CMTS

U.S. Committee on the Marine Transportation System

Strategic Action Plan for Research and Development in the Marine Transportation System

June 2017

PREPARE • RESIST • RECOVER • ADAPT

This report fulfills a task under the CMTS 2016-2017 work plan to revise the 2011 CMTS Strategic Action Plan for Research and Development in the Marine Transportation System.

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1. OVERVIEW

This strategic action plan for research and development (R&D) identifies priority needs toward improving the Marine Transportation System (MTS) to meet user and operator requirements. The development of this plan builds upon MTS-related challenges identified in the *Assessment of the Marine Transportation System (2017, final draft)* by the U.S. Committee on the Marine Transportation System (CMTS); the *National Strategy on the Marine Transportation System: Channeling the Maritime Advantage (2017, final draft);* and at the CMTS 4th Biennial Research and Development Conference, *From Sail to Satellite: Delivering Solutions for Tomorrow's Marine Transportation System*, Washington DC, June 21-23, 2016.

The CMTS is a Cabinet-level, interdepartmental committee consisting of representatives from Federal departments, agencies and offices with jurisdiction and interests in the MTS. It was established by Pub. L. No. 112-213 (www.cmts.gov) and is responsible for:

- Assessing the adequacy of the MTS (including ports, waterways, channels, and their intermodal connections);
- Promoting the integration of the MTS with other modes of transportation and other uses of the marine environment; and
- Coordinating, improving the coordination of, and making recommendations with regard to Federal policies that impact the MTS.

The final draft of the 2017 CMTS *Assessment of the Marine Transportation System* identifies challenges under areas of infrastructure, safety, security, environmental stewardship, and investment and makes over two dozen observations, which include the advancement of science, engineering, predictive tools, and data to adequately address these challenges. The CMTS R&D Integrated Action Team collaborated with the National Academy of Sciences' Transportation Research Board (TRB) to organize and conduct the CMTS 4th Biennial R&D conference. The conference included related technical sessions as well as keynote speakers, plenary panels, and cross-cutting technical breakout sessions to refine, define, and discuss specific user and operator needs for the MTS of the future. A conference summary is available for download at http://www.cmts.gov/.

This document synthesizes these sources to identify specific needs and to create an action plan that utilizes the Federal agencies of the CMTS and the broader MTS community including academia, industry and non-governmental organizations (NGOs) to guide next steps and actions for the next five years.

2. MTS R&D PROGRESS

The last CMTS *Strategic Action Plan for Research and Development in the Marine Transportation System*, January 2011, identified five specific priority R&D themes:

1. Integration of the MTS with other modes of transportation in the U.S. and with other MTS systems globally.
2. Making the MTS to be more adaptable to change on short- and long-term time scales.
3. The need for efficient access to MTS research opportunities, programs, and research results.
4. Requirements for real-time operational information of MTS use.
5. Value of MTS performance metrics that assess the national freight network in a systemic way.

Since this action plan was completed, these five research themes have been successfully advanced by MTS community researchers and in some cases CMTS actions. Progress has been significant such that in most cases the original research objectives have been achieved or current activities are well on the way to meeting them. This is especially apparent where the work of CMTS Integrated Action Teams (IAT) was enhanced; such as within the Future of Navigation IAT, the Maritime Data IAT and the MTS Resilience IAT. These IATs crosscut the research themes, providing broad insight into a number of MTS activities.

For example, the Future of Navigation IAT is implementing e-navigation and River Information Services that enable greater knowledge of freight flow, thus improving predictability needed for connection with other transportation modes; increasing waterway adaptability through precise communications; monitoring real-time waterway operations; and, providing accurate digital data for calculating MTS performance. The R&D IAT organized two additional biennial R&D conferences with the TRB on *Diagnosing the Marine Transportation System: Measuring Performance and Targeting Improvement* (2012) and *Innovative Technologies for a Resilient MTS* (2014). These CMTS actions and the associated agency-level research have supported considerable advancements made and shared across the broad MTS community.

The fifth theme of the 2011 *R&D Strategic Action Plan* focused on the creation of a high fidelity multi-modal freight flow network. The need called for high-resolution data at the port level with greater tracking of non-maritime freight on and across other transportation modes. Freight on the MTS is reported through the U.S. Army Corps of Engineers' Waterborne Commerce Statistics Center (WCSC); 100 percent of freight movements from origin to destination producing a complete database that may be used for a variety of planning and operational purposes and providing accurate input to many different predictive models and operations tools. Other modes collect or only release aggregated samples of data making the integration of a seamless national freight flow network challenging.

Since the previous January 2011 *Strategic Action Plan* there have been efforts to improve capabilities, including the Freight Analysis Framework (FAF), the Commodity Flow Survey

(CFS), and the Carload Waybill Sample (CWS), which are data rich and mature programs. There are newer probe data sets for the MTS (automatic identification system, AIS) and highway networks (Global Positioning System, GPS), but these are new and generating mountains of data. These have much potential, but we need to access and dig into them with new big data analytics to have them reach their full potentials. All of these are also limited because there is not a reporting mandate comparable to what the MTS operators have. Today there remains the need for a high fidelity solution the MTS and its stakeholders may access. As we look ahead at the new MTS research strategy and needs, such a national network remains a high priority without which there will be limitations producing cogent solutions.

3. SPECIFIC MTS NEEDS, R&D GAPS, AND EMERGING TECHNOLOGIES

As the MTS continues to play a critical role in an increasingly interconnected world, it must also evolve alongside the changes these interconnections bring with them. The 2016 CMTS R&D Conference speakers and participants emphatically stated the necessity for research to prepare the MTS to better withstand disruptions, adapt to changes, and take advantage of emerging technologies to address the challenges and other influences on the system. Strategic implementation of R&D will enable the MTS to evolve. The following subsections detail R&D needs and gaps. Some of the R&D needs are specific to particular aspects of the MTS, while others, such as resilience, crosscut different MTS research elements.

Data Integration

Data collection, availability, and integration remain critical to multiple aspects of the MTS, ranging from infrastructure investment decisions, to navigational guidance, to monitoring MTS health. This requirement for data has grown exponentially as operations have become further dependent on specific information alongside a greater number of data sources. The CMTS R&D Integrated Action Team has identified the following data integration research needs for the MTS:

- MTS organizations need data frameworks and integrated approaches for data collection tools to be more interoperable and thereby support more widespread sharing and knowledge generation.
- Better coordination requires more fully implemented data and metadata standards.
- Data communication demands high bandwidths to deliver data streams to a wide user group.
- Big Data analytics could successfully reveal potential interdependencies but require cross sector data transparency. While safety and security considerations and the proprietary nature of certain datasets must be respected, restrictions on data utilization should be relaxed to the greatest extent possible.
- The MTS R&D community should build more long-term test beds to better understand and comprehensively validate data.
- As data become more available and reliable, they should be incorporated to enhance performance metrics. Such application includes the need for resilience metrics and considering social risks related to MTS along with physical risks.

- There should be a survey of data needs and more effort to engage MTS stakeholders when deciding what data resources would be most applicable.
- Data should also be integrated with the Regional Ocean Planning processes to fully inform and leverage those efforts and represent MTS concerns.

MTS Infrastructure

Conference participants addressed a number of infrastructure and materials advances while also highlighting the increasing interest to investigate the potential to replace physical aspects of MTS navigation and other operations with virtual infrastructure (i.e. eNavigation). These approaches include the need to better observe the condition of existing strategic infrastructure through Structural Health Monitoring and Asset Management approaches. Other infrastructure research areas for suggested advancement include:

- The MTS can innovate to reduce investing in large fixed infrastructure where it is not absolutely critical, especially as environmental conditions are likely to become more variable in the future. Moreover, the MTS can develop and support tools that evaluate the degree of criticality associated with an infrastructure and how the loss or enhancement of the infrastructure could impact product flows or shipping costs.
- Treating MTS infrastructure projects as large, real-world opportunities for prototype investigations can generate critical knowledge. Greater engagement with academia and the private sector could improve infrastructure designs and reduce future issues.
- As R&D explores additional novel materials to extend infrastructure life, more work is needed to quantify materials' durability, derivative failures, operation in different conditions, and other fatigue characteristics.
- Standardized designs could decrease construction and maintenance costs and increase reliability.
- Current gaps in new projects and recapitalization shift operational emphasis to more efficiently use our existing infrastructure.
- Improved long-term planning approaches that more accurately capture full lifecycle costs and uncertainty, thereby leading to sustained infrastructure investments.

Supply Chain Innovation

To improve decisions related to efficient operations and future investments, the MTS stakeholders should continue to make R&D investments that lead to robust, cost-effective supply chains and associated multimodal logistics. A concerted R&D effort to increase the collective understanding of freight flows across all modes would significantly enhance the ability of predictive models and tools to capture the interconnectedness of the national and global supply chains. This will create a better understanding of the true role of the MTS within this complex, dynamic freight network so that decision makers can predict second order dependencies and disruption impacts. Needed research considerations are:

- Comprehensive data collection to allow for a quantitative suite of MTS performance measures.
- States should ensure they have incorporated MTS elements into their required freight plan in order to best integrate multimodal transportation operations and take full advantage of any recent advancement.
- Innovative efforts demand better understanding of new vessel and cargo technology, automation methods, and impacts. MTS stakeholders should work with each other directly to develop community acceptable port performance indicators and facilitate the sharing of knowledge and opportunities from these advancements.

From the national and regional perspective, better understanding and quantification of intermodal connections and MTS capacity for freight movement could assist overall supply chain investment optimization to relieve system bottlenecks and minimize the impact of disruptions. The improved knowledge though direct measures of these elements or heuristic approaches could increase MTS resilience as well as assist the prioritization of Federal MTS investments.

Environmental Conditions, Change, and Impacts to the MTS

MTS stakeholders have developed an understanding that the likelihood for changing sea-level, precipitation, storm intensity, and temperatures may potentially stress and disrupt the MTS of the future. Therefore, more research is necessary to better quantify these hazards and understand how they will influence port and waterway operation continuity and other critical aspects of the MTS, such as impacts on channels and shoaling or cleanup of oil in ice-covered waters. The MTS has a broad array of research needs to best adapt to changing conditions:

- Management of future disturbances requires understanding vulnerabilities, including accurate prediction of future conditions and not solely relying on historic patterns. Research can fill the gaps in understanding of what adaptation-related decisions will need to be made at the Federal level to increase MTS resiliency.
- Develop and incorporate technology that reduces pollution in the air and water to effectively meet Federal and State requirements. Some MTS activities, such as channel deepening and infrastructure construction, also must deal with land-based environmental issues. The best chances to implement improvements into the MTS will include market-based approaches and incentives.
- Future environmental challenges require that the MTS develop interdisciplinary teams to work efficiently, save money, and deliver the best possible, crosscutting solutions that enhance MTS resilience.
- Research is needed to better quantify benefits and services that environmental systems generate. Only when the myriad of costs and benefits are identified and carefully monetized can these efforts be fully considered in conventional solutions.

- Unmanned systems and imaging technology should continue to be used to measure and monitor underwater processes on the same scale and resolution we measure and monitor the MTS above the water surface.

Security

Alongside changes in the natural world, manmade threats continue to evolve. As a "system of systems," stakeholders need to understand all the potential vulnerabilities of the MTS during military engagements and everyday operation. As companies and MTS operators become technology companies to some extent, cyber-attacks have become the newest disruption to the overall system. Research issues include:

- Addressing the ability within the MTS to handle the associated risks of cyber threats to operations - the MTS must identify evolving cyber hazards and develop better protection systems against them.
- Advancing capabilities to recover after cyber-attacks and develop post-attack contingency plans to return to functional performance levels in an expedient manner.
- Including in future cyber technology solutions at the start, not something to address once a new solution has been developed; and cyber concerns should not be allowed to inhibit application of technologies that produce a safer, more efficient, and reliable MTS.
- Communicating and operationalizing research and model security risks through the MTS –to maintain proper security and address future threats and vulnerabilities.

The Human Element

Despite the transition to an ever more digital, automated MTS, the human component remains just as critical as ever. As technology advances, the MTS requires a workforce that can manage the increasing complexity in operations and security (e.g. cyber) as well as new environments (such as the Arctic). Raising or expanding the skill level of the workforce requires significant amounts of training to transfer technology and MTS-relevant research outcomes to human operation. In addition to adequately preparing the workforce for tomorrow's MTS, research must also work to better understand the adaptation of human behavior to changes associated with new MTS technologies. In particular, MTS research should address the following human-related issues:

- Training and data use procedures must be designed with the use capability and limitations in mind to encourage acceptance and implementation.
- The need for trained merchant mariners is critical. Engagement to promote fields in maritime should start as early as possible with more outreach to K-12 students about the wide array of MTS careers available to them.
- Student engagement and workplace training can be supported among the MTS R&D community by further involving, mentoring, and sponsoring students and

young professionals in CMTS R&D conferences and appropriate professional maritime activities.
- The MTS community should enhance research collaboration through the diversity of transportation centers at universities and other higher learning institutions with maritime focuses as well as looking abroad to see how the international community addresses similar R&D issues.
- Facilitating human connections to the MTS and associated demands, MTS stakeholders should be able to better optimize system design and management.
- MTS research must extend into the communities beyond MTS infrastructure as the value of the relationships and associated dependencies with sustainability and resilience become clear. Research must still identify how to best identify and quantify these codependent factors in order to improve the community-MTS system and linkages.

Governance

The evolution of MTS operations and technologies often will be significantly limited if Federal, state, and local governments fail to support the proper operating environment for technological advancements. There are a number of policy and research challenges that prevent the optimization of freight and passenger movement:

- MTS stakeholders need to understand how developing technologies (and the data they generate) fit into existing authorities and regulations.
- Policies must be updated to allow for new technology integration, clarifying where potential conflicts may exist and identifying what needs to be changed.
- Rules governing the travel of Federal staff associated with R&D efforts should also be reevaluated, as current limitations may restrict the collaboration and facilitation necessary to push MTS R&D forward. On-line collaborative tools such as webinars and teleconferences do not always lend themselves to the detailed exchange of information and ideas needed to advance the art of the possible.
- Altogether, MTS progress requires less formal, more agile research and application of technology-based policy and new ways to work together as a community of practice.

Collaboration

As with other aspects of the MTS, research and development must be a coordinated commitment that is implemented across the stakeholder community. Academia, industry and the government are collaborators with unique capabilities and responsibilities. Research considerations include:

- Improved collaboration between different Federal agencies in sharing their upcoming research plans to enhance efficiency.

- The Federal Government must also strategically shape its criteria and definitions for grants and proposals (such as resilience factors) to better shape and guide MTS R&D application across the nation.
- Improved impact analyses detailing the potential value of R&D could better leverage funding by illustrating where investments reduce other costs as well as augment future benefits.
- Creative financing must be sought to support MTS research. Beyond the Federal reach of the MTS, more non-Federal champions are needed to bring broader perspectives and build bridges between potential R&D partners.

More innovative public-private and public-public partnerships must be implemented to better link stakeholders with compatible resources and goals.

4. LOOKING FORWARD - Priority Research Themes

Based on these MTS needs and R&D gaps, four primary research themes emerged for the greater CMTS R&D community to focus on for the next five years.

a) ***Infrastructure*** – the priority across the CMTS is to extend the life of existing built infrastructure and make informed decisions on improvements to the MTS in the context of the national supply chain and multimodal connections. Extending the life of existing infrastructure has three priority research topics and challenges:

   1) Developing innovative materials with lower operational costs and greater durability for longer life to significantly reduce lifecycle total costs.
   2) Utilizing the science of structural health monitoring for accurate determination of remaining life of a component or system, including quantification of failure modes and new testing, instruments and observations to determine condition without harming the structure.
   3) Providing real-time situational awareness to the mariner with the goal of damage avoidance by reducing allisions, collisions, and groundings.

b) ***MTS Operations*** - the need across the MTS and multimodal connections aims to increase reliability, efficiency, safety, resilience and sustainability. There are significant challenges in these five priority topics that at times compete against each other for importance. Priority research needs are:

   1) Reducing the loss of MTS services due to unscheduled repairs, including channel shoaling.
   2) Predicting accurately travel time and movement from offshore to port or when transiting the waterway.
   3) Improving marine safety with authoritative information available seamlessly from agencies across geographic regions, downloaded through internet and AIS, displayed simply on electronic nautical charts.

4) Identifying short and long-term risks and vulnerabilities associated with extreme weather, sea level change, fluctuations in global and domestic markets, and impacts to existing and future infrastructure.
5) Developing and implementing strategies that plan for and adapt to potential transportation disruptions to increase MTS resilience.
6) Improving beneficial use of sediments and natural processes to increase performance and management objectives.

c) ***The MTS and its Surroundings*** – our goal is to maximize benefits of the MTS without jeopardizing the health and value of our ecosystems or the prosperity afforded to adjacent communities. Priority research includes:

1) Improving methods and tools to reduce impacts from vessel operations, and dockside air emissions; exploring port contributions to improve air quality; and improve methods to eliminate invasive species and their spread through marine operations.
2) Improving marine environmental response capabilities for remote areas, improve hydrodynamic model spatial and temporal fidelity, and continue oil spill research priorities identified by the Interagency Coordinating Committee on Oil Pollution Research.
3) Developing and deploying alternative technologies for fuels and energy, including advanced biofuels and green non-carbon based sources of energy into the MTS.

d) ***Data Access, The Crosscutting Research Theme*** **-** The challenge with data is what and how much data is needed to make the right decisions? Does more data translate into even better decisions and when is enough data sufficient? As the volume of data has grown and the methods of analyzing them have improved, CMTS agencies have been integrating data more firmly into the decision-making process. However, increasing numbers of traditional and non-traditional data sources can inundate us with data in volumes and types that may not be needed. Many are finding an increasing gap between the acquisition of data and its meaningful use (from *The evolving role of data in decision-making*, A report from the Economist Intelligence Unit, 2013). Yet, data is used in so much of what we do that making sure it is accurate, timely, authoritative, and accessible has become an extensive effort with many agencies having entire departments dedicated to data. Data is the crosscutting theme in the MTS because it is changing our culture to how we make decisions at the office or on the bridge of a vessel, and one that has many priority research needs. Priorities include:

1) Focusing on the discovery, access, and sharing capacity of data related to the operation and governance of the MTS.
2) Facilitating identification, archiving, linking, and integrating authoritative data from agencies and organizations with equities in maritime data.
3) Developing human and machine level access to interoperable and shareable authoritative data.

4) Creating specific MTS system-scale performance indicators that are periodically updated automatically using authoritative data from agencies and/or organizations.
5) Applying Big Data analytics to develop knowledge and reveal potential interdependencies regarding the MTS and where needed, intermodal connections.

5. MTS' MOST SIGNIFICANT TECHNICAL CHALLENGE

CMTS partner agencies are asking these and similar difficult questions:

- Where are the most significant system bottlenecks that have the greatest constraining effects on overall MTS capacity?
- To what extent does MTS port areas, terminals, and intermodal connection points act to constrain the seamless flow of freight across transportation modes?
- Where can targeted investments and operational changes best increase MTS reliability, provide the greatest return on investment (ROI), and eliminate significant vulnerabilities?
- What happens if port "A" closes?
- Does intermodal freight flow more efficiently across all modes if a navigation channel in a particular port is dredged three feet deeper?
- If a marketplace dispute leads to throughput disruptions across a region, is there sufficient capacity for that cargo to move to another region?
- Does chronic traffic congestion near a port subtract from the transportation cost savings provided by deeper and wider navigation channels?

The most significant R&D challenge facing the MTS is producing a tool that accurately reflects national freight flow, including the MTS and multimodal connections. Making informed decisions on MTS infrastructure investments and operations requires understanding and modeling the MTS, all the links with road and rail, and how freight flows from origin to destination. These connections and interdependencies are very complicated, but technical advances over the past five or so years have created an unprecedented opportunity to develop a high fidelity numerical network that can be used with operations research and systems engineering tools to accurately quantify freight flow over different temporal and spatial scales.

The MTS may not be the biggest player in the national freight flow discussion, but much of the national flow originates or terminates at a port. To succeed with this challenge requires participation from the other transportation modes and from across industry and academia. The CMTS should be the facilitator to assemble such a team. We know this topic is on national leaders minds through legislative actions, such as the former *Moving Ahead for Progress in the 21st Century* (MAP-21) initiative and the more recent *Fixing America's Surface Transportation* (FAST) Act with its Port Performance Freight Statistics Program at USDOT-Bureau of Transportation Statistics, and the new Administration's identification of infrastructure as a national priority.

The technical challenge is significant and requires a national multimodal, multidisciplinary initiative. Origin to destination data from the Automatic Identification System (AIS) on marine vessels and from similar GPS enabled tracking technologies (referred to as probe data) on road and rail produces not only historic performance metrics, but also with research could yield flow information. There needs to be coupling or calibration wherein the traditional reported data sets, including WCSC, FAF, and CFS data are used in tandem to understand how vehicle/vessel movements correspond to actual freight flows. Specific paths that certain commodities take as they flow from the ports to final destinations, how long it takes, what congestion is encountered, as well as many other evaluations are necessary to accurately model freight flow.

Another technical challenge is our inability to readily query these vast, new probe data sets. Advancements have begun using AIS data; we are several years in and still just starting to gain momentum. The truck probe data sets are an order of magnitude larger and the situation is complicated by industry being protective of their release. What is needed is a tool that would allow origin to destination pairs to be specified and resulting trip counts, travel times, dwell times, and other metrics (unique vehicles, vehicle types, etc.) to be quickly derived from the larger data set.

A generalized cross-modal "level of service model" is needed so that entire supply chains can be evaluated consistently instead of individual modes being measured separately and transition points (like ports, transfer terminals, distribution centers, etc.) often being completely missing from any sort of freight flow performance tracking system. That level of service model is the "freight fluidity" concept that the Transportation Research Board has been advocating along with the Federal Highways Administration Freight office, and it would support our own CMTS R&D efforts to derive fluidity metrics from AIS data.

Knowledge gained to create this freight flow network would serve not only the MTS, but also all transportation modes with granular, scalable, multimodal, interactive data, maps, and tools for scenario-based decision support. A collaborative effort would produce a national tool that produces transparent results. If the CMTS wants to accurately evaluate freight flow, determine impacts of investments, estimate where the most value is based on fixing aging infrastructure, or see the impacts caused with other modes invest, a high fidelity model is needed.

6. MTS R&D ALIGNMENT WITH AGENGY PLANS AND VISION – This table shows alignment of MTS R&D strategic topics with CMTS Agency research priorities and vision as detailed in agency plans and associated documents.

	BOEM	BSEE	BTS	Census	DHS	DOE	DOT OST	EPA	ITA	MARAD	Navy	NOAA	Treasury	USACE	USCG	USGS
Infrastructure - Materials											X			X		
Infrastructure - SHM							X			X				X		
Infrastructure - Damage Avoidance							X			X		X		X	X	
Supply Chain Network					X	X	X	X		X						
Operations - Increased reliability					X		X			X				X	X	
Operations - Accurate travel times							X			X				X		
Operations - improving marine safety					X		X			X	X	X		X	X	
Operations - Risks & vulnerabilities					X		X	X		X	X	X		X	X	X
Operations - Adaptive management to disruption					X		X			X	X	X		X	X	
Operations - Beneficial use of sediments	X							X						X		X
MTS Surroundings - Environmental Impacts and Response	X	X					X	X		X		X		X	X	X
MTS Surroundings - Environmental Monitoring	X	X						X				X		X		X
MTS Surroundings - Alternative Fuel/Energy	X	X				X	X	X		X	X					
MTS Surroundings - Port Community Relationships/ Interdependencies					X		X	X		X		X		X		
MTS Surroundings - Watershed Research and Management								X				X		X		X
Data - Metrics, Access, Integration & Analysis	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X

7. SUMMARY

Advancements in science and technology are needed to enable our vision for the marine transportation system. There are many opportunities and challenges ahead with far reaching possibilities. This document outlines priority research needs touching a range of topics that require immediate attention, including a critical need to develop a multimodal high fidelity freight flow model.

Infrastructure – the need is to extend the life of existing built infrastructure and make informed decisions on improvements to the MTS in the context of the national supply chain and multimodal connections.

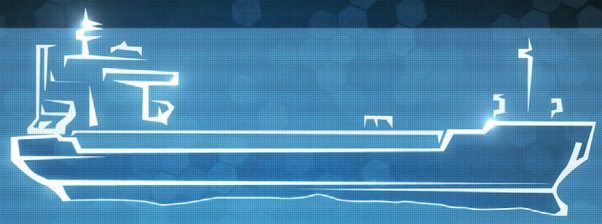
MTS Operations - the need is to increase reliability, efficiency, safety, resilience and sustainability.

The MTS and its Surroundings – the need is to maximize benefits of the MTS without jeopardizing the health and value of our ecosystems or the prosperity afforded to adjacent communities.

Data Access – the need is to integrate the right data into decision-making and to not get lost in the volume of available data.

High Fidelity Freight Flow – the need is to produce a tool that accurately reflects national freight flow, including the MTS and multimodal connections that support decisions on MTS infrastructure investments and operations.

The CMTS member agencies share many of the research needs presented, as shown in Section 6. A path forward is to connect researchers across these agencies to share on-going research and make connections to address the gaps identified in this document. In addition, many of these challenges are being researched across the broader MTS community that includes academia, industry, and non-governmental organizations. The most effective research teams will include a cross section of the community to ensure broad and comprehensive scientific perspectives and solutions. To address the priority need for a high fidelity freight flow model, MTS researchers must connect with the other freight modes to establish a multimodal team to tackle this very complicated and intertwined challenge. To be successful and create the next generation freight flow model it must be a collaborative, integrated effort.



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U.S. Committee on the Marine Transportation System

Enhancing the Marine Transportation System through Research and Development to address challenges in:

Data Integration • Infrastructure • Supply Chain Innovation

Environmental Conditions • Change & Impacts • Security

Workforce • Governance

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