Digitizing and Optimizing Marine Infrastructure for the Voyage Ahead

"*The Marine ecosystem, comprised of Ports, Vessels, Shipyards and Ship builders, have started the digitization transformation that will include new opportunities to improve safety, security, productivity, and profitability with intelligent maritime solutions. Computing and supporting technology advancements represent the next step in this journey for the maritime industry.*"

Mahadev Eakambaram
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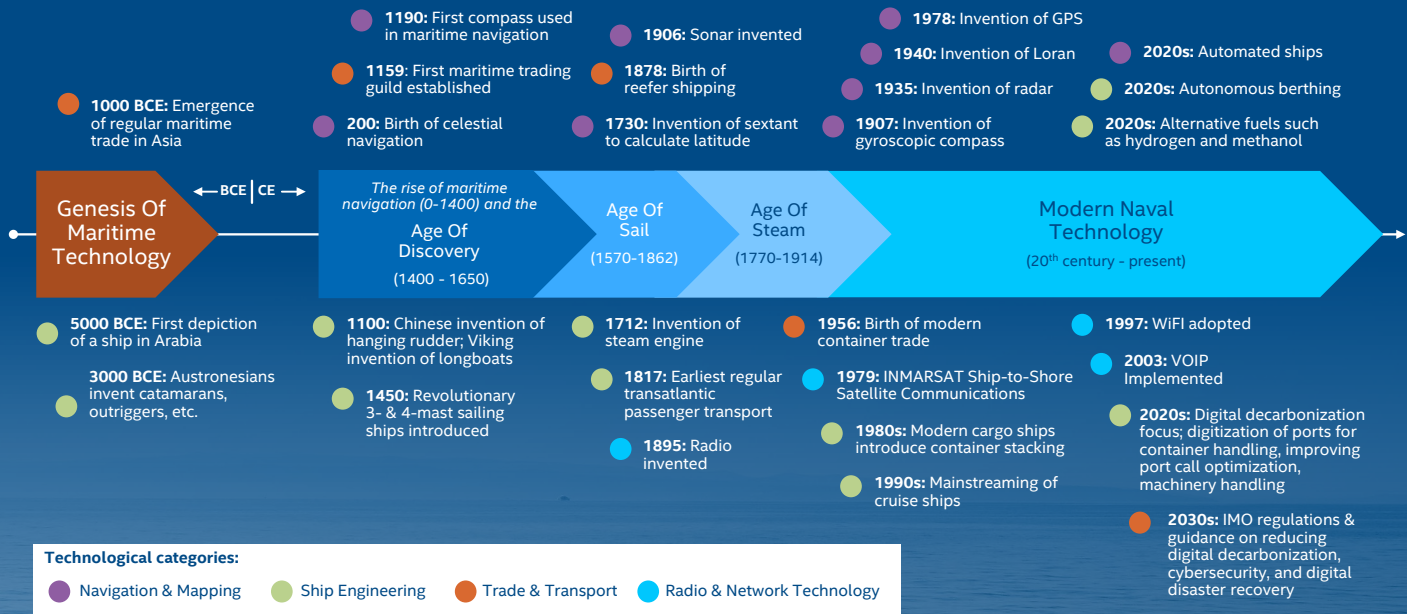MARINE@INTEL.COM

Overview

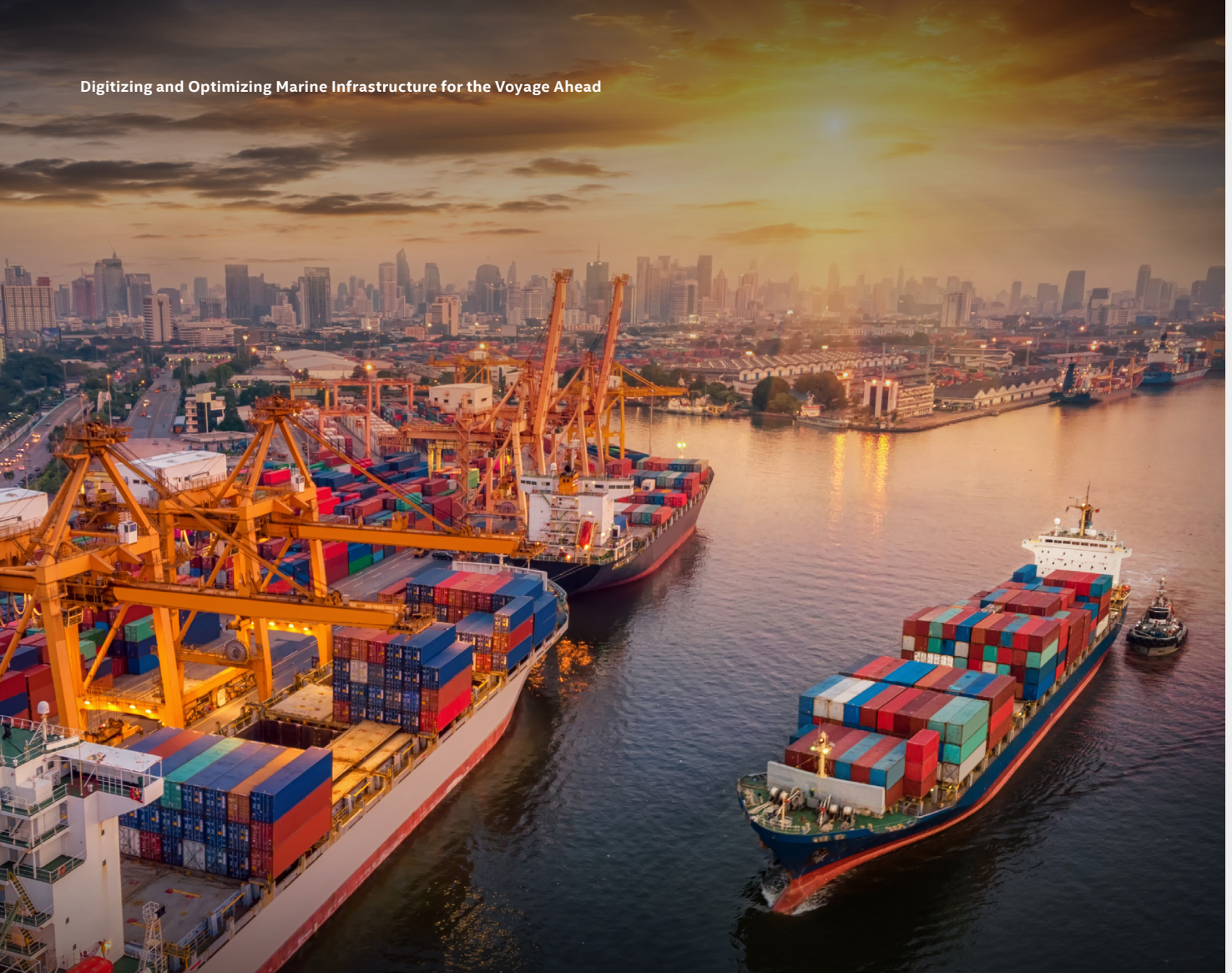## The Maritime Industry: A Story of Constant Evolution

The world's maritime industry, with a scope that spans both marine vessels and the related infrastructure (i.e., ports, equipment, marine roads, etc.), is constantly evolving. Marine infrastructure has served as a hub for innovation since the times when the earliest mariners congregated to trade spices and grains. Today's maritime industry has seen marked advancements on sea as well as on land, fueled by developing technologies and a host of primary drivers.

For years, most of the planet's largest cities started as ports, and seafaring nations were historically enabled with the capacity to develop power, prominence,

and riches, underscoring the importance of maritime involvement. Despite the relatively recent inventions of the automobile (1886) and airplane (1903), around 90% of all globally traded goods are transported over the ocean,[1] while shipping ports continue to handle 70% of all merchandise.[2] Over 32 ports worldwide move more than 15 million TEU (twenty- foot equivalent units) annually. Today's cruise liners have the capacity to carry more than 30 million passengers, with growth over the next five years expected to bring that number closer to 40 million.[3] Clearly, it has become a fact that most of the world's citizens in some important way rely on marine transportation and ports for our global economy to thrive.

History of Maritime: Innovation Through the Ages

1190: First compass used in maritime navigation

1159: First maritime trading guild established

200: Birth of celestial navigation

1000 BCE: Emergence of regular maritime trade in Asia

1906: Sonar invented

1878: Birth of reefer shipping

1730: Invention of sextant to calculate latitude

1978: Invention of GPS

1940: Invention of Loran

1935: Invention of radar

1907: Invention of gyroscopic compass

2020s: Automated ships

2020s: Autonomous berthing

2020s: Alternative fuels such as hydrogen and methanol

Genesis Of Maritime Technology

← BCE | CE →

The rise of maritime navigation (0-1400) and the
Age Of Discovery
(1400 - 650)

Age Of Sail
(1570-1862)

Age Of Steam
(1770-1914)

Modern Naval Technology
(20th century - present)

5000 BCE: First depiction of a ship in Arabia

3000 BCE: Austronesians invent catamarans, outriggers, etc.

1100: Chinese invention of hanging rudder; Viking invention of longboats

1450: Revolutionary 3- & 4-mast sailing ships introduced

1712: Invention of steam engine

1817: Earliest regular transatlantic passenger transport

1895: Radio invented

1956: Birth of modern container trade

1979: INMARSAT Ship-to-Shore Satellite Communications

1980s: Modern cargo ships introduce container stacking

1990s: Mainstreaming of cruise ships

1997: WiFI adopted

2003: VOIP Implemented

2020s: Digital decarbonization focus; digitization of ports for container handling, improving port call optimization, machinery handling

2030s: IMO regulations & guidance on reducing digital decarbonization, cybersecurity, and digital disaster recovery

Technological categories:

● Navigation & Mapping
● Ship Engineering
● Trade & Transport
● Radio & Network Technology

Because of their importance, marine vessels, global transport on the sea, and ports have been at the forefront of technological evolution for generations. The evolving maritime industry of tomorrow will undoubtedly harness the power of intelligent technology to improve safety and security, efficiency and reliability, the quality of the passenger experience, and environmental sustainability.

Nations all around the world have embarked on major initiatives in global infrastructure to support this evolution, with as much as 2% earmarked specifically for digitization. In China, the Belt and Road Initiative (BRI) leverages a nearly $8 trillion investment across nearly 70 countries, in an effort to develop a "network of transportation, energy, and telecommunications infrastructure linking Europe, Africa, and Asia."[4] In North America, the Infrastructure Investment and Jobs Act (IIJA), signed into law on November 15, 2021, "authorizes $1.2 trillion for transportation and infrastructure spending with $550 billion of that figure going toward 'new' investments and programs"[5] that include water infrastructure. In India, the $8 billion SagarMala initiative stands as "the flagship program of the Ministry of Shipping" meant "to promote port-led development in the country," which is expected to "have

a potentially transformative impact on India's logistics competitiveness and the wider economy."[6] Lastly, the European Global Gateway Initiative "aims at establishing smart and sustainable connections in the digital, energy and transport sectors across the world," fueled by $600 billion in investment.[7]

The initiatives enacted in each of these regions around the world will continue to drive innovation on the sea, as well as in ports, furthering strengthening both the industry and connections among the world's nations.

Around the globe, we continue to recover from the pandemic, as new challenges to the health of our global community arise. The geopolitical impact on the world's supply chains remains significant and will likely continue. Here, legislation that intends to positively impact cybersecurity concerns, digital disaster recovery, digital decarbonization, and a host of far-reaching environmental initiatives ushers in signs of hope in a challenging global landscape.

In every instance, transformative new technologies are emerging to address new realities and help the maritime industry succeed going forward.

Challenges

Embracing What's Ahead

There are significant challenges facing the maritime industry today, and they impact both vessels and global transportation, as well as ports and marine infrastructure. To begin, seafaring vessels are expected to manage increased loads and volume for a variety of reasons, ranging from supply chain and logistics issues to regional conflicts impacting the shipping trade. The International Maritime Organization is imposing new emissions regulations; and cargo theft continues to cost businesses more than $30 billion annually in the US alone.[8] And of course, people around the world are still confronting a global health crisis responsible for bottlenecks and major supply chain disruptions.

The good news is that innovations in Artificial Intelligence (AI), Machine Learning (ML), Internet of Things (IoT), 5G network connectivity, AMR/AGV (autonomous mobile robots/autonomous guided vehicles), multimodal sensing, Sensor fusion, and edge-to-cloud computing are giving the maritime industry and ports the ability to help anticipate problems before they occur, and to handle situations in real time. For example, the digitalization of cargo and container handling helps reduce congestion and human error incidents that can lead to injury. Optimizing time management has the added benefit of reducing costs, as well. Digitalization is spurring positive changes in environmental performance, too, helping operators of vessels and ports to discover new ways to use more sustainable fuel and decrease the amount of time vessels spend idling in port, curbing on-site emissions. By making better use of space and resources, optimized marine infrastructure is

reducing the industry's overall carbon footprint without compromising profitability.

As the world becomes increasingly connected and interdependent, demand on global supply chains continues to grow. Conflict and trade wars occur with increasingly regularity, further stressing logistics, shipping, trade, and supply chains that connect nations around the world. Because of these pressures, it's essential that the maritime industry embraces innovation to improve operations and maintain a competitive edge.

While many industries have embraced digitalization, seafaring vessels and ports face unique challenges due to harsh environments, space constraints, evolving certifications and standards landscapes, labor, supply chain interdependencies, and environmental and emissions requirements. Ships, including everything from cruise liners to cargo vessels, all face a host of challenges. These may range from improving reliability to managing cargo efficiently, increasing fuel efficiency, reducing human error in maintenance and navigation, reducing the impact on the environment, managing international conflicts, avoiding disaster and collision, supporting profitability, and more.

To address the many challenges facing today's maritime industry, Intel's ecosystem of cutting-edge technologies and solutions stands at the forefront of these rapidly evolving digital transformations, delivering the promise of future technology today.

Opportunities

Changes on the Horizon

Now more than ever, the shipping and logistics sector of the global economy is extremely vital, as nations become more interconnected, goods travel from one country to another, and supply chains become increasingly more complex. In this environment, incremental changes in operations have the power to dramatically improve conditions, yielding a direct and positive impact on everything from reliability and efficiency of cargo transport, passenger experience aboard cruise vessels, and the overall impact on the environment.

The seascape continues to rapidly evolve: transformative technology is powering the maritime industry forward at breakneck speed. Ports were already data-rich environments, but now port operators are leveraging Information Technology (IT) and Operational Technology (OT) systems to turn data into insights that improve operations. As a result, the ports that have modernized infrastructure and assets have been able to realize operational savings through the implementation of things like container management, automated yard inventory/control, and more.[9]

The maritime industry is still rebounding from the upheaval of the very recent past, with a positive outlook for container volume expected in the coming years. Ports today need to manage capacity tightly and adjust quickly. Businesses involved with the shipping sector can leverage things like Artificial Intelligence solutions to optimize operations, providing streamlined decision making, enabling automation of routine tasks, improving safety and security, and elevating the way in which preventive maintenance functions. The explosion of data analytics represents another critical path forward for the maritime industry, enabling increased ability to forecast and predict future events, which can be dealt with before disasters occur to minimize supply chain disruptions.

Ongoing urbanization, as citizens continue to flock to larger cities to build better lives, will create more opportunities for the global maritime industry.[10] Here, the urban demand for goods will drive continued growth, as over 68% of the world's population is expected to live in urban areas by 2050.[11] Ships and ports combined will be expected to manage increasing parcels and TEUs (twenty-foot equivalent units) in container volume, driving the cargo and shipping industry forward. According to Harbor Research, the digital maritime industry opportunity may exceed $36B by 2026, with as much as 90% of the market represented by ports and vessels.[12]

As vessels proliferate on the seas and the world's ports adopt new technologies, the risk of information or systems being corrupted, lost, or compromised will increase from shipping-related operational, safety, or security failures. Similarly, concerning emissions and the environment, considerable opportunity exists to leverage the power of technology in service of creating a more sustainable maritime industry. For example, in recent years, the International Maritime Organization (IMO) imposed new low-sulfur fuel regulations mandating that shipowners clean dirty ballast water using new equipment by 2024.[13] This represents an ideal use case for the application of digital technology solutions.

In terms of seafaring vessels, automated navigation promises to become instrumental to ushering in a new era of safe and efficient travel and berthing. In fact, the automated ships market size is projected to reach $134.9B by 2030, driven by cost efficiencies and improved customer service.[14] With all this infrastructure opportunity, physical security and monitoring also promises to create unique opportunity for vast improvements in operations, increasing security and reliability throughout the maritime industry. In the U.S. alone, cargo theft costs $30 billion or more a year, while over 10,000 ship containers disappear at sea.[15]

In many ways, technology advancements enable port and ship operators to address key challenges around regulation, safety, security, shipping activity, sustainability, and operational efficiencies in multiple aspects of maritime activity—including cargo handling, logistics, berthing of ships, and predictive maintenance. The next section outlines several key use cases to bring this picture into more depth.
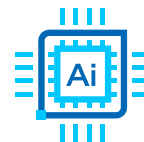
Core Technologies

IoT   5G   Edge to Cloud   AI   Sensing

Use Cases

1) Enhance Safety and Security

In the maritime industry, security and safety are essential aspects of supply chain management, passenger and cargo transport, and operations. Vessel navigation may be prone to human error, susceptible to pirate attacks, and under cyber security threat on several levels. Ports remain important distribution and transportation centers, crucial to the livelihood of local cities and residents. Protecting valuable workers, assets, cargo, and data is no easy task. Reducing supply chain risks requires agile, flexible risk management strategies. In both vessels and ports, the deployment of highly available, expandable safety and security solutions is necessary to avoid costly accidents, breaches, and disruptions.

The overwhelming majority of maritime and port accidents (an estimated 75-95%) involve some element of human error.[16] While our fellow homo sapiens might never be perfect, better use of data and analytics can reduce—and in many cases prevent—human errors by providing timely insights. For example, an AI algorithm could alert a dock worker that a crane's load is too heavy given the current wind conditions. By applying AI to data at the edge, key decision-makers can gain real-time insights through predictive analysis and alert employees to dangerous situations and equipment failures before they occur. This enhanced visibility also allows port and ship operators to better comply with standard operating procedures and industry regulations. Everybody wins.

From a centralized, integrated control center—a single pane of glass—ports can analyze data from IoT devices and plan equipment maintenance, identify opportunities to improve cargo handling, measure process time for docking and unloading, and gain a holistic view of operations. The ability to monitor operations and behavior helps evaluate performance as well as prevent unauthorized personnel from entering sensitive areas.
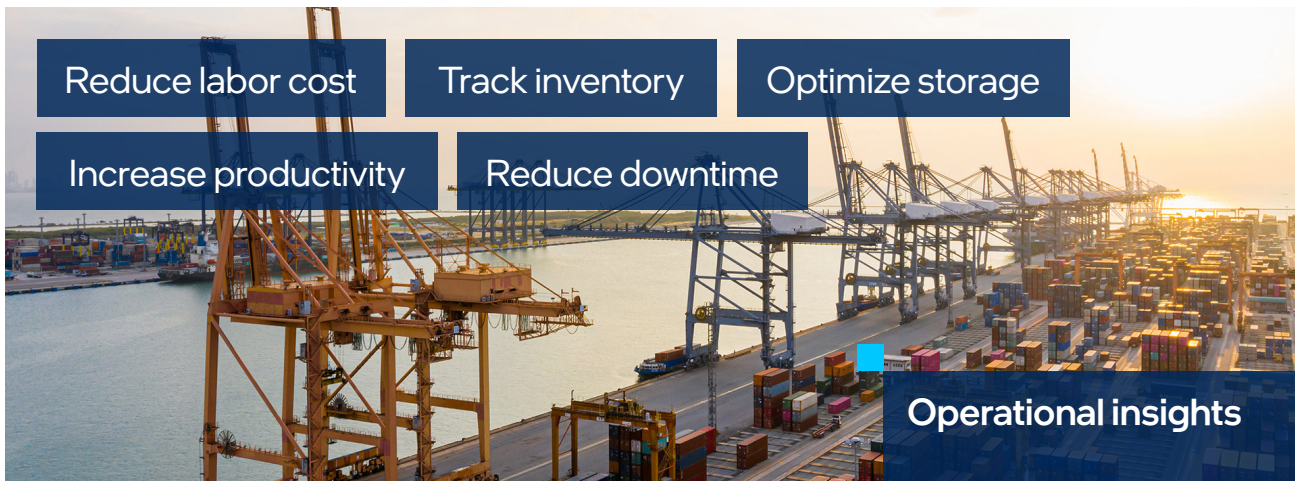
Passenger monitoring aboard seafaring vessels can control for health and safety issues, provide additional early warning from things like pirate attacks, and offer increased levels of security for both humans and cargo. Navigation safety, as well as cargo monitoring and management, made more efficient through digital technology, can vastly improve conditions on the sea. Digital sensors enable hazardous gas detection and alert systems (for things like CO, CO2, HS2, etc.), improving safety. Similarly, collision prevention aboard cruise lines and shipping vessels can be improved through automated ship control, integrated monitoring systems, insight from advanced analytics, and dynamic positioning systems that enhance a ship's maneuverability and control.

With near real-time visual sensing technology, ports can track assets, avoid congestion in cargo flow, and utilize warehouse space more effectively. Computer vision takes video captured by optical sensors (motion, thermal, and object detection) and then uses AI to analyze the image data. Video analytics solutions help prevent theft while enhancing the safety of workers and security of cargo alike.

Sensors & Edge Compute   Wireless Tech   Access Network   Core Network   Cloud & Analytics
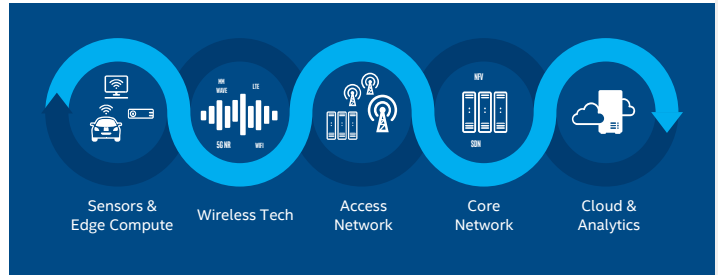
AI-enabled monitoring and video analytics provide added safety for:

- **Personnel**
  Detection of abandoned packages, boxes, or other suspicious items through managed access control, facial/biometric recognition, vehicle ID recognition, and more. Instant alerts are triggered for fights, slips, falls, and other disturbances. Computer vision-based access control can help to accurately identify persons, vehicle license plates, container IDs, and more.
- **Perimeter**
  Vehicle license plate and facial recognition enhance perimeter security and monitor suspicious activity.
- **Cargo**
  AI can report changes in temperature as well as smoke and fire in open-air environments. Wired, 5G connected cameras and sensors can enable everything from predictive maintenance that prevents disasters before they happen, to increased security and loss prevention on the seas.
- **Assets**
  Tracking and anti-theft devices help keep valuables secured and in their proper location.
- **Vessels**
  Automated ship control and dynamic positioning, using insight from advanced analytics, can improve operator control and minimize the risk of accidents on the sea and in ports and preventing collisions. Sensor Aggregation, Sensor Fusion, and Actuators can further be activated to improve safety and security.

Reduce labor cost   Track inventory   Optimize storage

Increase productivity   Reduce downtime

Operational insights

Creating Cybersecurity Resiliency

Cybersecurity technology is mission-critical in today's shipping industry. Recently, a ransomware attack on a major maritime organization impacted ports all over the globe, causing some of them to shut down completely. Reports of cybercrime are up 300% since the beginning of the pandemic.[17] Threat actors are increasingly organized and sophisticated in their capabilities, and the potential attack surface for organizations is growing daily. Trusted endpoints no longer reside safely within an organization's secured walls. Businesses today need integrated security solutions to safeguard digital assets and sensitive data—and avoid costly downtime. By identifying incidents and compromised systems early, seafaring vessels and ports are better able to respond to threats quickly and take the appropriate action to mitigate them.

2) Ensuring Reliability, Increasing Efficiency and Profitability

There are several key measures of success in the maritime industry, especially concerning the transport of goods on the seas. To deliver cargo safely, on-time, and in good condition represents just one of many metrics by which success can be defined. But distinct types of cargo require different solutions: livestock and perishable food items can't be treated the same as chemicals, for instance. Ensuring that employees on board vessels or at work in the ports around the globe are safe is obviously a top priority.

Transformative technology is making it easier for operators to achieve their goal of ensuring human and cargo safety, whether it's passengers aboard a cruise line, or operators on a crane working with cargo in the port. Advances in AI, computer vision, and blockchain technologies allow operators to integrate sensor and video data pulled from cargo monitoring devices. Equipment automation (see sections below) drastically improves cargo throughput, custom processing, and end-

to-end supply chain efficiency. Automation and machine analytics drive down costs associated with maintenance and safety incidents.

Intelligent Machine Orchestration can be enabled to dramatically improve operations and safety in both marine vessels and in ports. This includes the domains of machinery (AGVs and forklifts), technology management systems (digital twins and single-pane-of-glass dashboards), road and water-based logistics (traffic monitoring, equipment monitoring, and ship berthing), and operations planning (logistics and supply chain management.

Digitized forklifts, straddle carriers, sprinters, and terminal trucks can be used to improve container movement within ports, while LiDAR/video cameras and a host of sensors can be enabled to gather and share data across several points of operation, vastly improving operations and efficiencies. Similarly, computer vision can be used to avoid accidents and collisions in ports. Machine Learning, built on advanced analytics, can create a pathway to safe, more efficient cargo handling and tracking all throughout the supply chain.

Passenger Experience

On board cruise or passenger ships, digital technology enables optimized operations that can increase profitability and overall passenger satisfaction. Improved luggage scanning and tracking can promote improved experiences, while passenger infotainment and connectivity (5G/LTE, W-Fi, Fluidmesh) on-board creates a seamless transition from life on land in connected cities, to an experience on the sea. Capabilities like passenger monitoring and protection can mitigate the risk of pirate attacks of on-board accidents, while automatic fare collection and people counting can be leveraged to perform many of the same functions already enabled in critical infrastructure such as train stations, bus terminals, and public gathering areas.

Vessel Operations

On board vessels, digital technology can be used to improve navigation safety, to streamline route planning using multi-modal scene intelligence, and to automate berthing via remote-controlled abilities (using multi-modal scene intelligence, MaSSA, Navigation and positioning). Operators can more effectively prevent disasters, easily avoiding double stacking while enabling workplace collaboration using sensors (Panel PCs). With digital technology, cargo monitoring and management can prevent container loss (when cargo drops into the ocean), as well as theft by pirate attacks.

Radar-assisted berthing is an essential use case that aids the safety of piers and ships. Berthing is typically a human and cost intensive process. Radar-assisted berthing ensures that port control has better insight regarding the ship's movement toward the berthing process and can guide the ship better in terms of speed and angle of approach. This is enabled by means of an array of radar on the piers, connected to Mobile Edge Compute solutions, which communicate via 5G to the port controls, where a Digital Twin model of the approaching ship is seen. This enables the control center to guide the ship better and with less stress to the crew on the ship and land, thereby reducing accidents.

Automated navigation provides operators with improved situational awareness and greater control, allowing for more rapid detection of and response to obstacles that may compromise safety. Speed can be optimized while in transit on the sea, reducing onboard energy consumption, improving arrival time accuracy, and saving fuel that in turn reduces emissions. With less downtime and improved accuracy through a reduction in human error, ships can reach a higher level of predictable operation.

USE CASE
Digital Twin for Radar-Assisted Berthing
- Real-time assistance using Berthing Radar Systems (BRS)
- Integrated edge computing for hosting the service
- 5G private network infrastructure

Predictive maintenance can be performed at a higher level, reducing the risk of human error while discovering and remedying issues before they become more costly. This includes vehicle inspection by drones (in air and underwater), structural damage detection for both vessels and port infrastructure, corrosion detection, faulty electrical wires detection, and equipment wear and tear. Automated berthing support can be leveraged to improve cost efficiencies and time use, while further helping to minimize risk of cargo loss/damage, and the occurrence of incidents that harm personnel.

**Port-Call Efficiency
(Port Supply Chain Efficiency)**

By streamlining supply chain management, ports and shipping companies can identify the most cost-effective transportation options and decrease delays in transport and delivery of cargo. More timely delivery of cargo helps avoid stock-outs and lost sales at the retail level, too. Supervisors can also be alerted to environmental changes (moisture, temperature) which could potentially endanger workers, cargo, and equipment.

Intelligent Equipment Orchestration

Ports are rapidly moving toward complete integration of operational systems and landside distribution logistics. Automated cranes are especially useful in such a demanding and hazardous environment. Intelligent cranes can reduce labor costs, track inventory, optimize storage, and increase productivity. They can also reduce downtime, injuries, and damage to valuable assets. Video analytics capture every crane transaction for total visibility. Container tracking significantly reduces injuries caused by heavy equipment. Digital archiving of container conditions protects against questionable legal claims. By automating yard inventory, operators have more time to focus on keeping everything else running smoothly.

AGV and Forklifts

Automated Guided Vehicles (AGV), cranes, forklifts, straddle carriers, sprinters, and terminal trucks are increasing efficiency, enhancing safety, and speeding up deployment. AGVs use machine learning to choose the ideal route for optimal workflow and shorter delivery times. They navigate safely around people and objects with LiDAR (light detection and ranging) and avoid accidents with sensors and a built-in collision-avoidance system (computer vision). Automated forklifts have been increasingly in-demand during the pandemic as essential manufacturers have looked for ways to increase productivity and throughput.

Digital Twins and Dashboards

A digital twin is a virtual version of a physical object. Port authorities use digital twin dashboards to monitor the data being transmitted constantly from the network of sensors attached to key components of port machines and assets. Digital twins are also used for diagnostics and predictive analytics to optimize seafaring vessels, as well as the port's performance, and to address maintenance issues before they turn into liabilities.

Digital twins are more powerful than mere simulations because they leverage real-time data streams to bridge the gap between machine and dashboard. The more data it harnesses, the smarter the twin becomes—and the more insights operators have to improve productivity and efficiency, leveraging the power of a user-centric platform that exists on a single pane of glass.

Digital twins are also used to improve efficiency in cargo handling. Data from smart sensors on cranes, forklifts and containers helps operators gain a holistic view of operations, optimize storage, and quickly locate cargo. In the control room, operators can inspect the area using Virtual Reality (VR) solutions while the workers on the dock can access and apply those insights with Augmented Reality (AR) headsets that provide instructions in real time based on the most current and accurate data. The result? More efficient operations and fewer costly errors or incidents. AR is proving to be a valuable training platform as well, with powerful collaborative tools and the ability to safely simulate dangerous situations.

Object/Obstacle Detection

Computer vision accurately identifies traffic, objects, and potholes to avoid costly delays, repairs, and downtime. Operators use analytics dashboards to monitor the condition of road surfaces for the entire yard in real time. Thermal imaging determines where potholes might appear next based on surface temperature difference. The IoT network of data sensors communicate with each other while LiDAR or radar geo location data helps measure distances. If a pothole is detected, it's automatically logged into a database that cross- references recent road survey reports to determine whether the damage is new. Machines will automatically adjust their operations based on other variables too—like container spacing or in-lane driving. Perimeter security can be optimized through technology, enabling sensors and video capture to inform AI-enabled analytics, alerting personnel to real-time threats in all areas of the port.

3) Improving Environmental Efforts, Increasing Sustainability

The focus on sustainability that has impacted so many industries in today's global landscape has similarly affected the maritime industry. From creating more environmentally responsible vessels to investing in smarter infrastructure in the world's ports, efforts toward sustainability continue to drive technological advancements.

Because container ships and commercial seafaring vessels are typically created to last a long time, many ships function by virtue of outdated engines and equipment. Increasing the quality of fuel, proactively managing engine emissions, adopting energy-saving measures, improving loss prevention and loss of cargo on the sea, and more— these all represent meaningful ways in which technology is supporting initiatives to be more environmentally proactive within the maritime industry.

Technology aboard vessels can be used to rapidly detect oil leaks and chemical spills, mitigating the impact of these kinds of disasters on the environment, often before they occur. Sensors, video technology, and AI-enabled analytics can support operators to detect and remediate emissions (nitric oxide, CO_2, SO_2, N_2O, ethylene, etc.), pollutions from heavy metal contaminants, and container content-related hazards involving chemical and biological matter that could negatively impact the environment. Further advancements in automated ship navigation, logistics, and berthing have enabled the capacity to optimize route planning for greater sustainability on the sea and in ports, where crucial time can be saved, and disasters avoided.

Berthing

Critical infrastructure

Traffic flow

Stowage

Construction

End-to-end visibility

Parking

Technology Summary

Understanding the Core Technologies

IOT

The Internet of Things (IoT) is a network of integrated, internet-enabled sensors, machines, and devices that generate rich data which can be analyzed and used to increase productivity, help bolster security, improve efficiency, and reduce cost. For example, IoT can connect a variety of sensors, including vision, thermal, radar, LiDAR, chemical, environmental, or biological sensors. Through 5G or Wi-Fi connectivity, sensor and device data can be fused to create a complete picture of operations and enable decision making in real time. This ecosystem of intelligent assets is empowering business leaders everywhere to share information over the cloud and gain visibility into key performance metrics.

4G and 5G Connectivity

5G enables the next era of businesses driven by AI to tap into massive amounts of connected data. 5G and edge computing bring powerful data center-grade processing closer to endpoint devices, accelerating service delivery and improving the overall quality of experiences. 5G and IoT provide the ability to capture, store, and analyze device data at scale, resulting in more informed business decisions across the board.

Edge Cloud Compute / Mobile Edge Compute

The edge cloud brings the convenience and accessibility of the cloud closer to where data is being created and implemented. By collecting, storing, and processing data at the edge, businesses gain meaningful insights fast— and can act right away. An edge cloud is hosted on an edge server, bringing analytics and AI closer, helping to enable near real-time responses and experiences.

Intel® Smart Edge is a portfolio of software offerings that delivers performant and optimized solutions for service innovation—on-premises and at the network edge. This portfolio helps you quickly and efficiently deploy edge-centric networks, compute capabilities, and workload convergence across a range of vertical industries.[18]

AI

Artificial Intelligence refers to the science of machine perception, logic, and learning. Machine learning allows programs to perform better over time with more data input. Deep learning uses algorithms based on neural networks to find optimal solutions to existing problems. Inference is how programs use all that data to make better decisions.

Sensing

Through advancements in AI, telemetry, photonics, mapping and more, machines are adopting humancentric abilities for smarter, more useful data. Machines are now able replicate all the human senses—to see objects that even a sensitive human cannot see, hear things, know exactly where they are, and are increasingly able to feel and taste. AR serves to digitally enhance all a participant's senses.

> The automated port of the not-too-distant future will be run by operators with **end-to-end visibility** of operations

Harnessing the Power of IoT

The automated port of the not-too-distant future will be run by operators with end-to-end visibility of operations. Shipping containers will be equipped with tracking devices and destination awareness. Berthing schedules will be dynamic and port traffic will be more easily managed and scheduled. Automated cranes and vehicles will seamlessly handle loading/unloading, ship-to-shore transport, distribution, ship repair, cleaning, inspection, and maintenance. Cargo damage will be reduced through anti-sway transport.

AR and VR technology will allow for more effective, affordable simulation training for employees. Both operators and on-ground port staff will engage in scenario-based training remotely to assure preparedness for unforeseen circumstances and changes in port control procedures. This will minimize port incidents to streamline regulator inspection, lower insurance premiums, and reduce reputational risk for clients.

The port of the future will incorporate a fleet of unmanned aerial vehicles (UAVs) and remotely piloted aircraft (RPAs) for security patrolling, port infrastructure inspection, container transport, inventory measurement, incident detection, environmental monitoring and control, contamination detection, and mapping and surveying. Remote-controlled boats and underwater drones will monitor environmental issues, inspect vessels, and help bolster security.

Many of these changes are already underway, as the physical and digital worlds continue to converge. Interoperability plays a crucial role in creating significant economic impact.

Automated yard

Automated cranes

Cargo tracking

Traffic management

Vehicles

Predictive Scheduling and Traffic Management

The continuous development of the global economy and of urbanization has driven the rapid growth of traffic flow. This increases congestion to and from ports, which puts huge pressure on the existing transportation infrastructure connected to them. It has become an important task for transportation authorities in major countries around the world to promote the construction of the Intelligent Transportation System (ITS) through the digitalization of the transportation infrastructure.

Traffic monitoring enables the capture of traffic statistical data for port entry, tunnels, bridges, monitoring, and control systems to third-party ITS systems. Using aerial and marine-based drones that are connected via 5G v2x, information regarding port and vessel damage as well as security can be related in near real-time, improving operational efficiency and enabling faster response times when there is danger. Predictive analytics in ports also helps to reduce overtime expenses by scheduling personnel with the appropriate skill sets and expertise for specific assignments.

Partner Spotlights

Dell Technologies OEM Solutions

Designed for any environment

Dell Technologies OEM Solutions has extensive experience helping solution builders design and build solutions on edge-native infrastructure engineered to perform in environments where standard equipment has high failure rate—such as extreme temperatures, harsh conditions, and remote locations.

Their Marine Type Approved IT solutions are built to the highest standards of safety, quality, and efficiency and are specially engineered for use in the marine and offshore industries. These solutions are designed to comply with classification standards for temperature, humidity, vibration, electro-magnetic compatibility, and enclosure location classes.

Besides the standard portfolio of Storage, Servers, Workstation and Networking solutions, Dell Technologies offers a range of compute optimized for the Edge. Purpose-built for unpredictable and often challenging deployment environments. These solutions are pre-tested and pre-validated to recognized industry standards such as marine (DNV-GL certification) or military (the range has passed Military Standard rugged tests).

By collaborating with Dell Technologies OEM Solutions, customers will have access to the latest technology and capabilities. OEM Solutions has been helping customers design solutions for OT and edge environments for over 20 years across 40+ verticals and has been recognized as the #1 OEM Solutions provider worldwide since 2016*. Dell Technologies OEM Solutions also provides dedicated engineering, program management, customization and configuration, and marine services and support.

Global Share, VDC Research, Worldwide OEM Solutions Provider.

Cisco

Cisco, founded in 1984, delivers critical infrastructure solutions that provide reliable, automated, and secure networking for mission-critical data across a business's access, edge, core, data center, and Internet connections. Cisco solutions drive the new digitization journey by helping build and operate a smart port, delivering a robust IoT platforms and edge intelligence to help their operations to achieve profitable business outcomes and improve operational efficiency. Cisco Systems® solution for seaports combines a secure, unified, open standards-based communications infrastructure with wired and wireless, end-to-end IP networking technologies that maximize flexibility and productivity.

Cisco's networking products and solutions represent the necessary foundation for ports and terminal infrastructure, enabling port authorities to use the same network resources to transmit data, voice, and video for operations and security.

Key capabilities

- Network infrastructure
- Optimized cargo throughput
- Video monitoring capabilities
- Access control
- Managed IoT security
- Intelligent routers

Benefits

- Secured, scalable, and reliable critical infrastructure
- Simplified device onboarding and centralized control policy
- High bandwidth, low latency, seamless handoff
- Enhanced asset visibility
- Support for edge intelligence to act on data faster, and closer to its source

Advantech

Advantech is a global leader in IoT intelligent systems and embedded platforms, providing hardware and software solutions to industrial clients worldwide. Advantech collaborates with ecosystem partners to incorporate IoT sensor nodes, edge computing, software, cloud services and more for a wide variety of IoT applications. As a leading provider of IoT solutions, Advantech has leveraged its extensive experience in industrial automation, intelligent logistics, and smart city solutions, to form a holistic smart port solution. This facilitates the development of smarter applications and new innovation for smart ports.

Ports and terminals are facing ongoing pressure to reduce operational costs, implement appropriate security measures, and mitigate the effects of climate change. Advantech works closely with domain partners to help operators develop comprehensive smart port strategies to improve operations with new technologies. Implementation of smart crane systems are helping port operators enhance safety, security, and efficiency. The Advantech smart crane system features a vehicle-mounted terminal with a rugged design built to withstand extreme weather conditions, resulting in more uptime and a longer lifespan. The terminal optimizes data communication between cranes, trucks and management systems through wireless networks. The terminal collects operational data, including plate number, driver's license and container number, and sends it to the management system for task monitoring and further data analyzing. Operators can track the status of each crane in real time and optimize loading schedules. In addition, crane drivers can be notified of changes in cargo information from the ship to avoid loading the containers with the wrong sequence.

Key capabilities

- Real-time communication and data transmission between edge devices and cloud-based management system
- Automated cargo handling, asset tracking, and task management
- Intelligent gate and truck management
- Wi-Fi communication for open area and moving assets to connect to network infra

Benefits

- Built-in cellular, GPS, Wifi, and Bluetooth to provide superior wireless connectivity for real-time data transmissions
- Rugged system design and high computing performance for uninterrupted operations in harsh and outdoor environment of port
- A wide range of product offering to fulfill every task at port

Cellnex

The efficient deployment of next-generation connectivity is essential to drive technological innovation and accelerate inclusive economic growth. Cellnex is the **independent wireless telecommunications and broadcasting infrastructures operator** that enables operators to access Europe's most extensive network of **advanced telecommunications infrastructures on a shared-use basis**, helping to reduce access barriers for new operators and to improve services in the most remote areas.

Cellnex manages a portfolio of more than 138,000 sites—including forecast roll-outs up to 2030—in Spain, Italy, the Netherlands, France, Switzerland, the United Kingdom, Ireland, Portugal, Austria, Denmark, Sweden, and Poland. Cellnex's business is structured in four major areas: **telecommunications infrastructure services, audiovisual broadcasting networks, mission critical & private networks,** and **solutions for smart urban infrastructure and services management** (Smart cities and the "Internet of Things" (IoT)).

Cellnex deploys a complete **connectivity solution meeting all port requirements** to enhance management for the benefit of the authorities, workers and clients.

Cellnex's Private Network delivers capacity and coverage across business-critical areas of operation and provides real-time feedback to improve operational decision-making and problem-solving as well as enabling high-end IoT solutions.

Key capabilities

- Enhance port management and logistic efficiency for arrival/handling/dispatch
- Location tracking of individual items with the highest accuracy
- Upgrade road traffic management for asset tracking and carbon footprint reduction
- Enable 5G automated smart systems
- Enhance security by using drones to monitor restricted ocean areas
- Manage port digital twin to ease berthing operations

Benefits

- Less traffic congestion
- Gain awareness of cargo flow beyond the gate
- Increased productivity in planning and operations
- Less manual entry and human error
- Keep valuable assets safe
- Improve security within the port premises

Fivecomm[19]

Fivecomm is a Spanish SME focused on the use and implementation of 5G mobile technologies for industrial applications. Founded in 2019, Fivecomm addresses industry real-world needs enabling B2B market opportunities through 5G connectivity. The activities of Fivecomm cover design, development, integration and validation of systems, solutions, and products on 5G public and private networks. As a 5G IoT company Fivecomm offers hardware and software E2E solutions in the following verticals:

Energy and Utilities
The company offers a real-time remote critical infrastructure inspection E2E solution, providing hardware and software, for improving the security, the efficiency in fault detection and the operations reducing the maintenance costs.

Smart Cities and Smart Mobility
Fivecomm, hybridizing 5G, radar and AI technologies, provides a disruptive real-time mobility control and management solutions for urban and suburban areas

enhancing traffic congestion, road safety and air quality by reducing C02 footprint and improving public and private transport. These solutions enable data-driven cities for taking the best urban planning decisions.

Smart Ports
Fivecomm, using the 5G smart radar E2E solution, increases security, operational efficiency and productivity in a port logistics area.

Key capabilities

- Vessels berthing assistance through real-time velocity, distance and orientation
- Docked vessels real-time monitoring
- Enhance crane operators safety
- Terrestrial vehicles traffic management and control using free flow technology
- Maritime and terrestrial parking tracking
- 5G Private Networks planning (3D Dynamic platform) and optimization (DriveLess Test)

Awake.AI

The Awake.AI multimodal security platform enables real-time collaboration and optimization for ports and maritime operators. Awake.AI deeply analyzes network communications to discover insights that make port operations safer, more secure, and more sustainable.

Awake.AI's Smart Port as a Service™ addresses maritime logistics operation supply chain challenges, such as operational delays due to resource and capacity management inefficiencies and traffic congestion. The platform enables open information-sharing among collaborating partners and provides accurate predictions to save users time and cost. Its virtual infrastructure brings distributed and siloed port logistics operations together in a neutral AI-open platform. With its pay-per-use pricing flexibility, Smart Port as a Service™ offers significant value in the current environment by eliminating the need for high upfront investments. Awake.AI's machine learning-based solution for ports accelerates logistics planning and offers accurate estimations of vessel arrival and departure times.

"Awake.AI's collaborative AI platform expedites the transition to connected operations, aiding smarter operational decision-making," said Suriya Anjumohan, Senior Industry Analyst. "With a reliable data flow, Awake.AI reinvents port logistics operations management by offering a virtual infrastructure and connected process governance for maritime logistics industry participants. Its scalable digital solutions, strong port ecosystem partner network, and commitment to amplifying digitized port operations established it as a trusted, smart port ecosystem orchestrator."

Key capabilities

- Enable transparent and real-time status sharing of ports and vessels
- Connect port actors through a multimodal communication channel
- Predict, monitor, and optimize storage usage
- Asset tracking

Benefits

- Enhance harbor pilot and control center decisions based on real-time data
- Increase port logistics area staff and visitor security
- Improve operations efficiency, control and productivity
- Reduce operations and transport CO_2 footprint
- Optimize the use of parking areas

Etteplan/congatec

Etteplan is a technology service company specializing in software and embedded, engineering, and technical documentation solutions for businesses in the engineering and manufacturing industries. congatec is a rapidly growing technology company focusing on embedded computing products used in a wide range of applications and devices in industrial automation, telecommunications, and other markets.

Etteplan's Evaluation Platform leverages congatec Computer-on-Modules (COMs) and Intel Atom® Processors for connectivity, positioning, and integrated edge computing in the marine and ports space. The platform improves the ability of fleet managers to control data while improving operations and logistics.

Etteplan and congatec's tools deliver long-life expectancy and power efficiency, while helping operators to pinpoint vehicle locations, ensure operator safety, provide navigation, gain analytical insights, and more—thereby increasing fleet safety and efficiency as a result.

Tech Mahindra

Part of the Mahindra Group based in India, Tech Mahindra is a multinational information technology services and consulting company serving a wide range of industry verticals and delivering innovative, customer-centric digital experiences to facilitate growth.

For the maritime industry, Tech Mahindra offers ports, shipping, and ferry operators smart solutions through a suite of RFID, IoT, AI, Blockchain, and 5G-enabled digital enterprise offerings that enable operators to achieve maximum equipment and resource utilization, optimized management of container flow, and greater visibility into terminal operation and financial metrics.

The company's AI-based solutions for maritime offer capabilities like UAV-Based Surveillance for the automatic detection and analysis of ocean debris; anomalies such as fire, smoke, intrusion into restricted areas, driver safety compliance, and more via fixed on-board cameras; oil spill detection through IoT and IR cameras; and leakage and hazard detection via drone data analysis.

NEXCOM[20]

Since NEXCOM's inception in 1946, our mission has been to provide our customers quality goods and services at a savings and to support Navy quality of life programs. NEXCOM's seven primary business lines include the Navy Exchange (NEX), Navy Lodge Program, Navy Gateway Inns & Suites, Ships Store Program, Uniform Program Management Navy Clothing and Textile Research Facility and the Telecommunications Program Office. Each of our business lines provide the necessary support for our Navy's warfighters and military families to remain ready and resilient.

As a Navy command, NEXCOM contributes to mission readiness by providing quality of life services to our patrons no matter where they are stationed around the world. Throughout every stage in your career, know that we are here to support you and your loved ones every step of the way - whether it's providing PREMIER customer service at NEX retail stores, PREMIER guest service at our Navy Lodge and NGIS locations, quality Navy uniforms, snacks aboard ship or telecommunications services on Navy installations worldwide. We are committed to being an essential resource for our nation's most deserving patriots for years to come!

NEXCOM solutions for maritime port and warehouse management bring the intelligent edge to the supply chain.[21]

NEXCOM provides robust and reliable marine computers for customers and partners, including high performance fanless computers, assorted sizes of applied panel PCs and displays. The certified marine computers are ideal for severe environments, and can be applied to fishing and container vessels, recreational boats, workboats, sailing yachts, etc. All marine solutions are built and tested according to critical industrial standards to ensure compliance.

Getac[22]

Ports are busy places where it can be difficult to keep track of all the activity. Getac devices provide a tool to execute comprehensive strategies for container yard management, terminal capacity optimization, and improved visibility of performance and maintenance needs. They can also be deployed on harbor pilot boats to help guide larger vessels to their assigned berths, facilitating smooth logistics and timely loading/unloading of cargo.[23]

By adopting a digital solution that can send data wirelessly, ports achieve increased efficiency in tasks such as cargo inspection or container handling. Errors are minimized, costs can be reduced, and response times improved because data becomes information available to management in real-time. Getac solutions are inherently rugged, certified by international third parties to MIL-STD 810H, and up to IP67 standards. They thrive in all weather conditions and withstand impacts, vibrations, harsh temperatures, humidity, dust, and drops up to six feet.

Rugged Computing for Smart Ports

Finding a rugged computing solution that can perform at a high level and withstand the harsh environmental conditions of a port, including corrosion and weather, can be challenging. Getac solutions bring you the ruggedness and power you need to increase port productivity.

Salt Fog Resistance

Maritime environments and the exposure to salt they involve are a great challenge to computing devices. Getac offers a unique anti-corrosion technology. Getac tests its salt fog resistant products in a rigorous salt fog chamber test, using a 2-cycle 24 hour exposure and drying testing process. The sealed port design prevents salt fog from damaging the system, while our microstructure drainage design protects against corrosive salt fog accumulation on internal components. This helps prevent computer failure, work disruption, and additional costs.

Processing Power for Maritime Automation

Running multiple applications, such as maritime navigation and yard management are needed to run a smart port, requires reliable connectivity and significant processing power to work smoothly. Getac's solution offers devices with powerful Intel® Core™ i7 and i5 vPro™ CPUs, with the processing power needed for your applications.

With Wi-Fi and 4g LTE WWAN

Connectivity is vital for any port management solution. With dedicated GPS, 4G LTE WWAN and IEEE 802.11ax Wi-Fi, our solutions help professionals in tasks such as container handling or truck identification by sending and receiving data directly from the port's system. This includes location data, which helps organize cargo pickups.

Solution Components

Powering Intelligent Maritime

Intel's portfolio of cutting-edge technologies and solutions are at the forefront of intelligent maritime. With decades of experience delivering state of the art technology, Intel powers every area of intelligent ports, connected ships, supply chain, and services—from the edge to the network, to the cloud, to insights. Intel and its vast set of ecosystem partners are working together to create a more dynamic, extensible, and sustainable way for maritime leaders to innovate.

Taking AI to the Network Edge

As maritime organizations connect more devices to the internet and the need for near real-time intelligence grows, more AI inference will move to the edge of the network to avoid the need for data transfer to the cloud. One of the most important ways to move AI to the edge is with federated learning. This process enables edge devices to collaboratively learn a shared prediction model while keeping all the training data on the device, decoupling the ability to enhance models from the need to store data in the cloud. This also enables devices to be used for model training. The device downloads the latest model, improves it by learning from data on the device, and then summarizes the changes as a small, focused update. Only this update is sent to the cloud, using encrypted communication, where it is immediately averaged with other user updates to enhance the shared model. All training data remains on the edge device, and no individual updates are stored in the cloud.

For more information on solutions for AI at the edge, visit [Intel® AI in Production](#).

Compute Acceleration with Intel® Artificial Intelligence

A growing customer requirement in port solutions is the provision of acceleration and offload solutions to boost the compute performance of platforms. Intel technologies deliver broad capabilities and support diverse approaches for AI—including today's AI applications and more complex AI tasks in the future. Intel's AI portfolio helps customers enable AI model development and deployment at any scale from massive clouds to tiny edge devices, and everything in between. Intel is leading the next wave of AI with new products designed to accelerate AI system development and deployment from cloud to edge.

Additional technologies supporting AI include:

- Intel® Vision Accelerator Design products: Based on Intel® Arria® 10 FPGAs, the Intel® Vision Accelerator Design products provide powerful, deep, neural network inference for fast, accurate video analytics to meet the demands of computer vision applications at the edge and to enable solution providers and their customers to take advantage of a wide spectrum of video analytics-based use cases.
- Intel® Xeon® Scalable processors: powerfully designed to handle the broadest range of AI workloads including deep learning
- Intel® FPGA: Near real-time, programmable acceleration for deep learning inference workloads.

Computer Vision with Intel® Distribution of OpenVINO™ Toolkit

The Intel® Distribution of OpenVINO™ Toolkit is a comprehensive toolkit for quickly developing multiplatform applications and solutions that emulate human vision. Based on Convolutional Neural Networks (CNNs), the toolkit extends Computer Vision workloads across Intel hardware, maximizing performance. Maritime organizations can accelerate and deploy CNNs on Intel platforms with the Intel® Deep Learning Deployment Toolkit that's available in the OpenVINO™ toolkit and as a stand-alone download. Together with the new Intel® DevCloud for the Edge, OpenVINO addresses a key pain point for developers—allowing them to try, prototype and test AI solutions on a broad range of Intel processors before they buy hardware. The OpenVINO™ toolkit:

- Enables CNN-based deep learning inference on the edge.
- Supports heterogeneous execution across computer vision accelerators—CPU, GPU, Intel® Movidius™ Neural Compute Stick, and FPGA—using a common API.
- Speeds time to market via a library of functions and preoptimized kernels.
- Enables development and optimization.

Intel 5G

From device to network to cloud, Intel is leading the way in developing 5G technology that will shape the future of connectivity. The next generation of wireless, 5G is a complete revolution in the way data and services will be consumed on a network, offering enhanced speeds, more capacity, and low latency. With the move to 5G, Intel-powered networks help maritime organizations become AI ready with the compute power to handle networking, cloud, and AI workloads. Transformed networks with powerful computing resources at the edge enable operators and cloud providers to intelligently deliver highly personalized services for maritime organizations today and in the 5G future.

Intel is driving network transformation and enabling edge compute that's needed to bring 5G to life. Intel is transforming purpose-built networks to become more agile, flexible, and scalable with Software Defined Networking (SDN) and Network Function Virtualization (NFV)—setting the stage for 5G.

Video/RADAR/LiDAR/SONAR/Sensor Fusion

- Empty/full container detection and tracking
- Container truck profiling
- Oil leak and chemical spill and leak detection
- Cargo monitoring and management at sea

Private Networking (5G/LTE, Mobile Edge Compute

- Collision prevention
- Digital disaster recovery
- Automated or remote-controlled vessels
- Bridge systems: Navigation, communication, and control
- Vessel inspection for wear and tear
- Automated berthing
- IT/OT Security
- Perf Meas Sys (please define)
- Route planning

AI Inferencing (On-Prem and Cloud)

- Luggage scanning and tracking
- Passenger infotainment and connectivity on-board
- Passenger monitoring and protection
- People counting
- Automatic fare collection

Forward Thinking

Accelerating Port Digitization

"The pandemic has greatly created a need for ports to accelerate their digital transformations with solutions that allow them to have more flexibility, visibility, and efficiency in their operations. We'll see an acceleration and adoption of marine solutions that help address that need, ranging from AI, including machine learning, machine vision, and advanced analytics. As shipping volume continues to increase, we'll continue to see investment in the foundational OT infrastructure with more IT capabilities to allow the broad ecosystem of players to deploy these solutions."

Wei Chen
Vice President, Video, Cities, and Transportation
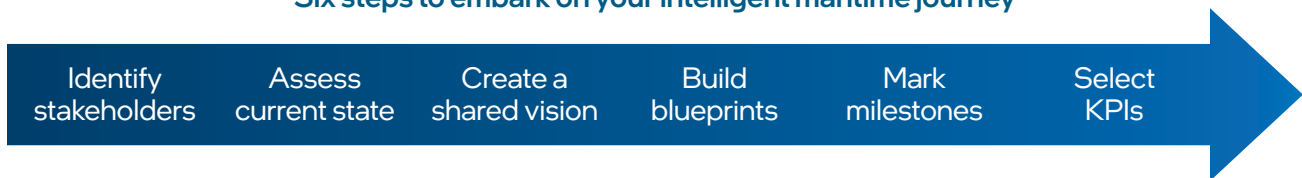Intel

Next Steps

Getting Everyone on Board

Catching the wave of innovation in the maritime industry requires assembling a crew of like-minded leaders to take the journey together. Leading management teams plan their intelligent maritime initiatives across three action areas to:

1. Identify the common challenges, efficiency improvements and opportunities, and transform data into insights using Intelligence from the edge to the cloud.
2. Leverage proven intelligent maritime solutions and scope potential improvements to support stakeholder goals.
3. Consolidate systems at the edge for greater efficiency and value.

Stakeholder identification, participation, and clear priorities are essential foundation points for building your plan.

Six steps to embark on your intelligent maritime journey

Identify stakeholders	Assess current state	Create a shared vision	Build blueprints	Mark milestones	Select KPIs

Exploring Financing and Partnerships

Implementing a comprehensive vision for intelligent maritime in your organization will require committed funding and careful planning. As recent examples around the world show, the innovations come not only from new technologies and processes, but also from a variety of funding and financing sources. Exploring multiple options such as regional economic development; local and federal agency funding for transportation, public safety, environment; and private developer and industry partnerships can reveal new sources of investment. Developing financing partnerships which also embrace industry knowledge, best practices, plus key solutions and technologies, provides insight from planning to implementation.

Defining and executing an intelligent maritime strategy is neither straightforward nor without risks—but the benefits can be significant. At Intel, we believe that successful maritime innovation requires certain key components: the right level of stakeholder participation, clear priorities, and methodical planning of technology infrastructure.

This is only a starting point for a transformative maritime journey. We believe stakeholders can achieve success by establishing clear priorities, encouraging active stakeholder participation, and ensuring methodical technology infrastructure planning while enabling the right policy and governance. With our edge to core to cloud solutions and strong partner ecosystem, Intel Technologies can help bring your vision to life.

For follow-up and questions, please contact: marine@intel.com

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Endnotes

1 OECD: Ocean Shipping and Shipbuilding
2 UN COVID-19 and maritime transport: Impact and response (2020)
3 Cruise Industry News
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6 SagarMala.gov: Mission and Vision
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9 Bloomberg
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12 Harbor Research Smart System Forecast (as quoted in Harbor Marine Opportunity Assessment, 2020)
13 International Maritime Organization
14 Bloomberg
15 NICB
16 Maritime Journal
17 Forbes
18 Intel Smart Edge Computing
19 Next Generation IoT: Fivecomm
20 NEXCOM's Enterprise Info webpage
21 Intel IIJA eBook
22 Getac Port Management webpage
23 Intel IIJA eBook

Think big

Chart your future with intelligent maritime

Start small

Begin with projects and opportunities

Move fast

Learn, adjust, iterate

intel.