners can contribute to the improvement of safety and security within the entire transportation system. A broad challenge is how to harness and coordinate the capabilities, skills and experience of the many Federal agencies dedicated to the safety and security of the MTS. In an era of budgetary constraints, agencies tend to focus their priorities on retaining internal project and program resources. However, now more than ever, CMTS partners need to coordinate existing Federal resources in an effort to improve safety and security not only for the maritime industry, but for the transportation system as a whole.

Priorities: The overall Safety and Security R&D priorities for the MTS include casting a wide net to engage innovative futurists capable of leapfrogging barriers to exploit technology in the application of tools and processes that are supported by collaborative Federal agencies. Fostering a system-wide comprehensive approach to modeling safety/security will allow the MTS to be prepared for, rather than react to, large-scale natural or manmade events. It is crucial to recognize that technological implementation advances faster that the ability of the human element to safely control it. A final consideration is to encourage the integration of safety management principles into an organization's safety culture. Specific research and development priorities are:

- Develop and implement improved technologies that address reduced dependency on foreign-supplied fossil fuels and the associated environmental harm and security risks (RT2).

- Develop system-wide, adaptive modeling tools to measure, monitor and mitigate the dependencies and interdependencies in the MTS that potentially can contribute to added risk to commerce from events such as supply chain disruptions and cascading failures (RT2).
- Incorporate the application of the social science of human factors interface to navigation technology research and development to enhance navigation safety and reduce associated human error (RT2).
- Develop a reliable estimate of the potential impacts of a terrorist event in the MTS through programs such as the Department of Homeland Security (DHS) Centers of Excellence's Center for Risk and Economic Analysis of Terrorism Events program. Update existing models to foster a system-wide, comprehensive approach to safety/security requirements and investment decisions (RT2).
- Share relevant information and data, and create a data integration framework for accessing and disseminating data (RT4).
- Adapt planning tools, models, and capabilities that address improving safety and security from the successes of other national MTS programs (RT2).
- Encourage and improve existing frameworks that plan for, operate, maintain, and mitigate risk to the MTS by adapting the principles of International Maritime Organization's Safety Management Code to improve organizational safety culture (RT2).
- Develop smarter marine observation infrastructure and e-navigation systems (RT4).

Environmental Stewardship

Challenges: Over the last 50 years, American society has become increasingly aware of and concerned about the environmental and human health impacts associated with industrial activities. The Marine Transportation System is the most environmentally friendly mode of cargo movement even though its constituent components generate deleterious impacts on the environment. Regulations designed to protect the environment create operational challenges for the MTS. However, if the MTS is going to continue to grow and thrive economically it must manage its environmental impacts.

Queen Bess Island, LA, Photo Courtesy USACE

Priorities: Contingent with an overall goal to improve the environmental performance of the MTS, environmental impacts associated with the MTS should be eliminated while the system's efficiency and economic competitiveness is simultaneously enhanced. Specific research and development priorities are:

- Use science, engineering and technology to support system-scale risk analysis using the metrics of sustainability and concepts and practices associated with ecosystem-based management (RT2).
- Working with the National Ocean Council, improve dissemination and communication of ecosystem-based management approaches among Federal agencies, policy makers, academia, industry and the public to harmonize environmental standards and regulations

with new technology development and requirements, and to inform long-term infrastructure planning and development (RT3).

- Research the relationship between the results of land-based testing of ballast water treatment systems and shipboard testing. Develop ballast water treatment technologies suited for use in fresh-water (RT2).
- Research the tradeoffs between cleaner fuels and emission scrubbing technologies to reduce criteria pollutant emissions. Consider the applicability of alternative fuels to reduce greenhouse gas emissions, and improve engine efficiency and hull design to reduce greenhouse gas emissions (RT2).
- Develop environmental databases for monitoring air pollution, noise, and the effects of vessel and port landside operations on terrestrial and aquatic communities (RT3).
- Develop decision support tools based on risk assessment analyses to aid in infrastructure planning and climate change adaptation (RT2).
- In alignment with the Climate Change Adaption Task Force, develop climate change adaptation strategies: Operational Responses, Design Changes, Sharing of Best Practices, Planning, and Land Use Controls (RT2).

Resilience and Reliability

Soo Locks, Sault Ste. Marie, MI, Photo courtesy of USACE

Challenges: The loss or reduction in the movement of freight caused by natural hazards, land and ocean use practices, or climate change has substantial impacts locally, regionally, nationally, and internationally. Resilience and reliability must be intentionally designed into the MTS. Resilience and reliability involve all facets and stakeholders in the supply chain including: engineering and construction; intermodal linkages; emergency response; global access; climate change; jurisdictional organization; life-cycle management; environmental sustainability; regulatory permitting; information sharing; and data access and dissemination. Without a resilient and reliable marine transportation system the supply chain will shift to minimize risk, and the U.S. will rely on neighboring countries to move global freight while crippling U.S. highways and choking urban centers with increased surface transportation. Many of the challenges of today and in the future can be solved through new technologies, innovative applications, and science-based decisions. However, the U.S. MTS is currently a decentralized system with many local, state, Federal, and private sector stakeholders, so developing and implementing a comprehensive research and development plan to improve resilience and reliability is a challenge in itself.

Priorities: Covering the broad range of resilience and reliability topics and needs from the many public and private stakeholders without a single comprehensive plan that includes all modes of transportation is an additional challenge. However, the CMTS *National Strategy* takes important steps in identifying Federal resilience and reliability priorities, as described in the previous section. Specific research and development priorities are:

- Increase remote monitoring of operations to provide accurate data on improving efficiency and quantifying uncertainty. Effectively managing individual components or regional scale systems requires accurate information, which can only be obtained through monitoring. It also provides the entire community with an accurate and integrated common operating picture (RT4).
- Create a data integration framework for accessing, sharing, disseminating data. On-going programs like the Integrated Ocean Observing System (IOOS), Coastal Data Information Program (CDIP), National Coastal Mapping Program (NCMP), the National Information Management System, the Coastal and Marine Spatial Planning portal, Physical Oceanographic Real-Time System (PORTS), and many others are excellent examples of on-going data collection programs available to leverage. These authoritative data sources and many others must form the framework of data necessary for models, decision support, and operations. Many stakeholders collect data and are the competent authority on their own data. Making data widely available to support R&D and inform science-based decisions will go a long way to improving resilience and reliability (RT4).
- Develop advanced predictive capabilities with next generation numerical models. Many existing models are ready to be updated. Examples include multi-phase flow modeling of ship motions and interactions, levee stability and breaching, lock filling/emptying and outflows, wave current interactions, sediment transport, geomorphology, and freight throughput models (RT2).
- Develop new capabilities for managing sedimentation of navigation channels to prevent sediments from entering channels, work with existing sediments through establishing nautical depths, and manage sediments at project, regional and system scales (RT2).
- Develop adaptive management technology, tools, and data to address daily operational issues, develop new short-term solutions, and address longer-term topics like climate change impacts and Arctic and Bering Sea shipping routes. Adaptive management is practiced today, but new tools, approaches, and technologies are needed. As there is still much uncertainty and debate, remain engaged and proactive to assess present condition and develop long-term plans for adaptive management of project, regional and system scale issues (RT2).
- Update existing engineering design guidance for MTS components, like ship squat and navigation channel design, lock design and standardization, port and harbor design, environmentally sustainable engines and vessels, intermodal connections, and many more topics (RT3).
- Develop planning tools, models, and capabilities that address improving resilience and reliability (RT1).
- Ensure that the MTS is included in the current work of the National Climate Assessment, which will report on U.S. climate and its impacts (RT2).

Finance and Economics

Challenges: Providing a safe, reliable, efficient MTS to benefit the United States requires investment of both private and public funds. Unlike the primarily privately owned railroads or the publicly owned highway system, waterways and ports rely on a combination of public and private infrastructure. The design and maintenance of that infrastructure affects the capacity, reliability, efficiency and robustness of the MTS.

Investments in the MTS are a combination of private and public funds with the public funds coming primarily from the Harbor Maintenance Trust Fund and the Inland Waterway Trust Fund. In 2009 and 2010, unexpected funding was provided through America's Recovery and Reinvestment Act.

Port of Long Beach, Photo Courtesy Port of Long Beach

Research and development in finance, business and in the decision sciences could provide ideas on how to manage this blending of funds and decision-making. Politically viable concepts for improving the decision-making process itself could have a great benefit if they can assure continuity of funding for high-priority investments and coordination among modes. Many investments in the MTS require several years to design and construct but will provide many decades of use. When considered in the light of uncertain forecasting for commerce and climate change, the planning process and the structures need to be adaptable.

Priorities: The suite of economic and financial research and development required for the MTS does not stand-alone. This research links into the needs for better understanding of the marine environment, security, resilience and reliability. The economic and financial issues focus on how to make the best investments to gain benefits across the functions of the MTS—commerce, recreation and national defense. Specific research and development priorities are:

- Develop tools for selecting among investment options using a systems approach with expanded modeling horizons to include interactions between multiple facilities and with other modes. Intermodal linkages are critical, and lack of capacity or coordination at these interchange points creates bottlenecks. Thus, models must capture not only the physical infrastructure but also the information infrastructure. Inland waterway planning requires an understanding of locks and ports as well as the links to rail, highway and deep draft vessels. All these dimensions for expanded research and development challenge current abilities to model mathematically and computationally, particularly as the models are expanded along other dimensions (RT1).
- Incorporate external costs, such as environmental and social costs, into economic analyses of the MTS and into MTS planning (RT1).
- A better understanding of how movements on the waterways relate to national supply chains will improve understanding of how business will react to changes in the MTS. It is not enough to model demand as a function of cost and to estimate elasticity as a parameter. The wide variety of ways businesses can react to changes in cost, delay, reliability and even environmental impacts must be captured (RT4).
- Expand our understanding of the supply chain process, instead of merely estimating quantity to be shipped or modal choice, will allow changes in sources for commodities, inventory policies, routing, or intermediate processing to be modeled more accurately. Modeling movements at the supply chain level will provide an understanding of the effects of delays or disruptions on the economy (RT1).
- Create a new framework, possibly incorporating concepts from agent-based modeling, should be able to model shippers' and carriers' responses to major structural changes such as opening new ports or widening the Panama Canal (RT1).
- Develop long-range marine forecasting to improve ship routing to save fuel savings and port congestion (RT4).

Intermodal Linkages

Challenges: During the 20th century, U.S.-built highway and aviation networks fueled unprecedented economic prosperity, individual mobility, and connected the Nation's cities, towns and regions to the rest of the world. The U.S. has been well served by these highway and aviation networks, as well as by its railroads, pipelines and transit systems, ports and waterways.

Photo Courtesy Port of Long Beach

In the 21st Century, however, the U.S. transportation system faces changing social, environmental and economic challenges. In turn, policies and individual investment decisions for highways, public transit, railroads, seaports, inland waterways and airports often lack an outcome-driven approach and, at times, conflict with each other and with key national priorities. Federal transportation programs also face unprecedented fiscal challenges, with current dedicated revenue sources no longer adequate to operate and maintain our existing infrastructure and fund future investments.

Priorities: To meet the challenges of U.S. transportation needs, these different modes must become more effectively linked into an intermodal system. Research and development providing new technologies and tools will provide the means for improving the linkage with the MTS. Specific research and development priorities are:

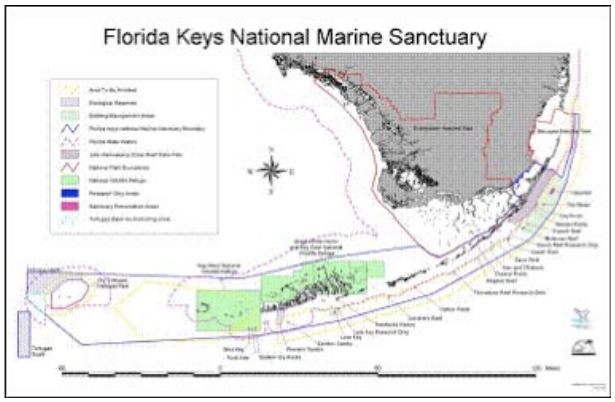
- Development with Federal partners of a consolidated MTS view that can be leveraged to evaluate and plan a robust, seamless, well integrated multimodal MTS, thereby increasing overall transportation system efficiency by using an overall systems approach (RT1).
- Develop standards with industry partners and academic centers to support the integration and exchange of MTS models and to develop protocols for data acquisition and distribution (RT4).
- Develop models for incorporation of MTS performance assessments, planning analyses and trade-off studies to address concerns of energy utilization, emissions, congestion relief and other transportation system related attributes (RT5).
- Investigate opportunities for inclusion of the maritime mode to improve multimodal integration. Utilize Metropolitan Planning Organizations, academic centers and others to support multimodal model development (RT1).
- Develop and implement new technologies to improve MTS operation, utilization and integration to promote more efficient maritime operations (RT1).
- Implement the application of information technology and wireless communications to create a fully connected MTS and to enhance transportation coordination and integration (RT4).
- Evaluate and implement human systems integration within MTS to improve performance and safety (RT5).
- Develop methods to educate users as commercial practices change (RT3).

National Ocean Policy

Challenges: Traditionally, ocean governance has been very fragmented, complex, and lacking in transparency. Over 140 different Federal laws implemented by 20 different Federal agencies

currently manage the oceans[5]. The Marine Transportation System (MTS) is only one component competing for use of ocean, coastal and Great Lakes areas. The National Ocean Policy's priority objective on Coastal and Marine Spatial Planning (CMSP) will build an integrated marine spatial framework and implementation process to facilitate decision-making. This requires facing the challenge of addressing not only existing competing uses such as recreation, commercial marine transportation, ecosystem sustainability, and fishing, but also a dynamically emerging set of uses such as renewable energy, eco-tourism, and aquaculture.

The National Ocean Policy also places priority on the changing Arctic Ocean. The Arctic Council's recent assessment supported by the U.S. Government, on Arctic marine shipping outlines the rapid climate changes that will alter this oceans transportation patterns in this century. Research is clearly needed to predict future climate and commerce changes in the Arctic Ocean.



Spatial Planning, Photo courtesy of NOAA

Over the past decade, the U.S. has worked to refine and integrate ocean policy and to prioritize CMSP efforts to support the stewardship, understanding, security and prosperity of our oceans. On July 19, 2010 the President signed an executive order adopting the Final Recommendations of the Interagency Ocean Policy Task Force. This document calls CMSP a key objective necessary to address conservation, economic activity, user conflict, and sustainable use of the ocean, coasts, and the Great Lakes. The coordinating function of the CMTS can be useful in advancing the coastal and marine spatial planning framework and other priority objectives outlined in the National Ocean Policy. This will support the common goals of greening the MTS, assessing ecosystem impacts, multi-sector use and understanding, valuing marine transportation activities in decision making, and addressing the demands for improved security and economic vitality.

Priorities: To meet the challenges of sustaining a safe, healthy and prosperous ocean and ocean economy in which to operate, the MTS needs to be fully integrated into the broader national transportation system and actively engaged in marine spatial planning efforts at the National and Regional level. Research is needed to ensure MTS governance, data, infrastructure, and interests are supported by CMSP. Specific research and development priorities are:

- Manage MTS research and development within the framework for CMSP. Embrace the regional, but system-wide, approach inherent in CMSP. Participate in and provide science to CMSP regional planning bodies and assessments (RT1).
- Focus on improving MTS data standards and processes, including collection, data sharing/access, interoperable, scientific validation, and documentation. Pursue providing data through emerging technologies such as GIS layers, web services, etc (RT3).

[5] Final Recommendations of the U.S. Interagency Ocean Policy Taskforce

- Work toward real-time data integration to improve marine safety and deliver decision support systems. Examples include Vessel Traffic System, Automatic Identification System, and real-time weather and navigation information (RT4).
- Use pilot projects as a way to "deploy research," and consider creative partnerships with the operational private sector (ports, shipping) as well as academia to accelerate moving innovative tools into operations (RT3).
- Engage in research and development projects to support and improve MTS value among competing uses (socio-economic, environmental) in order to highlight the short and long term MTS needs that can be easily understood by all stakeholders (RT1).
- Assess the changing marine transportation issues in the Arctic Ocean and surrounding seas (RT1).
- Work to establish productive international partnerships to address regional issues in areas such as the Arctic, Atlantic Coast, Gulf of Maine, and Gulf of Mexico (RT1).
- Consult with other Federal agencies and organizations, such as the interagency Federal Geographic Data Committee and the National Ocean Council's Interagency Policy Committee on selecting and developing useful and compatible collection/sharing/access for geospatial data processes and practices (RT3).

Research and Development Themes

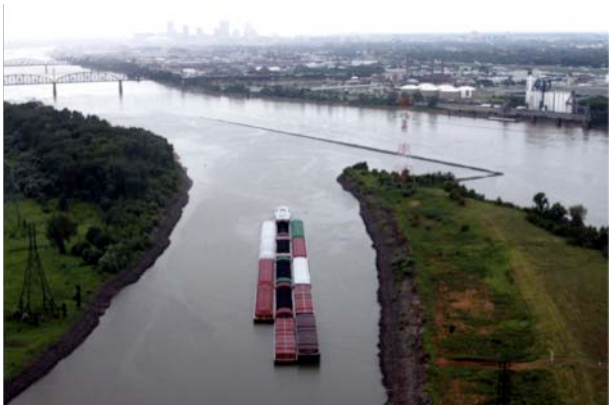


Photo Courtesy USACE St. Louis District

As seen in the previous section priorities recur across the primary categories, such as the need for MTS data access and sharing to aid in developing new tools. Five research themes are identified below that group and crosscut the research priorities. Following each research priority in the previous section there is an identifier of RT1 to RT5 that directly crosswalks the priority with the research theme described below. Thorough reviews of the CMTS *National Strategy* and the Federal Research Program Inventory have helped refine the research themes. In addition, thoughtful discussions with representatives from Federal agencies, academia, and industry during the CMTS and Transportation Research Board's Conference on Research in the MTS ("Transforming the Marine Transportation System: A Vision for Research and Development, June 29-July1, 2010, Irvine CA) allowed for a more comprehensive perspective on themes in addition to the Federal perspective. Specific research themes are:

- **RT1 The need for integration of the MTS with other modes of transportation in the U.S. and with other MTS systems globally.** MTS research and development are needed to produce new tools and technologies to enhance intermodal freight movement that uses an inclusive approach with respect to national and international concerns will strengthen the overall transportation system.
- **RT2 The need for the MTS to be more adaptable to change on short- and long-term time scales.** Research and development are needed that increases system reliability with adaptive management tools, technologies and practice. The research deployment strategy should

incorporate sustainability and adaption, including evaluation of impacts (climate change and other natural and man-made changes), ecosystem-based management, and creating green and efficient routes in the face of change.

- **RT3 The inefficient access to MTS research opportunities, programs, and research results.** A central knowledge, information, and data hub would allow R&D results to be disseminated throughout the MTS community, allowing for better social science integration, and aid in identification of additional needs.
- **RT4 The need for real-time operational information of MTS use.** Both inland and coastal ports are expanding operations and bringing new commodities on the waterways. To do this efficiently and effectively, there is a need for R&D to create tools, technologies, and practices for an electronic infrastructure to track cargo, have real time information on lock operations, explore alternative pricing strategies, and many other applications.
- **RT5 The need for MTS performance metrics that assess the national freight movement system in a systemic way.** While each agency and industry has performance metrics associated with its programs, there is a need for R&D to create metrics that adequately quantify system performance through combining and assimilating individual community metrics as well as through connection with other transportation modes. Filling this gap could provide information for a variety of interests, from developing risk informed decision tools, to identifying the impacts of hazardous materials on the waterways to identifying economic and environmental impacts due to changes in capacity and trade routes.

Research themes are created by pairing needs with on-going research focused on topics that are only solved with a multi-discipline and multi-agency integrated approach. It is the multi-agency issues that this report prioritizes and proposes as actions. Those priority research needs from the *National Strategy* that are not identified for action may be addressed by individual agencies in existing programs.

Action Plan

Photo Courtesy USACE St. Louis District

To begin addressing these research themes and supporting the strategic needs of the MTS, actions are identified in the table below and divided into Near-Term, one- to five-year, and Long-Term, greater than five year, actions based on the level of difficulty and state of related technology. These actions have some component in an existing R&D program that will form the beginning for multiagency research to address a broader multiagency solution. The table presents priority R&D actions that can only be fully addressed with multi-agency participation, defined by the topics' multidisciplinary nature of the problem and/or no one agency has the clearly defined national leadership position to holistically address the problem. It is here the CMTS R&D effort will offer the greatest benefits, through efforts to address the tougher multi-agency problems. Table 2 notes which of the five *National Strategy* areas the R&D supports, with priority given to actions that address more than one *National Strategy* area.

Table 2 Near-Term and Long-Term R&D Actions

Near Term Actions	**Capacity**	**Safety & Security**	**Environmental Stewardship**	**Resilience & Reliability**	**Finance & Economics**	**Intermodal**	**National Ocean Council**
a. R&D into resiliency from all hazard types		X	X	X		X	
b. Develop framework for R&D pilot projects	X	X	X	X	X	X	X
c. Develop data & sharing master plan	X	X	X	X	X	X	X
d. R&D in e-navigation, vessel tracking, real-time operations, and reliability	X	X	X	X		X	X
e. Create a framework for MTS performance metrics	X	X	X	X	X	X	X
f. Develop inventory of system scale models and capabilities	X	X	X	X	X	X	
g. Identify supply chain dependencies	X	X		X	X	X	X
h. Ecosystem health and benefits R&D			X		X		X
i. ID technological gaps for systems approach to national freight movement	X				X	X	
Long Term Actions							
j. R&D to support system switch to alternative fuels		X	X		X		
k. R&D to improve port automation	X	X		X		X	
l. Incorporation of social science and human factors into the MTS		X	X			X	X
m. Tools for risk-based adaptive management	X	X	X	X	X	X	
n. Holistic approach to global freight movement	X	X	X	X	X	X	X

The immediate next steps are for the CMTS Research and Development Integrated Action Team to develop implementation plans for each action and to identify specific R&D plans with milestones, study approaches, multidisciplinary team members, and resource requirements to address the 14 actions in Table 2. These implementation plans will leverage the existing 44 R&D programs, prioritizing research where possible in the Federal and private sectors as well as academia to obtain top national subject matter experts, maximize the assimilation of multiple on-going R&D efforts, and identify existing or new creative sources to fill any remaining resource gaps, including funding. The plans and subsequent research and development will include the CMTS agencies and be reported back to the CMTS on a recurring basis. This is the same approach as the successful CMTS Navigation Technology Integration and Coordination IAT, which leverages on-going programs, to build interagency work groups for each action. This approach allows a thorough scoping of the problem, vetting of specific solutions and products, identification of on-going R&D programs that have resources from the interested agencies, and a stepped approach that builds on sequential successes. If research gaps cannot be met through this approach then the multiagency team may develop options for additional resources, including funding.

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Strategic Action Plan

for Research and Development in the Marine Transportation System

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