



Innovative Science and Technologies to Improve Security and Safety of the Marine Transportation System

U.S. Committee on the Marine Transportation System
8th Biennial Conference on the Marine Transportation System
Held on June 24-26, 2025

Summary of Recommendations
December 4, 2025

The views expressed in this document are those of the author(s). They are intended to help inform and stimulate discussion. This document is not a report by the National Academies of Sciences, Engineering, and Medicine (NASEM), and it has not undergone NASEM review procedures.

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Forward

The U.S. Committee on the Marine Transportation System (CMTS) partnered with the National Academies of Sciences, Engineering, and Medicine's Transportation Research Board (TRB) to host the 8th biennial Innovative Science and Technology Conference on June 24-26, 2025. This year, the conference focused on *Improving the Security and Safety of the Marine Transportation System* (MTS). The action areas identified at this conference will guide CMTS programs and projects over the next two years.

Presenters and attendees discussed maritime safety data systems, including research needs and persistent barriers to enhancing cybersecurity for port and vessel infrastructure, as well as the importance of the maritime workforce and data-sharing and interoperability for emergency preparedness and response synchronicity. Other robust discussions included marine facility and waterway security, port and vessel security, cargo carriage safety, physical infrastructure protections, risks related to adopting innovative goods movement technologies, and collaboration mechanisms among all MTS-related stakeholders and sectors.

During the closing ceremony, all participants were invited to join an open forum discussion to review the key takeaways from each session.

That dialogue produced three primary action areas:

- (1) enhancing data integration and interoperability,
- (2) accelerating the adoption of cybersecurity standards, and
- (3) modernizing the mariner workforce training and certification requirements.

First, participants acknowledged the importance of data-sharing during emergencies, using the CMTS 2023 simulation exercise on the Key Bridge collapse as an example. Second, participants identified that most ships in the global fleet have fragmented or nonexistent cybersecurity protections. When protective measures do exist, they often differ from vessel-to-vessel, leaving critical data susceptible to targeted cyber-attacks. Third, current mariner training programs do not incorporate adequate technological aptitude requirements. Without massive curriculum updates, these outdated training processes will produce unprepared mariners who are susceptible to digital-overload and vulnerable to cyber-attacks.

Moving forward, the CMTS, particularly the MIST IAT will use these action areas to develop its 2025-26 work plan, collaborating with federal agency partners and other IATs to generate action and solutions.

Note: All opinions expressed are those of the conference presenters and not of the CMTS or its individual member agencies. The CMTS and its Maritime Innovative Science & Technology (MIST) Integrated Action Team (IAT may consider and use recommendations resulting from the conference to guide its work plan initiatives.

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Plenary 1 – Living Room Session: Perspectives on Marine Safety & Security

Moderator: Rear Admiral James A. Watson (USCG-Ret.)

Panelists:

- Vice Admiral Peter Gautier, Acting Vice Commandant, U.S. Coast Guard
- Mr. Ted Tregurtha, President & CEO, Moran Towing
- Mr. Charles (Bud) Darr, President & CEO, Cruise Lines International Association
- Ms. Sara Fuentes, Vice President, Government Affairs, Transportation Institute
- Rear Admiral Benjamin Evans, Director, Office of Coast Survey, NOAA

This plenary session challenged panelists to disclose “what keeps you up at night” regarding maritime security and safety. Several participants cited the 2024 Francis Scott Key Bridge collapse in Baltimore, Maryland. While immediate emergency procedures were effective, prolonged coordination deteriorated in the absence of a designated coordinating body. The United States needs a cohesive national maritime strategy that conceptualizes safety culture as a continuing process, not a static achievement. This strategy must accommodate the increasing complexity of maritime logistics, environmental disruptions, and increased shore-side resilience. Known hazards – oil spills and vessel groundings – still occur, but now face compounding pressures from targeted, sophisticated cyber-attacks. Panelists described the challenges placed on mariners.

When technologies fail or when cyber-attacks happen, mariners must recognize imperfect or ‘spoofed’ data and be prepared to respond with traditional navigation methods. One story recounted an incident in which a vessel became stranded due to a computer system malfunction. The crew had become so technologically dependent that they neglected basic visual navigation – i.e., looking out the window. Their exasperated captain emphasized that bridge windows serve a purpose beyond “keeping the cold air out.” Humor aside, this anecdote underscores the importance of avoiding excessive technological entanglement. Instead, vessels should install intuitive equipment, such as clear “go/no-go” decisional indicators.

The panelists discussed how those technologies can create known and unknown risks, while another panelist noted that there are lots of things that could be done, but it should not be put on the backs of mariners. Another panelist described how increased data could make it harder for the mariner, but technologies need to work for the mariner to improve safety and efficiency.

As the United States reinforces its maritime capabilities, there may also be opportunities to benchmark the MTS against alternative transportation modalities. For example, the aviation and rail sectors have pursued automation with greater enthusiasm than the maritime industry, often implementing these technologies faster than regulatory development. The MTS should capitalize on this experience – using aviation and rail accidents as instructive case studies regarding human-machine interface failures. This information may train mariners to anticipate and prevent similar incidents, thereby guaranteeing vessel and crew safety.

Plenary 2 – Innovative Approaches for Emerging Security, Safety, and Resiliency Concerns

Moderator: Rear Admiral John Nadeau (USCG-Ret.)

Panelists:

- Mr. Eric Christensen, Director of Regulatory Affairs and Risk Management, Passenger Vessel Association
- Captain Alex Soukhanov, Partner & Owner, True North Group LLC
- Mr. David Walker, Vice President for Global Government Services, American Bureau of Shipping
- Captain Rob Compher, Chief, Traveling Inspections, U.S. Coast Guard

Within the maritime industry, ports risk becoming disconnected from each other as compartmentalized knowledge and localized data systems hinder collaboration. The U.S. Center for Maritime Innovation (USCMI) coordinates collaborative efforts to modernize port operations to streamline infrastructure upgrades, data-sharing standards, and digital integration. Operating under the Maritime Administration (MARAD) as an advisory council, the USCMI receives additional support through a cooperative agreement with the American Bureau of Shipping (ABS). This public-private partnership enables the Center to fund pilot programs and disseminate best practices to receptive stakeholders at different ports.

The maritime industry, often seen as slow to embrace innovation, functions as a key end user for most advanced technologies. Many factors influence this perception. For example, the last major update to domestic passenger vessel standards occurred in 1996, while the U.S. fishing fleet receives even less attention. To bridge this gap, independent consulting firms, such as True North LLC, offer comprehensive fleet cyber assessments.

Captain Soukhanov explained that cybersecurity approaches do not function as one-size fits all. He further clarified that future innovations should incorporate security by design, or risk repeating mistakes and compounding cyber risk. In the graphic below, Soukhanov illustrates how an assessment occurs for a common deep sea commercial vessel. Each assessment begins with establishing a baseline for cybersecurity protocols, including expectations for shoreside support. Each crew member aboard a ship has an assigned emergency station – from entry-level positions to chief engineers. Shoreside information technology (IT) teams should implement complimentary procedures and share that information with their seafaring counterparts to minimize confusion during crisis situations.

Technology upgrades also present significant challenges for small, family-operated businesses. For example, an operator of a seasonal ferry may face prohibitive

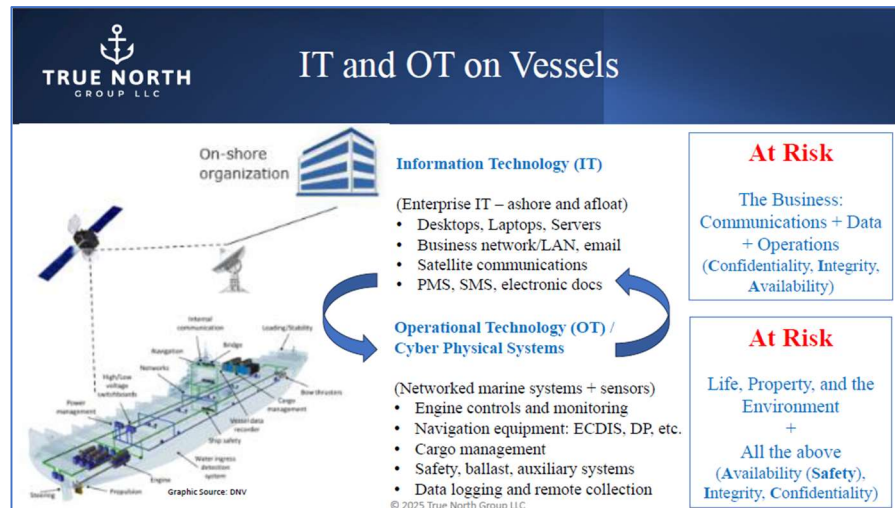


Figure 1.1 IT and OT on Vessels. Adapted from "Innovative Approaches for Emerging Security, Safety, and Resiliency," Capt. Alexander N. Soukhanov, 2025, True North Group LLC.

installation costs, compounded by concerns about revenue losses associated with removing that vessel from service. That operator may also question the complexity and fragility of new systems, requiring additional crew training and specialized maintenance. The USCMI addresses this skepticism by identifying technology that enhances vessel reliability and emphasizes four key pillars: maritime energy, maritime operations, maritime resilience, and U.S. maritime competitiveness. If technology supports one or more pillar, the Center considers it for deployment to a maritime innovation incubator within a regional prosperity zone.

Presenters described challenges with vessel operators adopting new technologies. Traditional vessel technologies are integrated with multiple redundancies in case something fails, there are back-up systems in place for safety and security. New information technologies may be segmented in construction so back-up technologies may not fully integrated. There is concern with technology vendors having unauthorized access to vessels at sea, and, in one case, necessitating the removal of technologies from a fleet of ships because of security concerns with the vendor.

The time to adopt new technologies was also discussed. A new vessel may wait three years for necessary approvals and crew training. There is a need to create the right environment to facilitate the uptake of new technologies. Because maritime is globally competitive, there also needs to be a business case for adopting new technologies. Where there is not a willingness to pay or ability to pay for new technologies, we need to consider the business case or level of subsidies necessary to implement new technologies for security and safety. This was raised as a particular concern for ferries.

Student Honor Panel

1 – Orkhan Khalilov, Texas Southern University – The Invisible Crew: How AI is Reshaping Maritime Workforces and Global Training Standards

The first student presenter, Mr. Orkhan Khalilov, addressed the disconnect between traditional mariner training and the rapid integration of artificial intelligence (AI) into maritime operations. Drawing on over a decade of offshore experience, Mr. Khalilov stressed that AI will not eliminate mariners entirely. Instead, he emphasized that technology would transform working conditions and role expectations as the industry increasingly focuses on shoreside jobs requiring digital competence. Beyond downsizing onboard crews, this transition may pose challenges for organizations looking to retain experienced personnel who lack tech fluency. Mr. Khalilov acknowledged the psychological strain of displacement and advocated for practical AI training that prioritizes those individuals to ensure retention.

Hybrid positions – such as “deckineers” (deck/engineer specialists) – will also emerge during this shift. These new roles, supported by AI systems, form an “invisible crew:” automated tools that assume routine operations, allowing human capabilities to relocate onshore. Mr. Khalilov identified global gaps in training and certification to support these new operational environments, including digital ethics education and cybersecurity drills. He also cited a 2023 Ocean Technologies Group finding that 75% of maritime educators report insufficient AI-readiness at their institutions. This discrepancy may reflect the significant costs associated with workforce transition or ‘re-skilling’ initiatives. Among his recommendations, Mr. Khalilov suggested massive curriculum updates and the introduction of

simulation-based training that incorporates tiered AI learning paths. To pay for these initiatives, Mr. Khalilov proposes fostering public-private partnerships and seeking joint funding schemes through port alliances (e.g., Singapore and Rotterdam). He concluded that countries that align training, regulation, and innovation will lead maritime operations in the future.

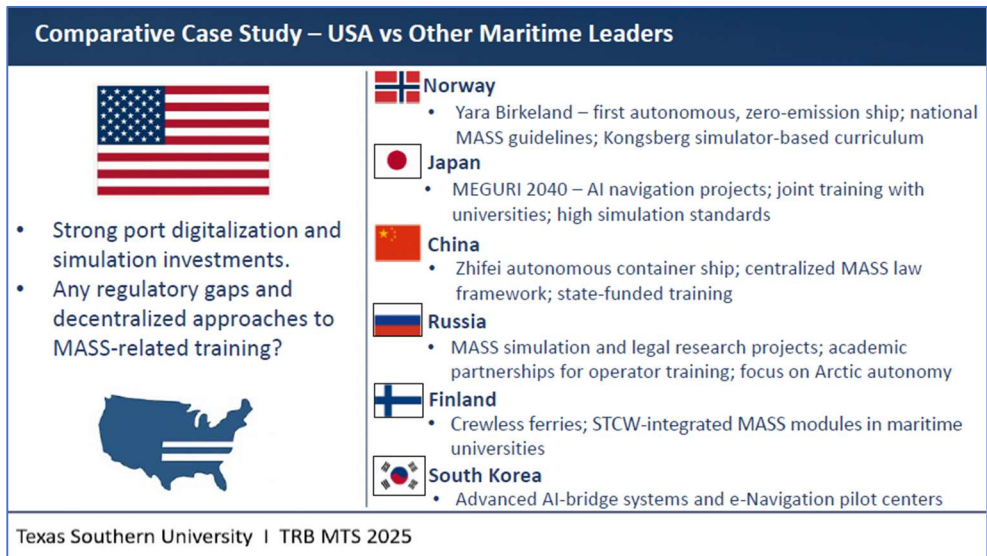


Figure 2.1. Comparative Case Study – USA vs. Other Maritime Leaders. Adapted from “The Invisible Crew: How AI is Reshaping Maritime Workforces and Global Training Standards,” Orkhan Khalilov, 2025, Texas Southern University.

2- Niping Duan and Huan Zhou, University of Maryland – Adaptive AI-Agent for Marine Freight Routing and Shipping

The second presenter, Ms. Niping Duan, with support from Ms. Huan Zhou, explored AI-based strategies for improving maritime freight routing and scheduling. Traditional methods rely on static models informed by historical data averages, which often fail in adapting to real-time environmental changes. These outdated frameworks can generate inefficient and unsafe routes, leading to wasted fuel and delayed freight arrivals. Ms. Duan and Ms. Zhou developed machine learning techniques to identify optimal operational behaviors – e.g., when a ship traveling at 16 knots under certain wind conditions will achieve peak fuel efficiency.

Ms. Duan elaborated that they applied deep reinforcement learning to enable vessels to avoid hazardous areas, including risky storm systems and congested shipping zones. Their approach involved compiling multi-source navigational information into a data fusion system, combining automatic identification system (AIS) vessel trajectory records, gridded weather datasets, ocean current fields, and historical accident reports. This unified dataset spanned January to February 2022 and encompassed East Coast shipping corridors from New York to Florida.

After collecting this data, Ms. Duan and Ms. Zhou generated a single analytical map for training their reinforcement learning agent. They prioritized safety and efficiency, penalizing outputs that showed high fuel consumption, unnecessary turns, and persistent slow speeds, while rewarding minimal course corrections and risk adverse operations. These findings show benefits for improving safe and efficient freight routing and scheduling and underscore the importance of complementary tools, like digital twins and simulation-based training. Ms. Duan and Ms. Zhou also demonstrated the feasibility of integrating AI into multi-source data analysis within the maritime context.

3- Juana Jaramillo-Rios, University of Missouri—St-Louis – Enhancing Safety, Infrastructure, and Intermodal Connectivity in Inland Waterway and marine Freight Transport

The graphics included in this section reflect preliminary findings and are subject to further revision.

In the United States, inland waterway transportation (IWT) plays a critical role in freight movement, handling over 630 million tons annually through fuel-efficient and low-emission channels. However, despite these advantages, IWT represents less than 5% of total U.S. freight volume. The third student presenter, Ms. Juana Jaramillo-Rios, linked this underutilization to aging infrastructure, fragmented regulation, limited digital coordination, and ongoing workforce shortages. Her project examined stakeholder-driven capabilities that shape IWT performance, including barriers to its growth and opportunities to increase its freight market share.

IWT system performance depends on the collective interests and actions of all stakeholders. Building on the stakeholder theory, Ms. Jaramillo-Rios conducted semi-structured interviews with 21 public and private members of the inland-waterways community. Those interviews were designed to uncover patterns undetectable through conventional data analysis, using coding technologies for thematic analysis and key problem identification. Ms. Jaramillo-Rios distilled her findings into four main capability domains – regulatory alignment, infrastructure modernization, digital integration, and workforce capacity.





	Antecedent → Outcome	Operational Reliability	Value Co-Creation	Exploitation Efficiency
	Regulatory Alignment	P1a: Greater regulatory alignment will improve operational reliability of IWT services.	P1b: Greater regulatory alignment will foster value co-creation among waterway stakeholders.	P1c: Greater regulatory alignment will enhance exploitation efficiency of the IWT system.
	Infrastructure Modernization	P2a: Modernized infrastructure will improve operational reliability.	P2b: Modernized infrastructure will facilitate value co-creation.	P2c: Modernized infrastructure will increase exploitation efficiency.
	Digital Integration	P3a: Higher digital integration will improve operational reliability.	P3b: Higher digital integration will enable value co-creation.	P3c: Higher digital integration will improve exploitation efficiency.
	Workforce Capacity	P4a: Stronger workforce capacity will improve operational reliability.	P4b: Stronger workforce capacity will support value co-creation.	P4c: Stronger workforce capacity will enhance exploitation efficiency.

Figure 2.2. Research Propositions. Adapted from “Enhancing Safety, Infrastructure, and Intermodal Connectivity in Inland Waterway Freight Transport,” Juana Jaramillo-Rios, 2025, University of Missouri-St. Louis.

Ms. Jaramillo-Rios constructed a matrix connecting these domains with multiple outcome categories. For example, within regulatory alignment, stakeholders noted that funding “only arrives following a catastrophe.” Or, within digital integration, stakeholders sought promising tools, but that equipment remained siloed without a national interoperability mechanism. Ms. Jaramillo-Rios anticipated that the next phase of her project would assess domain synergies to enhance operational reliability. She

emphasized that stakeholders function as system drivers and must be invited to participate in research aimed at improving IWT performance.

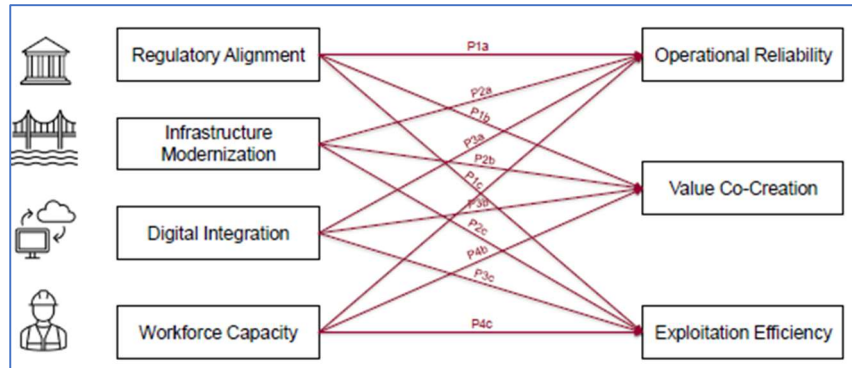


Figure 2.3. Conceptual Framework. Adapted from “Enhancing Safety, Infrastructure, and Intermodal Connectivity in Inland Waterway Freight Transport,” Juana Jaramillo-Rios, 2025, University of Missouri-St. Louis.

Plenary 3 – Marine Transportation System Operational and Economic Resilience (Part I)

Moderator: Ms. Ashley Chappell, Executive Director, U.S. CMTS

Panelists:

- Ms. Anne Strauss-Wieder, Lecturer, Rutgers University
- Mr. Brian Tetreault, Navigation Program Manager, Woolpert
- Ms. Patricia DiJoseph, Port Performance Program Manager, U.S. Department of Transportation

This panel discussed how disruptions can range in intensity and severity, from planned and predictable to rapid and abrupt. Yet even a small disruption has the potential to jeopardize the global supply chain. Preserving its integrity requires the MTS to strengthen three pillars of freight resilience: physical movement, communication and information flows, and regulatory considerations. If even one of these pillars fails, it can precipitate cascading consequences for the entire MTS.




Activities	Definitions and Examples
Physical Flows 	<ul style="list-style-type: none"> • Any physical activity directly needed for freight movement • Vessels, terminals, railroads, trucks, pipelines, aircraft, warehouses and distribution centers
Communication & Information Flows 	<ul style="list-style-type: none"> • Any information and transactional exchange needed for freight movement • Bills of lading, financial flows, customer notifications, delivery appointments, warehouse management systems, inter-agency communications, etc.
Regulatory Considerations 	<ul style="list-style-type: none"> • Any gov't regulations, rules, and agency activities needed for or shaping freight movement • USCG, CBP, truck driver credentials, Jones Act

Figure 3.1. Three Sets of Activities for Freight Movement. Adapted from “Collaboration, Coordination, and Communication: Building Resilience,” Anne Strauss-Wieder, 2025, Rutgers University.

Hurricane Sandy (2012) revealed this vulnerability by simultaneously compromising all three pillars and exposing how technologically sophisticated facilities still contain structural weak points. With the MTS increasingly reliant on electrical power systems, prolonged utility outages can immobilize port operations, leaving whole facilities ‘in the dark’ for days to weeks. As utility companies prioritize

residential service restoration over commercial, ports can remain dormant and unproductive even as the surrounding community comes back online. To avoid this operational paralysis, ports must establish comprehensive contingency frameworks before disruptions emerge.

The MTS can measure supply chain health by evaluating community continuity – the capacity to sustain a population and its economic base following disruptions. This continuity depends on three elements: collaboration, coordination, and communication. To effectively implement these three “Cs,” the MTS must restructure its operations to

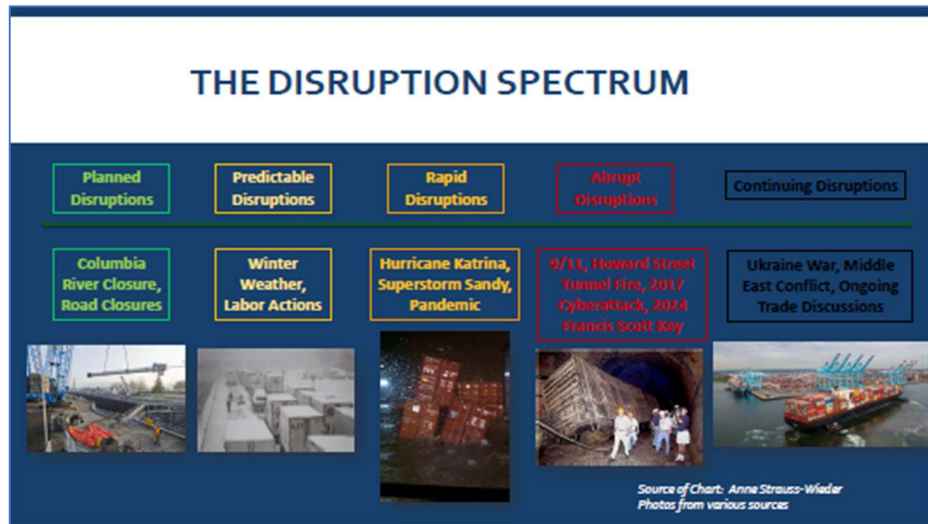


Figure 3.2. The Disruption Spectrum. Adapted from “Collaboration, Coordination, and Communication: Building Resilience,” Anne Strauss-Wieder, 2025, Rutgers University.

reconceptualize established emergency protocols. For example, the CMTS Supply Chain and Infrastructure Integrated Action Team (SCIAT) hosts simulation or ‘tabletop’ exercises to gauge how the supply chain would perform after different disruptions. In September 2023, SCIAT members studied a hypothetical scenario involving a bomb collapsing the Francis Scott Key Bridge (Key Bridge) in Baltimore, Maryland. Participants identified deficiencies in communication and information flows, particularly the absence of secure, reliable, real-time data-sharing capabilities. Most significantly, they requested metrics capable of assessing cargo redistribution.

When the actual Key Bridge collapse occurred in March 2024, these observations gained painful relevance. What began as a sudden, localized disruption evolved into a months-long supply chain crisis. Ports in Norfolk and New York absorbed some diverted cargo, but vehicle imports plummeted by 40% immediately following the incident and failed to recover until later that summer. This event raised several questions regarding port recovery capabilities, including: which operational areas demonstrate superior recovery resilience?

Current analytical tools provide partial answers. The Port Performance Freight and Statistics Program publishes standardized capacity and throughput metrics, while the developing Waterway Intelligence Monitoring System will issue automated reports on transit times and daily waterway traffic conditions across vessel classifications. However, the maritime industry must adopt these tools into standard operational practices rather than rely on improvised solutions developed during crises.

Plenary 4 – Marine Transportation System Operational and Economic Resilience (Part II)

Moderator: Dr. Amit Mokashi, U.S. Merchant Marine Academy

Panelists:

- Dr. Jan Hoffmann, Global Practice Manager, The World Bank
- Mr. Cameron Humphrey, Director of Maritime and Industrial Capacity, National Security Council
- Mr. Vesa Koivumma, Head of Strategic Growth, Voyage Services, Wärtsilä

This panel considered evolving patterns in global maritime trade and the implications for U.S. shipping capacity and capability. Global maritime participation has increased since 1970 as developing countries have earned greater shares of seaborne trade. Cargo unloaded in those nations has risen from approximately 15% in 1970 to over 60% in 2020. Simultaneously, the number of global container ports offering regular liner services has expanded considerably, generating more diversified shipping options, and reducing dependency on historic hubs. However, concerning negative trends have also emerged.

Rising emissions from increased maritime activity has drawn considerable attention from global environmental forums. Also, market consolidation through massive corporate acquisitions has reduced the number of competitive options and heightened the maritime sector's vulnerability to successive disruptions. The World Bank reports that the COVID-19 pandemic in 2020 triggered freight rate surges as demand curves steepened, and supply capacity constraints pushed shipping costs well beyond sustainable levels. During this period, shipping vessels spent 20% additional time in port due to operational delays stemming from health protocols. Then, the 2024 Red Sea crisis imposed extended transit times, with ships spending 9% more time at-sea while navigating alternative routes to avoid conflict zones. These responses demonstrate how the global supply chain has become increasingly volatile, with limited buffer capacity to absorb these disruptions. However, the United States can build its resilience through domestic capacity development alongside coordinated international cooperation.

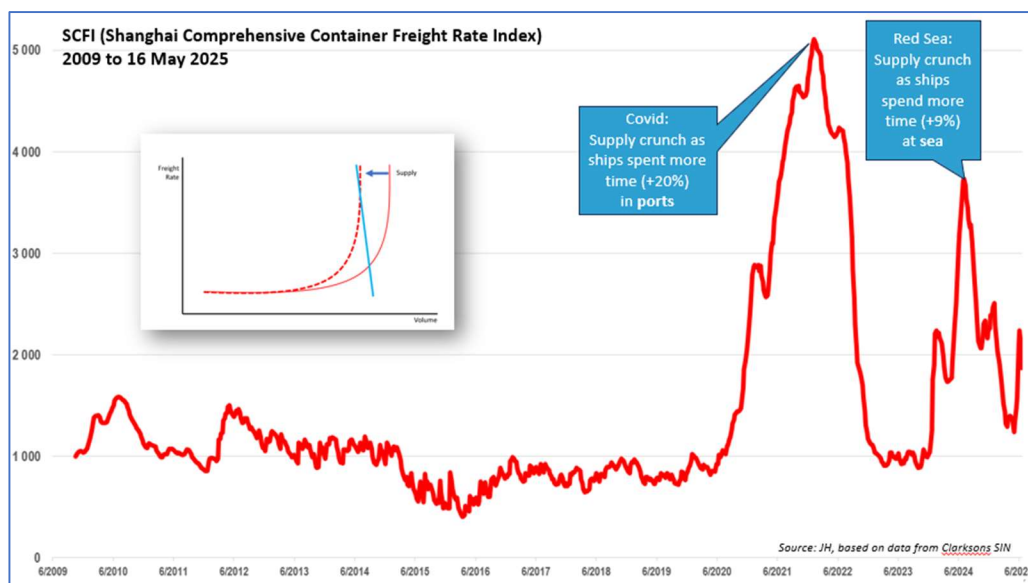


Figure 4.1. Shanghai Comprehensive Container Freight Rate Index. Adapted from "Global Trends in Maritime Logistics: Past, Present, and Future?" Dr. Jan Hoffmann, 2025, World Bank.

The new Directorate for Maritime and Industrial Capacity within the Trump Administration’s National Security Council will spearhead initiatives revitalizing the U.S. maritime industrial base. This development reflects growing Administration recognition of the domestic MTS and its deteriorated condition, which puts the nation at a strategic disadvantage. The Directorate has acknowledged that this atrophy creates significant homeland security vulnerabilities – e.g., should war erupt, it could disrupt access to foreign vessel component suppliers. This infrastructure gap represents decades of institutional neglect and chronic underinvestment across the maritime sector, requiring an immediate intervention to ‘right the ship.’

Executive Order 14269 (“Restoring America’s Maritime Dominance”) addresses both industry-wide and sector-specific vulnerabilities. This Order should consolidate disparate reports, research findings, actionable recommendations, administrative measures, and legislative proposals. It prioritizes maritime infrastructure modernization and the needs of adjacent, waterfront communities, particularly domestic shipyard productivity. For example, the Directorate aims to examine methods of combating anticompetitive and unfair trade practices that have undermined U.S. domestic capacity. However, the Directorate recognizes that these interventions will be ongoing and iterative processes that may span multiple presidential administrations.

Operational efficiency was also discussed in this session, including the need for port optimization and the use of digital simulations. While earlier presenters described concerns with cyber security, this panel explained that 93% of vessel service calls could be resolved remotely, using virtual training rooms as an emerging opportunity.

Concurrent Technical Breakout Sessions (Part I)

Session 1A: Maritime Safety and Security I

Moderator: Dr. Amit Mokashi, U.S. Merchant Marine Academy

Panelists:

- Ms. Catherine Lawson, University of Albany
- Mr. Anthony Mulligan, Hydronalix Inc
- Mr. Matthew Mitchell, Zelim LLC
- Mr. Dylan Sparks, Mythos AI

This panel discussed novel maritime technologies. Four presenters demonstrated how those technologies can shift maritime operations from reactive to proactive safety paradigms. The panelists also acknowledged cyber-fatigue concerns and worries that operators may disengage from digital tools. They advised that operator acceptance occurs when educational efforts and value demonstration align with tech integration into familiar systems, like the NOAA Weather-Ready Initiative for small craft operations.

Dr. Lawson addressed weather intelligence and decision support systems, highlighting the risks that unanticipated conditions pose to small vessels. Her research has identified gaps in existing maritime weather data, particularly affecting small and medium vessel operations. She collaborated with the University of Washington to access its low-cost, 3D-printed Automatic Weather Stations in Puget Sound

and integrate those systems with AIS to create “Wx AIS.” The Wx AIS enables weather-aware situational awareness for ferry operators and fishermen by using modified open-source code to alert crews to emerging dangers. These affordable, localized forecasts require plug-and-play installation – already available on most modern ships. Dr. Lawson also proposed “fog computing” architecture to support distributed maritime data collection and processing, advocating for global systems that incorporate onboard sensors, lighthouses, and virtual control centers.

Mr. Mulligan presented on disposable Uncrewed Surface Vessels (USVs) designed for emergency response applications. These inexpensive vessels only require foam and fabric construction and can operate in sea states up to level three while maintaining modular, field-repairable designs with crash-resistant properties. USV operators report operational simplicity through a smartphone app and ground station radar interfaces, designed for ease of training and deployment. The vessel applications vary and include post-disaster reconnaissance, bridge and infrastructure inspection, and supply delivery during hazardous flood conditions. There may also be opportunities for medical evacuation capabilities through patient duffel bag conversion systems.

Mr. Mitchell focused on Search and Rescue (SAR) optimization through AI applications. Current open-water search attempts achieve rescue success rates below 20%, with human error representing the primary limitation. Mr. Mitchell proposed transitioning from basic detection to intelligent recognition through AI-powered systems that recognize humans underwater with over 95% accuracy at distances up to 335 meters. This reliable recognition could improve SAR success rates and additional studies should reduce false positive incidents.

Mr. Sparks described Advanced Pilot Assist Systems (APAS) for collision prevention. The maritime industry reports over 2,600 serious incidents annually, with human error contributing to 75% of collision events. Delayed adoption of digital tools, like APAS, compounded by aging crews and staffing shortages, exacerbate existing collision prevention efforts. Comparatively, APAS capabilities include real-time object tracking and threat ranking, generating verifiable safety metrics and data-driven risk profiles.

Session 1B: Marine Transportation System Operational and Economic Resilience I

Moderator: Mr. Ned Moran, Moran Towing

Panelists:

- Ms. Nubia Del Carpio, Bureau of Transportation Statistics, U.S. Department of Transportation
- Mr. Aswin Janardhanan, Vessel Docker Inc.
- Mr. Phil Thompson, BMT Global
- Dr. Ashok Pandey, Massachusetts Marine Academy

This panel highlighted how evolving vessel characteristics and traditional maritime challenges require innovative approaches to enhance MTS operational effectiveness. With vessels growing larger and faster, infrastructure must keep pace. Mr. Thompson explained how bridge designers must accommodate larger vessels while building with static channel dimensions. The REMBRANDT navigation simulation system can assess which designs to avoid, reducing the likelihood of collision events. Using digital forensics applications, the REMBRANDT system offers incident reconstruction and replay through precision ship hydrodynamic, high-fidelity port hydraulic, and crane modeling. This 3D modeling transforms complex collision incidents into an interactive simulator, allowing maritime professionals to modify outcomes and

explore multiple perspectives. Mr. Thompson predicted that increased AI integration will enhance predictive analytics through improved and versatile risk assessment approaches. Mr. Thompson also observed that ports are in the best position to influence operations such as transit restrictions, vessel speeds and assist tug requirements which may have prevented the Key Bridge collapse.

Mr. Janardhanan complemented Mr. Thompson's presentation by analyzing recent maritime incidents, including the recent grounding of the *Ever Forward*. That incident involved operational mistakes, worsened by budget-constrained maintenance that reduced channel width below specifications. Mr. Janardhanan emphasized that deepwater port and channel dredging projects often face high costs and completion delays. He applied the "Swiss Cheese" risk model, noting that aligned vulnerabilities across multiple systems create prime conditions for major incidents. Mr. Janardhanan noted that over 50% of vessels are flagged for convenience. Rather than having large vessels making multiple port calls, he described the opportunity to have smaller U.S. flagged feeder container vessels making shorter trips in U.S. waters to improve efficiency and reduce emissions. He also noted that barge and tug bridge collisions could be reduced with self-propelled barges.

Ms. Del Carpio further addressed channel vulnerability. Following the 2024 Baltimore Key Bridge collapse, the National Transportation Safety Board assessment of other bridges revealed additional vulnerabilities, ultimately determining that 67 bridges required major updates. Ms. Del Carpio emphasized using existing tools as a pathway to build resilience while new technologies develop. For example, the Standardized National Bridge Inventory contains information on all bridges within the United States, including dimensions and operational conditions. This data can inform mariner navigational safety while repairs remain ongoing, especially in high exposure areas.

Dr. Ashok Pandey studies Arctic shipping challenges, describing the Arctic as a tenuous link between global shipping networks. Receding sea ice creates shorter shipping routes while cargo movements involve intra-Arctic transport and burgeoning mining operations. Dr. Pandey clarified that receding ice differs from 'ice free' conditions, with open water defined as 10% or less ice coverage. Increased ship traffic, including ice breakers, may produce negative externalities by disrupting fragile Arctic ecosystems, particularly with vessel traffic increasing as climate change extends navigable seasons. These extended seasons require enhanced, proactive planning through digital route optimization models and simulation for optimal ice navigation. Dr. Pandey advocated using AI tools, such as digital twins, to improve mariner sea ice understanding while incorporating localized ecosystem knowledge to cultivate sustainable shipping practices.

Session 1C: Data Integration and Artificial Intelligence I

Moderator: Ms. Patricia McKee, 2025 Knauss Fellow, U.S. CMTS

Panelists:

- Dr. Ricardo Ungo, Old Dominion University
- Dr. Dominic Thomas, Kennesaw State University

This panel presented two ongoing research projects involving the application of large language models (LLMs) to improve the handling of ship manifest data and other information during disruptions. LLMs offer significant potential for enhancing maritime operations through real-time incident response capabilities, automated stakeholder communications, and permanent virtual assistance functions.

However, these systems require continuous human oversight to prevent machine errors, such as miscalculations regarding port disturbance assessments that could compound operational challenges.

Dr. Ungo outlined how LLMs can help when disruptions impair data-sharing capabilities. Data-sharing protocols remain a challenge across the maritime sector, particularly regarding files containing container and cargo location information aboard vessels. Current practices lack standardized sharing mechanisms across industry participants. This standardization gap impedes information flow while undermining legitimate security needs and hindering operational transparency requirements. However, LLMs can assist with rapid analysis of unstructured data, enabling customizable extraction and identification of key information and lessening operator overload. Machine learning can also parse and summarize data feeds to draft quick context-aware reports that decrease miscommunication and allow automated interactions with stakeholders (e.g., email, queuing).

Dr. Thomas suggested opportunities to incentivize data-sharing, such as offering carbon credits to reluctant stakeholders. He also emphasized that ports should join the conversation on the clean energy transition. For example, as decarbonization efforts gain momentum, will ships need to reroute to ports that can handle specialized fuel or hybrid engines? Dr. Thomas cited an International Organization for Standardization report that 15% of fuel consumed by ships occurs at port, claiming that this excess port time could be “a direct consequence of information failures.” Both panelists recommended increasing educational opportunities for all maritime stakeholders, from mariners to maritime lawyers to security personnel, and a review of current frameworks to recommend improvements.

Keynote – Cybersecurity in Maritime

Rear Admiral John Mauger (USCG-Ret.) delivered the conference keynote on maritime cybersecurity, advocating for rigorous incident investigations and the establishment of robust liability frameworks. A considerable portion of the global shipping fleet has only rudimentary cybersecurity protections. Those organizations must be held accountable for deficient prevention policies. RADM Mauger urged the adoption of mechanisms comparable to those implemented under the Oil Pollution Act of 1990.

Effective cybersecurity requires constant vigilance and awareness of every vulnerability. RADM Mauger characterized network nodes as threat amplifiers, with each connection point representing a potential breach or “hole in the hull.” A single hole can precipitate cascading system failures, granting hackers sustained access, control, and influence over compromised systems. Restoring system integrity, or patching the hull, can take time. It involves the reconstruction and careful validation of all network components to identify and address residual threats.

RADM Mauger also referenced the 2024 CrowdStrike incident, where a prominent endpoint security provider updated its software and “crashed the internet.” This disruption impacted operations for hundreds of clients, including major airlines, like Delta. Yet the provider experienced a rapid stock price recovery. This conspicuous lack of financial accountability raises questions about the economics of mitigating cyber risk. RADM Mauger explained that maritime professionals often question whether coverage parameters for cyber insurance justify the associated premium costs. However, maritime stakeholders must recognize that insurance cannot replace proactive risk mitigation, which remains crucial for ensuring operational continuity and long-term system resilience.

Concurrent Technical Breakout Sessions (Part II)

Session 2A: Maritime Safety and Security II

Moderator: Ms. Ashley Chappell, Executive Director, U.S. CMTS

Panelists:

- Dr. Mayir Mamtimin, ABS
- Dr. Amit Mokashi, U.S. Merchant Marine Academy
- Mr. Nate Gilman, MM-SEAS USCG Licensing Software
- MIDN Blake Giannamore, U.S. Merchant Marine Academy

With the MTS facing new dilemmas – from decarbonization to AI integration – this panel offered a vision of how innovation might influence next steps in fostering maritime safety and security. For example, many researchers have begun evaluating marine alternate fuels, such as advanced nuclear reactors, to reduce vessel emissions. In fact, when applied in a maritime context, nuclear power could help the industry meet the International Maritime Organization (IMO) targets for carbon neutrality. While public acceptance of nuclear remains low, modern Generation 4 reactors offer increased operational control and scalability compared to earlier models. However, current IMO and U.S. Nuclear Regulatory Commission (NRC) standards have not evolved to accommodate advanced nuclear technologies. The MTS must advocate for regulatory reform, including investment in training pathways and public-facing informational campaigns to assuage skepticism.

Maritime training still suffers from inconsistent standards and inadequate support systems, often causing low preparedness and poor mental health. Conversely, AI-powered simulations and adaptive learning can deliver personalized, scalable training programs on nuanced topics, like nuclear reactors. These systems can also provide much needed mental health support, especially Cognitive Behavioral Therapy (CBT), which can mimic real-world stress scenarios and evaluate decision-making criteria. CBT also offers virtual mentors and AI-enabled communications that address isolation and other issues that disproportionately impact seafarers. Those tools must be integrated into the complex and outdated certification processes used in maritime credentialing programs. By introducing AI, these programs would benefit from automated document verification and assistance translating regulatory text into plain language to support mariners transitioning from the military.

Session 2B: Marine Transportation System Operational and Economic Resilience II

Moderator: Mr. Daniel Hackett, Hackett Associates

Panelists:

- Dr. Yi Victor Wang, Massachusetts Maritime Academy
- Mr. Chad Fuhrmann, Chaos Ready Inc.
- Ms. Kim Gavin and Mr. Rob McGurrin, BLUEiQ
- Dr. Christopher Kolodziej, Argonne National Laboratory

As maritime threats evolve, the MTS must adapt methods designed to quantify vulnerability through reliable, data-driven models. The Empirical Predictive Modeling (EPM) technique uses a two-step process – logistic regression to determine loss occurrence, followed by beta regression to quantify loss severity.

Altogether, EPM translates historical event data into actionable forecasts that have already proven effective, such as flooding in North Carolina during Hurricane Helene and seismic risks in Taiwan and Nepal. When paired with hazard simulations, EPM gains predictive strength, allowing maritime professionals to assess not only where disruptions may occur, but also their probable scale and impact. Machine learning further enhances EPM modeling and can allow researchers to shift their attention toward the maritime industrial base.

Through lifecycle assessment, the MTS can model energy use and emissions. Using the M/V *Suquamish* ferry as a case study, the Argonne National Laboratory has conducted a cradle-to-grave analysis of vessel emissions to gauge ownership cost. The findings linked low-emission systems to greater operational continuity. The Lab also applied Bayesian network modeling to evaluate probabilistic risk assessments (PRAs) across the global supply chain. PRAs, originally developed for nuclear safety, help identify hidden vulnerabilities in shipbuilding equipment, such as automated cranes, and other maritime technologies. For example, the Argonne Lab reported that the United States lacks capacity for producing large, slow-speed diesel engines, but dominates in high-powered marine engine manufacturing (>85% global market share). This information positions policymakers to focus investment on areas of the MTS and refine regulatory oversight to benefit the maritime industrial base.

Nuclear marine propulsion has recently received renewed interest as policymakers evaluate the domestic fleet. Often a provocative topic, nuclear propulsion could enhance vessel long-range capability and emissions reduction. However, widespread adoption faces significant hurdles, with regulatory uncertainty being the primary constraint. Public acceptance, also, has yet to match technical readiness. Until the United States addresses these dilemmas, nuclear propulsion will remain a prospect, not a reality. That said, presenters described increased business interest in micro reactors, and the NRC proposed new rules for 1 to 10 megawatt reactors.

Plenary 5 – All Hazards Approach to Emergency Response Planning and Training for Ports

Moderator: Ms. Andrea Williams, Maryland Port Administration

Panelists:

- Mr. Bill Burket, Senior Director, MIRT & Business Continuity, Port of Virginia
- Ms. Danielle Hale, Director of Emergency Management, Port of Corpus Christi
- Captain Steve Czawlytko, Baltimore County, Maryland Fire Department

Emergency response at ports demands more than reacting to disasters. It also requires systematic planning and early stakeholder engagement – at the port level and beyond. Ms. Williams cited a fatal 2014 vessel fire in New Jersey as her ‘wake-up call’ regarding emergency response planning and training for ports. In the aftermath, her team created a marine firefighting committee and launched a response working group with the U.S Coast Guard Captain of the Port. That early investment helped lay the groundwork for gradual capability building or -- as Ms. Williams articulated it – crawl, walk, run.

Training came up repeatedly during this panel, not just as a requirement, but as a culture. Ms. Hale explained that her team conducts full-scale annual exercises and regular regional training. Her approach emphasized familiarization – walking first responders through vessel tours, reviewing available assets, and establishing common terminology. Captain Czawlytko reinforced this concept of tiered training.

Drawing on his HazMat background, Captain Czawlytko emphasized the need for buy-in, particularly from fire departments unfamiliar with maritime operations. Unified Command, he explained, requires a different mindset than other emergency response operations. Trust among agencies and other qualified individuals must be built long before a potential crisis emerges. The conversation, according to Ms. Williams, must be held 'long before a siren sounds.'

Call To Action

During the closing ceremony, all conference attendees were invited to participate in an open forum discussion to review the key takeaways from each session and develop a 'call to action.' The conference organizers provided five questions to guide the conversation, which resulted in discussions that coalesced around three priority action areas. The questions and summaries of the priority areas for potential follow-up are below.

- 1. Pull out your crystal ball and envision the future MTS.**
 - a. What are the demand signals and stressors being placed on our MTS that affect maritime resilience, safety, security, and capacity constraints?
 - b. What are the known and nascent vulnerabilities that will impact the resilience of MTS components and the overall system (natural, nefarious, innovation deployment risks related to automation/AI/new propulsion systems, etc....) emerging and growing over the next five years/ten years?
- 2. Wave your magic wand!**
 - a. What promising new and emerging technologies/methodologies related to safety and security would you deploy as the most beneficial to the MTS over the next five to ten years?
 - b. What gaps in research and development do MTS-related public agencies need to be focused on to maintain a safe and efficient MTS?
 - c. In what areas will regulatory functions related to safety and security need adjustment to mitigate for identified risks and be balanced with innovation, efficiency, and business impact?
- 3. What is the education, training, and workforce development imperatives** for the future maritime workforce related to safety and security, both landside and aboard vessels?
- 4. How can coordination, communication, and collaboration at all levels of governance be improved in the maritime sector?**
 - a. What are gaps related to meta leadership and partnership between the public and private sector during major maritime/supply chain crises that should be further studied?
- 5. The keynote speaker, RADM John Mauger, discussed cyber threats in the maritime context.**
 - a. What are the potential measures, inducements, and practices that can be employed to assist us in managing cybersecurity impacts on MTS operations? How can government and the private sector co-produce system-level cyber resilience?

Three Primary Action Areas

Enhance Data Integration and Interoperability

A recurring theme at this conference was the need to repair fragmented data systems and ensure complete standardization to eradicate information silos and eliminate real-time data-sharing failures. For example, the CMTS 2023 Francis Scott Key Bridge Supply Chain and Infrastructure IAT tabletop exercise identified communication deficiencies and irregular information that could hinder, or even harm, emergency response efforts. When the actual Key Bridge collapsed in 2024, those predictions were proven accurate, with responders reporting that trust building must occur “long before the first siren sounds.”

The Student Honors Presentations further demonstrated the benefit of large-scale integration and interoperability, particularly Duan and Zhou, who compiled multi-source data into a single system. Assuming data compatibility, these kinds of fusion systems can address technical and operational challenges across the MTS. Moving forward, this action area will drive collaboration between the CMTS MIST IAT and the Maritime Data IAT. The Maritime Data IAT seeks to improve data discoverability while optimizing interoperability, mobilizing task teams to identify and address Federal resource overlaps between interagency partners. With the insights gained from this conference, the MIST and Data IATs can develop a strategic roadmap for future collaborations focused on enhancing data integration and interoperability.

Accelerate the Adoption of Cybersecurity Standards

The U.S. Coast Guard released its final rule on cybersecurity in the marine transportation system in January 2025, requiring vessel and facility operators to report cyber incidents. Unlike other maritime challenges, cyber threats compound every other risk. For example, the CrowdStrike incident demonstrated how cyber failures can “crash the internet,” with minimal consequences for the actors involved. In his keynote address, RADM Mauger acknowledged that most of the global shipping fleet has rudimentary cybersecurity protocols. A recurring theme at the conference was whether legislation, like the Oil Pollution Act of 1990, could serve as inspiration for a cybersecurity counterpart. However, those discussions were tempered by the understanding that any cybersecurity protocols must integrate with other emergency response operations and preparatory curriculum.

Modernize Mariner Workforce Training and Certification Requirements

During the Student Honors Presentations, Khalilov revealed that around 75% of maritime educators consider their institutions insufficient for AI-readiness. He also emphasized the emergence of new, hybrid positions that involve digital and “basic” skills, with the disclaimer that current training does not prepare mariners for this dual competency expectation. Without massive curriculum updates, outdated certification and credentialing processes cause low-preparedness, isolation, and undue stress for mariners.

Khalilov and other conference attendees also characterized mariner workforce modernization as a national competitiveness issue. The CMTS supports this characterization and will continue to promote the mariner workforce through its dedicated Mariner and Workforce IAT and congressional outreach, such as with the inaugural “MTS Day on the Hill” that focused on the maritime workforce in May 2025.