WÄRTSILÄ

The future of Smart Autonomy is here

DISCOVER A STEPWISE APPROACH

Wärtsilä white paper

Contents

Introduction

When it comes to autonomous shipping, grandiose visions of 100 % unmanned vessels sailing the world's oceans and ports are often painted. And while this scenario may or may not eventually become a reality, there are still many obstacles to overcome if we're to reach such a vision. The main barrier is the lack of compelling business cases, along with the lack of an agreed regulatory framework to govern autonomous operations and uncertainty over whether fully unmanned vessels are even desirable. Indeed, a common misconception is to equate "autonomous" with "unmanned".

The reality is that autonomy is a spectrum, with solutions that can offer decision support at one end and fully unmanned vessels at the other, with various degrees of automation of the vessel systems in between. Because autonomy is a spectrum, it's also something that can already be harnessed to create benefits for the shipping industry today. To make this happen we need an understanding of what problems can be solved with autonomous solutions, what makes autonomous operation possible and how to start implementing solutions that can move your operations in the direction of more autonomy.

Instead of contributing to the debate around what the future of shipping will look like and what role unmanned vessels will play, this paper argues that the journey itself may turn out to be more important than the destination. The pursuit of autonomous operations is already leading to smarter systems that can enhance the safety, cost-efficiency and environmental performance of today's vessels; in practice, this means reducing collisions or incidents—especially in busy ports—assisting with docking, saving fuel through optimised speed profiles, reducing associated emissions and optimising crew numbers. At Wärtsilä we call this "smart autonomy," and it means a stepwise and commercially viable approach for your operations that can be applied today—as part of a longer journey towards an autonomous shipping future.

Naturally, automation—the replacing of human effort by machines—is a key enabler for autonomous solutions. But this alone is not enough. In order to make autonomous systems a reality, three broad capability areas and enablers are critical.

Situational awareness—creating awareness of what is going on around and onboard the vessel and collecting data by using sensors such as radars, lasers and cameras.

Decision making and logic—intelligent algorithms that are able to interpret a scenario based on data and decide on a safe and effective course of action.

Action and control—the contro systems that enable autonomous actions, where decisions made by algorithms are executed to accurately and safely take care of functions that are typically handled by humans, such as manoeuvring the vessel, adjusting speed etc.

By implementing solutions to improve operational capabilities in any of these three areas, you are already on the path towards autonomous operations. In order to show how this is possible in practice, this paper will also look at examples of solutions and concepts from Wärtsilä Voyage in these areas.

1

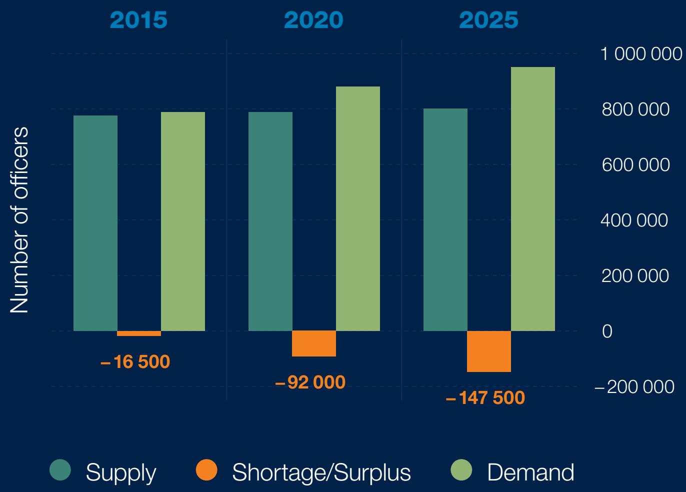
Key drivers, trends and industry dynamics

The owners, operators and managers of today's maritime fleets find themselves confronted by a range of pressing challenges. Overcapacity is leading to growing pressure to make savings without sacrificing vessel efficiency, while environmental and safety regulations are becoming increasingly strict. On top of this, the COVID-19 pandemic has added further pressure. Some of the key challenges facing the maritime industry are summarised below.

CREW CHALLENGES

Aging populations and changing career aspirations may lead to a reduction in available human resources and according to a BIMCO manpower report, there may be a shortage of workers in the maritime industry in the near future. However, a more pressing concern among many is finding enough qualified seafarers, especially officers, with the necessary skills to operate vessels at the high levels of efficiency desired today.

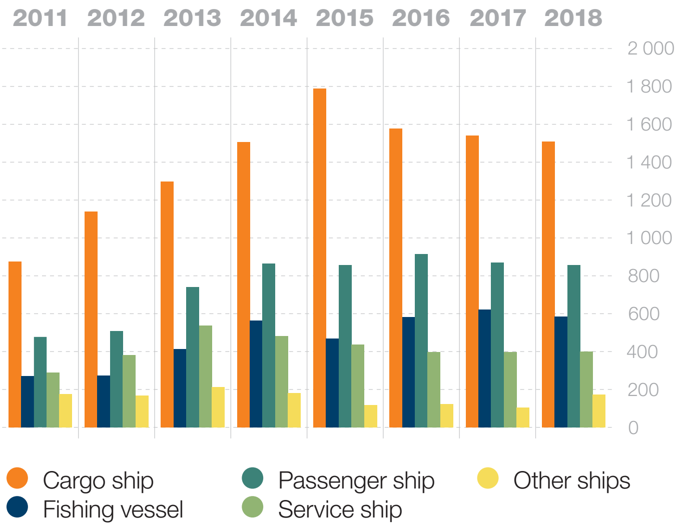
Basic forecast for the future supply-demand balance for officers



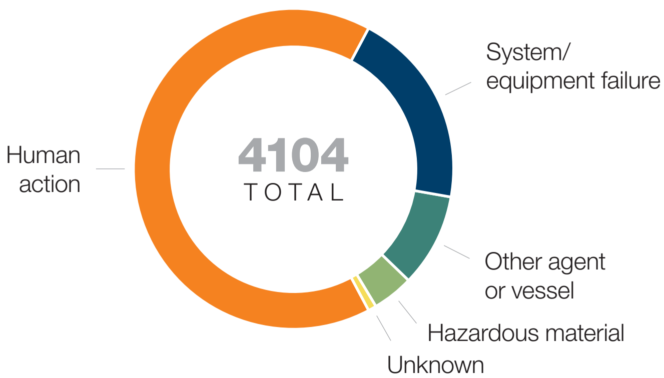
SAFETY

In general, shipping has a relatively poor safety record. According to the Shell Zero Incident report (LISW 2019), the safety record for the maritime industry is approximately 20 times worse than the average onshore worker and about five times worse than the construction industry. Within the maritime industry, the worst-performing segments were general cargo ships and passenger ships. The cargo ship figures could be a result of the ever-increasing size of vessels, meaning more blind spots, though the passenger vessel figures may be a reflection of better transparency in reporting in that segment. In 2018, there were a total of 3174 casualties and incidents, with 25 ships lost and 3515 ships involved (EMSA 2019).

Distribution of ships involved by main category



Distribution of accident events for 2011–2018



From a total of 4104 accident events analysed during the investigations, 65.8 % were attributed to a human actions' category and 20 % to system/equipment failures.

Key figures for 2011–2018

25 614 Ships involved

230 Ships lost

23 073 Casualties and incidents

665 Very serious casualties

7 694 Persons injured

696 Fatalities

1377 Investigations launched

HUMAN ERROR

Mistakes made by humans are the source of most incidents in the maritime industry. According to Allianz Global Corporate & Speciality, 75 % of shipping insurance losses, equivalent to USD 1.6 billion, are caused by human error. There are many reasons for human error, including poor visibility, inclement weather, fatigue resulting from long hours and insufficient rest, the nature of the working environment onboard vessels and poor leadership both onboard and ashore. This is increasingly relevant as more decision-making capability moves onshore, a trend supported by the digitalisation of the maritime industry and the improved connectivity of vessels.

SAFETY AND SHIPPING REVIEW 2018 IN NUMBERS

90 %
of global trade transported by shipping

1129
total losses over past 10 years

94
total losses in 2017, second lowest total in a decade

53
losses—cargo ship most frequent vessel last globally in 2017
↑ up year-on-year

21
losses due to bad weather

180
piracy attacks in 2017, lowest total for 22 years
↓ down year-on-year

61
losses caused by foundering in 2017
↑ up year-on-year

6
vessels lost to fire in 2017
↓ down year-on-year

3
regions account for almost half of all losses

30
losses in South China, Indochina, Indonesia and Philippines—the main hotspot

MAJOR RISKS

- Busy seas
- Typhoons
- Piracy
- Safety standards
- Political risk

Container ships are getting bigger, capacity has increased by almost 1500 % in 50 years

MAJOR RISKS

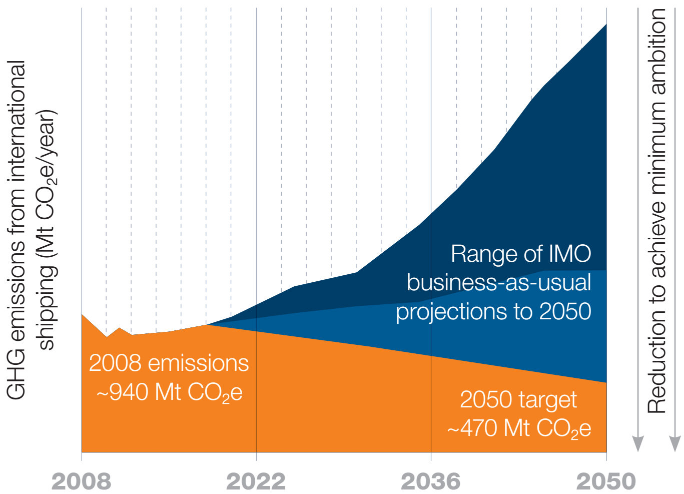
- Fire-fighting capability
- Cargo misdeclaration
- Salvage challenges
- Ports of refuge

75 % of shipping insurance losses are caused by human error, equivalent to **$ 1.6 BN**

DECARBONISATION

In 2018 the International Maritime Organisation (IMO) imposed a target to reduce greenhouse gas emissions from the global shipping fleet by at least 50 % by 2050 compared to 2008 levels, with the aim of achieving full decarbonisation by the end of the century. Along the route to the 2050 requirements there are also some challenging legislative milestones. By 2030, emissions—primarily CO_2—from new and existing ships must be cut by 40 % on average compared to 2008 levels. To meet and comply with this legislation is an immediate concern and requires a step change in the design and operation of next-generation vessels. In response the IMO target, the Poseiden Principles and Sea Cargo Charter are initiatives launched by a group of leading financial and leasing institutions that make acquiring finance/refinance and cargo dependent on a vessel's environmental performance.

In addition to global programmes, there are also regional initiatives such as in the EU, with its target to move more freight transport from roads to rail and inland waterways.



A NOTE ABOUT THE COVID-19 PANDEMIC

While not a key driver pushing towards autonomous operations, COVID-19 has accelerated digitalisation. The COVID-19 pandemic affected all aspects of modern life, and shipping was no exception. Though the impact was experienced differently depending on region, one common issue was that COVID-19 dramatically affected the safety of crew onboard vessels as well as maintenance staff. COVID-19 created new demands for a more coordinated response to ensuring safe crew changes and the mental and physical wellbeing of sailors aboard. The pandemic increased the need for solutions that minimise the number of people who need to be aboard—for example, remote guidance systems for vessels as well as remote support and monitoring systems that allow for troubleshooting and issue resolution without the need to send maintenance personnel aboard.

Autonomous operations are often touted in industry publications as a way of solving or helping to deal with many of these challenges, but what does it mean in practice? In the next section we look at Wärtsilä Voyage's definition of autonomous operations in more detail.

2

How smart autonomy can help solve today's shipping challenges

In this paper we refer to "smart autonomy," which means moving towards autonomous operations in the future, by finding targeted autonomous solutions that solve specific problems today. This approach allows for further evolution as needed and provides the ability to respond to changing regulatory environments related to emerging standards for autonomous operations. The end goal is not necessarily fully autonomous unmanned vessels. Instead, the goal is to harness existing—or co-create—modular autonomous solutions that solve specific problems and make commercial sense today, while offering the extensibility to install additional solutions in the future, allowing our clients to tailor their own pathway to autonomy.

The types of concrete challenges that autonomous solutions can help solve are summarised below

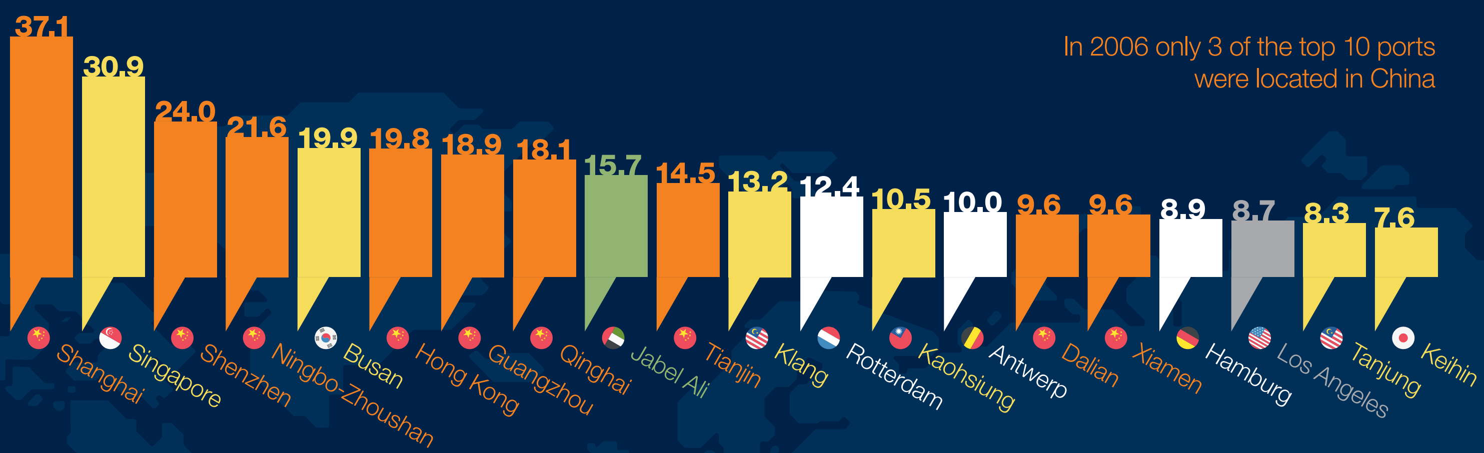
INCREASED SAFETY

Autonomous solutions have the potential to reduce the incidence of human error and therefore the number of mistakes and accidents. Removing humans from the equation or giving them the tools to enhance their capabilities for carrying out repetitive routine tasks improves performance and safety. Such changes also allow the crew to focus on more important tasks and key decision-making duties. By increasing situational awareness of what is happening around the vessel, these solutions also increase safety for those onboard surrounding vessels. This will be particularly important in areas where incidents are most common, such as busy ports.

> 13 of the world's 15 busiest ports are in Asia (World Shipping Council), and efforts are already underway to improve safety with innovative autonomous solutions, such as PSA Marine's IntelliTug trial, carried out in collaboration with the Maritime and Port Authority of Singapore

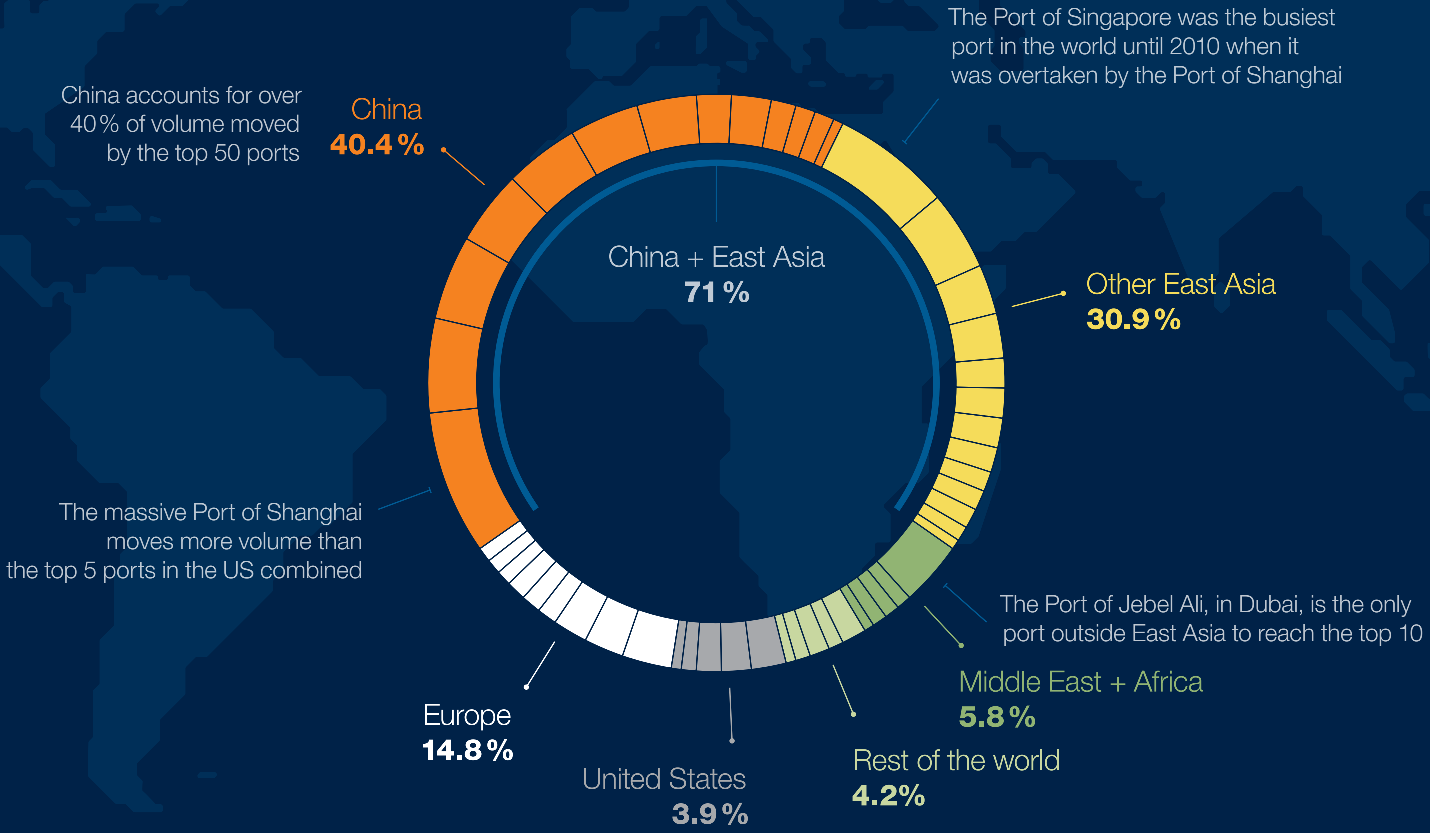
THE WORLD'S BUSIEST PORTS

Volume by million TEU (2016)



TOP 50 CONTAINER PORTS

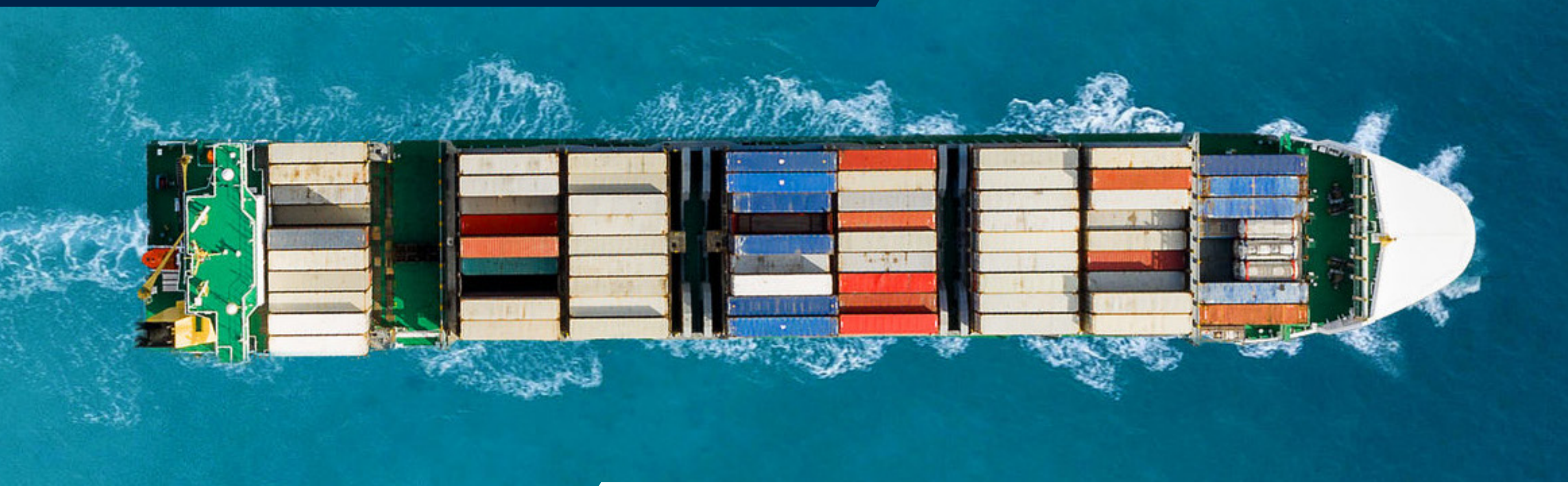
Shave of volume



DECARBONISATION AND FUEL SAVINGS

Autonomous solutions support efforts to sail in the most fuel-efficient manner, which leads to both economic and environmental benefits. This approach builds on earlier digitalisation efforts which provide actionable insights on fleet operations, squeezing more efficiency out of existing assets and operations and fostering a new operating culture and ways of working.

Autonomous solutions improve efficiency by allowing vessels to reliably and consistently replicate precise and safe vessel performance. For example, we've seen that for ships on shorter voyages, reducing the average docking time by a single minute can have a significant impact on the overall fuel consumption (reducing it by two to three per cent per minute on a two-hour voyage). For longer voyages, fuel savings of 10 % or more are possible through route and speed optimisation, and using autonomy solutions can help ensure a more consistent level of performance across vessels and voyages in a fleet.



MEETING CREW CHALLENGES

In the future, there may be an opportunity to operate with fewer crew, which will be important in order to make up for the projected shortfalls in finding experienced, skilled crew as mentioned earlier. This is also important in the context of initiatives that will increase the demand for shipping, such as the EU's target to move more cargo by rail and sea instead of road, which may well increase the number of ships needing to be crewed. Autonomous solutions may also allow redeployment of crew, for example, if ships can be steered remotely from land-based centres instead of from the bridge. Re-deployment onshore can make the maritime profession more attractive, but will require re-training. For this reason, high-quality simulators will become more important and useful in assisting with testing, training and transitioning to autonomous solutions.

MORE EFFICIENT VESSEL DESIGN

Autonomous solutions are already being retrofitted to existing vessels, integrating sensors, data collection, processing and cabling. Doing this in a new build enables a more holistic 'digital by design' philosophy for vessels.

Looking further ahead, as the nature of crew deployment, the role of shoreside responsibilities and the usage of vessels changes, vessel design can also be optimised. This means naval architects will have more freedom when allocating space to cargo, and integrating solutions for maximum efficiency and safety. For example, a key change will be enabled by enhanced situational awareness—when operators no longer need a direct line of sight, this will impact vessel design in terms of bridge placement.

FOUR AREAS WHERE AUTONOMY WILL BRING VALUE OVER TIME

Increased safety

Less human errors will decrease amount of accidents and mistakes

Fuel and OpEx savings

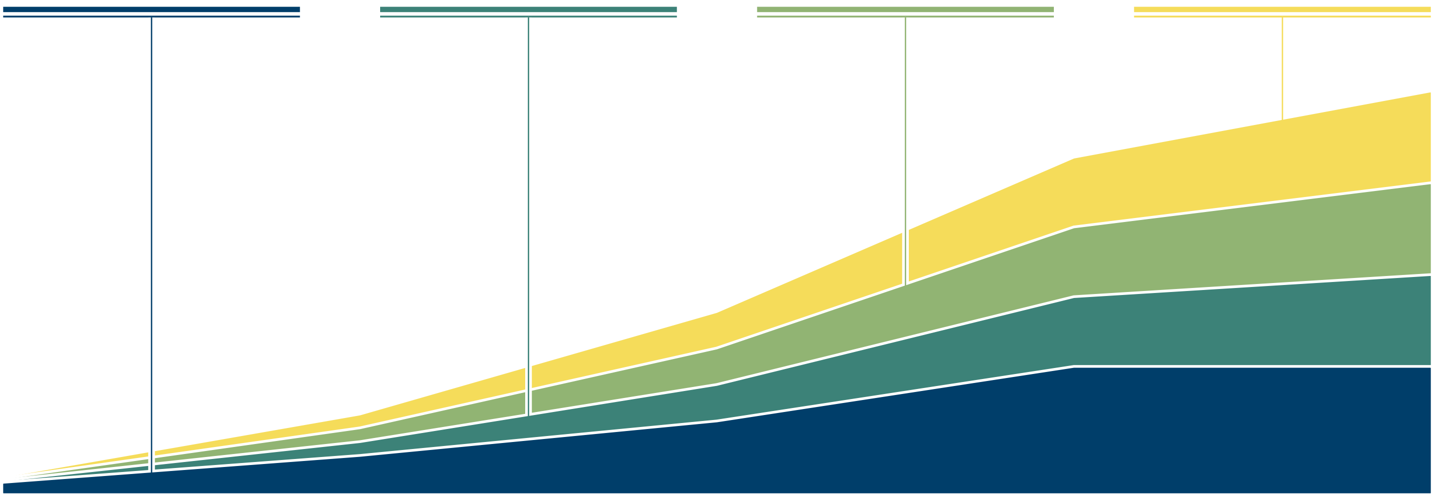
Autonomy is 100 % compliant to optimization advices and sail in most efficient manner

Low crew requirements

Once vessel is secure and sail efficiently there is opportunity to reduce crew

Efficient ship design

When less crew is needed space can be redistributed to more hotel/cargo area



3

The building blocks of smart autonomy

IN WÄRTSILÄ VOYAGE'S VIEW THERE ARE THREE KEY AREAS THAT NEED TO BE CONSIDERED TO ENABLE AUTONOMOUS SOLUTIONS

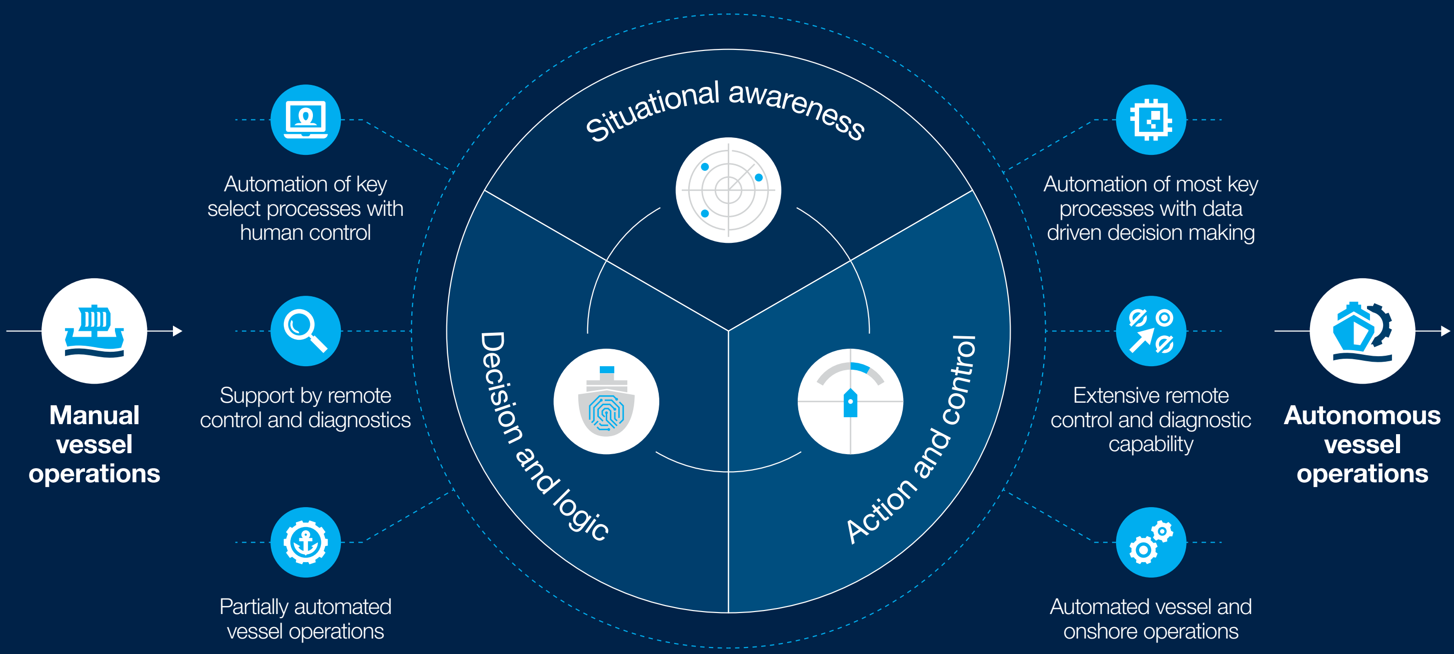
Situational awareness

Decision making and logic

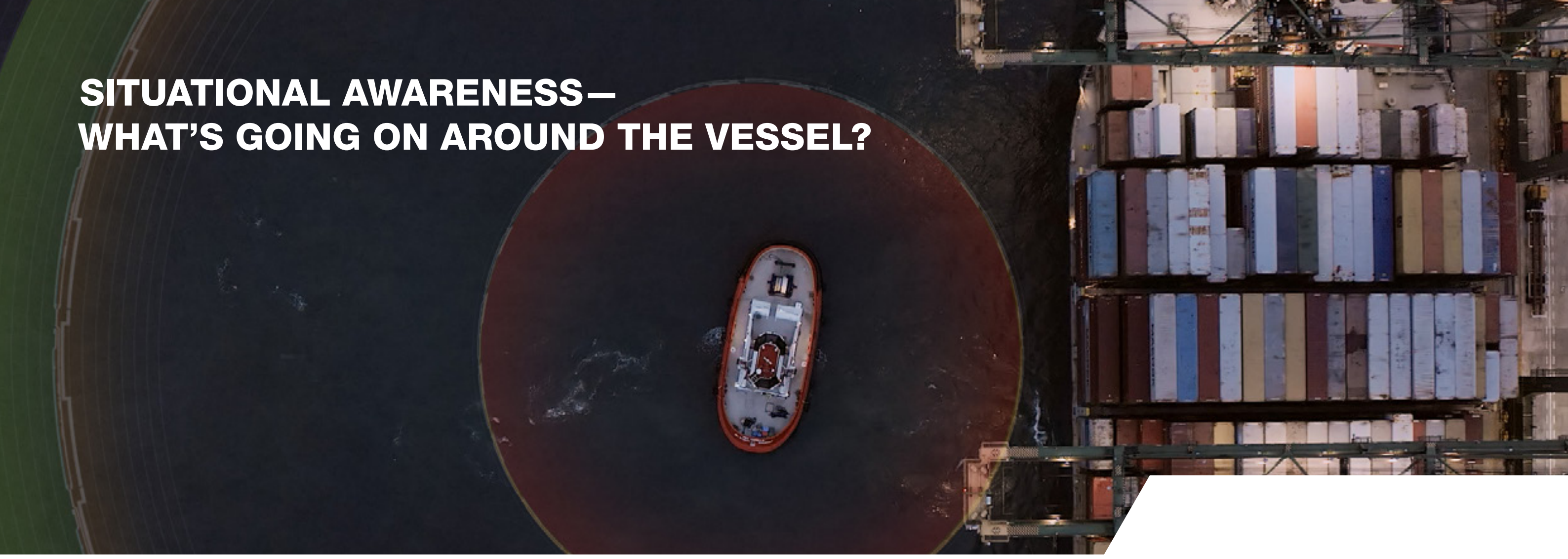
Action and control

Very often these build on each other as a solution combines elements of all three areas, but solutions can also exist in just one of these areas, which we will look at later in this paper. To begin, let's define what each of these areas entails in practice.

TOWARD SMART AUTONOMY



SITUATIONAL AWARENESS— WHAT'S GOING ON AROUND THE VESSEL?



As an enabler of autonomous operations, situational awareness refers, among many other things, to building a digital understanding of the vessel's surroundings and own operating state.

Situational awareness around the vessel is important for vessels of all sizes and is achieved by combining data from several different sources to digitise the environment and provide an accurate picture in order to detect and recognise hazards. These sources include radar, laser, cameras and environmental sensors (GNSS, wind sensors, MRUs, Echosounder etc.) to build up a complete and reliable picture of the environment around the vessel. Ensuring a complete overview of what's going on also requires integration between all these sensors. This kind of integration requires action in three areas.

The hardware stack: including a server with enough computing power to process huge amounts of data and predict/plot in real time, as well as peripheral hardware, power management and a well-balanced sensor suite.

Software/data: the fusion and treatment of data is needed as every sensor generates both high volumes of data and different interpretataions of the ship's environment.

Governance/management: a process is needed to patch and update the various applications within the entire suite to maintain cyber security without impacting/breaking the entire system.

Based on that understanding, the crew or an autonomous system receives the inputs needed to decide on a safe and optimal course of action, which is handled by the decision-making and logic capability.

In many ways modern technology can already be used to augment the detection and tracking capabilities of crew and in some ways greatly surpass human capabilities. Human eyes and ears still play a central role in a mariner's hazard detection but the advent of night vision, laser, LIDAR and short-range radar technology makes information accessible under conditions where humans are literally blind.

In addition to knowing what is happening around the vessel, onboard situational awareness is also important for autonomous operations. This can include the state of the plant, cargo, ongoing maintenance activities on board and power management, which all have an impact on navigational decision making.

DECISION MAKING AND LOGIC CAPABILITY— WHAT NEEDS TO BE DONE IN A GIVEN SITUATION?

At the heart of autonomous systems are decision-making algorithms that can apply machine learning to interpret a scenario based on data provided by situational awareness solutions and decide a safe and effective course of action. At its simplest, decision-making and logic capability is the ability to understand a vessel's situation and make good decisions. In certain situations, such systems can help relieve some of the cognitive load on the crew and optimise operations onboard.

Decision-making algorithms have become more and more sophisticated, leading to smarter systems that have increased autonomous capabilities. For example, the goal of a future smart navigation system is to take a vessel from port to port in a safe manner while avoiding collisions or other hazards and maintaining compliance with COLREGS. Such systems would take advantage of digital modelling of the vessel and its environment.

Because of the risks of testing on real vessels at sea, simulation is a critical part of developing autonomous solutions. The computer models that underpin simulation-based training—capable of replicating almost infinite permutations of marine environments, vessel traffic situations and ship equipment—are the same that can be used to inform the decision-making capabilities of intelligent systems. Deployed in real time with real people in simulators, those same models can be used to test and validate autonomous solutions. These simulators can also be used to train crew to understand and use new systems.

Autonomous solutions can help humans make better decisions based on existing information and also make consistent, accurate calculations based on given and programmed data. At the same time while working alongside humans, this provides great feedback opportunities to ensure such algorithms are sufficiently robust and reliable when it comes time to switch from human control to a more autonomous control system.

ACTION AND CONTROL—HOW DO WE SAFELY AND EFFICIENTLY MAKE THE VESSEL TAKE ACTION?

When we talk about action and control, we're talking about how a vessel executes the decisions made by algorithms to precisely take actions onboard. For the purpose of this paper, the focus is mainly on solutions for navigation as they can offer immediate benefits to operators in today's markets. Smart vessel control and drive systems are needed to safely travel from port to port and to handle such tasks as docking, harbour entry and remote pilotage.

For example, an autonomous navigation system can dynamically plan a route in real time that avoids collisions based on situational awareness and decision-making and logic. These instructions are then sent to the action and control systems to execute. If manual control is required, the crew can intervene at any point.

The benefit of action and control in autonomous solutions is that, in applications ranging from ferries to long-distance voyages, the ability to repeatedly and consistently deliver the same course of action greatly increases levels of efficiency and operational safety and helps reduce crew fatigue. In the future, action and control solutions will be essential to fill in for humans once they have left the control loop.

HOW SMART AUTONOMY FITS IN TO CURRENT AUTONOMY CLASSIFICATION SCHEMES

At Wärtsilä Voyage, we see that situational awareness, decision making, and action and control are the enablers for autonomous solutions. It's up to each customer to decide how far they want to move in the direction of fully autonomous operations. How these levels are defined, and how useful they actually are, is still being discussed—here are two prominent examples.

Lloyd's Register has defined different levels of autonomy as a scale with capabilities as follows:

AL0
Manual—no autonomous function

AL1
On-ship decision support

AL2
On and off-ship decision support

AL3
"Active" human in the loop

AL4
Human on the loop—operator/supervisory

AL5
Fully autonomous, rarely supervised

AL6
Fully autonomous, no supervision

The **IMO**'s view on autonomous shipping is based on four levels:

- Vessel with automated processes and decision support for onboard crew
- Remote controlled vessel with humans onboard
- Remote controlled vessel with no humans onboard
- Fully autonomous vessel that can make and execute all needed decisions

It's important to note that Wärtsilä Voyage is not proposing an alternative or replacement level of autonomy scale in this paper—instead, we are focusing on clarifying the enablers and the opportunities that already exist in this area. This ensures that Wärtsilä solutions relate to customer needs while also being mappable to relevant class levels and regulations in the future.

4

Challenges to the adoption of smart autonomy

Currently, there are several potential blockers that need to be considered when rolling out autonomy solutions, including technical, organisational and regulatory. These key obstacles can be summarised as follows.

AN EVOLVING REGULATORY ENVIRONMENT

This is perhaps the biggest obstacle to rolling out fully autonomous operations. The IMO is looking into a regulatory framework for autonomous shipping and is currently undergoing a scoping exercise. In the meantime, the IMO's Maritime Safety Committee (MSC) has released its Interim Guidelines for Maritime Autonomous Surface Ships (MASS). These guidelines have been used to guide recent trials such as Wärtsilä and PSA Marine's IntelliTug trial conducted in collaboration with the Maritime and Port Authority of Singapore. In practice, rolling out autonomous solutions means operating in a fragmented and changing environment based on regulations set out by flag states and local authorities.

REGULATIONS THAT IMPACT REMOTELY OPERATED AND UNMANNED VESSELS

Regulations related to shipping are based on the principle of a "manned vessel" with crew onboard. This means that several regulations need to be updated for remote guidance and unmanned operations. These include:

- The International Convention on Standards of Training, Certification, and Watchkeeping for Seafarers (STCW Convention)
- The United Nations Convention on the Law of the Sea (UNCLOS)
- The International Convention for the Safety of Life at Sea (SOLAS Convention)
- The Convention on International Regulations for the Prevention of Collisions at Sea (COLREG Convention).

HUMAN AND ORGANISATIONAL INERTIA

Whenever rolling out a new solution, it is critical to ensure the people who are supposed to use it not only understand it and are properly trained, but also see its benefits. Such changes are not always easy as they require adjustments to ways of working, challenge old methods and routines and also raise fears about job security. Added to this is the fact that the shipping industry has relatively long innovation cycles, due partly to its operating nature, but also linked to expensive assets and asset lifetime. To Wärtsilä Voyage, autonomous technologies are foremost about helping existing crew operate more efficiently and safely. Autonomous operations should not be just equated with unmanned vessels, but seen as technologies to help operate vessels better, today.

Moving from more traditional operations to the smart autonomy operations model requires a shift in mindset and the adoption of new processes and competencies across the entire organisation. Rolling out new solutions requires bespoke training in order to ensure buy-in from all stakeholders. Commitment from leadership is key—it will be up to management to help set out the vision and guide the process of both choosing a solution and evolving roles, processes and partnerships to ensure successful uptake of autonomous solutions.

TECHNICAL CHALLENGES AND LACK OF INTEROPERABILITY AND SYSTEM INTEGRATORS

While massive improvements have been made in machine learning and AI, these technologies are still developing and will need to develop further to ensure that fully autonomous operations are both realistic and safe. Development of integration between sensors into a single system needs to continue to ensure there are no blind spots and that small-object detection is reliable. One of the challenges in this area is that some of the more mature sensors (such as GNSS and AIS) have well established data standards. Other sensor types are still maturing and there are new areas of innovation (such as LIDAR and video) where the data standards are not as established—this will mean customisation is required. Furthermore, it's worth noting that most of the available current sensors are not built to support autonomy; their data frequency is fine for situtional awareness but it isn't high enough for the real-time decision-making needed by an autonomous system.

Multiple players make single systems that do one thing (and may do it very well) but expanding from there is difficult if not impossible. As these solutions are not mutually compatible it leads to multiple data silos as more onboard systems are added, increasing rather than reducing complexity. The solutions are often not linked to real-life operations or a specific business goal, which makes it hard to see any concrete benefits and hence define a compelling business case for smart autonomy.

One of the ways to improve systems is through simulation before deployment to test that they function as expected. These systems can then be further improved through gathering real-life operational data that filters back to continuously improve the system with the help of machine learning.

CYBER SECURITY CONCERNS

As autonomous solutions rely on digitalisation, integration and automation, marine cyber security risk management is a growing and justified concern. There is also a regulatory aspect to this. As the IMO has recognised that cyber security is becoming critical for data protection and reliable and safe marine operations, from January 2021 it requires that cyber security be addressed in safety management systems.

In 2017, the IMO adopted resolution MSC.428(98) on Maritime Cyber Risk Management in Safety Management Systems (SMS). Any digital systems should have a robust cyber security framework based on best practices and guidelines to ensure the security of operations.

5

How to get started on your journey towards smart autonomy

At Wärtsilä Voyage, we believe that moving towards autonomous operations should be done in a pragmatic and scalable way that makes business sense for your operations.

The key to this stepwise approach is to roll out and co-create autonomy solutions that address a real business need and offer immediate benefits. Different segments and markets will have different drivers. However, starting with a concrete problem that needs to be solved and finding a compelling and scalable business case is the obvious first step.

The next step is about looking for development opportunities that provide more scope to scale up or expand towards more autonomous functionalities. This building block approach means combining capabilities to unlock more autonomous functionality, but also extending existing capabilities where needed.

A CALL FOR CO-CREATION

The reality in this area is that co-creation is often needed to find just the right solution to the business need. Co-creation is a process that requires close collaboration between partners, not just the customer and supplier, but also other relevant players like technical experts, regulators, start-ups, universities and other ecosystem partners relevant to the project.

The rewards of sharing and developing knowledge openly are great. Wärtsilä has learned through collaboration and co-creation pilots over the years that sharing best practices among involved parties enables us to reach results faster.

In order to move forward successfully with rolling out new autonomy solutions or taking part in a co-creation project, it helps to have a dedicated team around autonomous solutions that is focused on solving problems that have a strong value case. The key is to define the problem and identify its root cause. It then needs to be ascertained whether a technological solution, rather than organizational or procedural for example, is among the range of potential solutions. If it is, there needs to be development and testing of minimal viable products (MVPs) to roll out solutions. From here, the solution requires testing, often through simulation, before real-world trials. Learnings from these stages are then applied to improve the solution iteratively. Crew and personnel also need to be brought fully onboard, which requires strong commitment from management.

THE BENEFITS

The benefits of moving towards autonomous operations in a pragmatic and scalable way include:

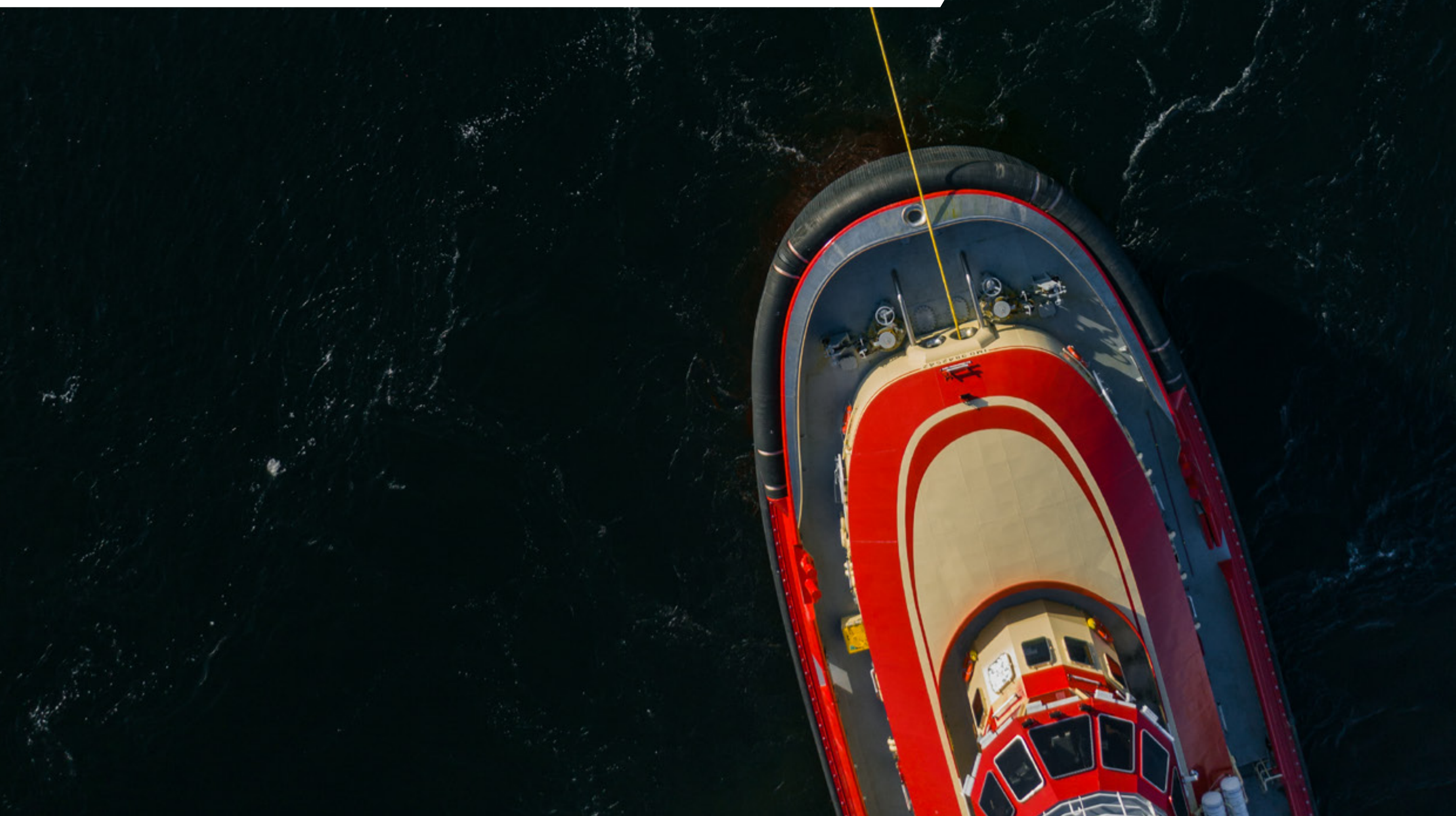
- Increased safety through improved situational awareness and better control, for example collision detection and avoidance
- Reduced OpEx and CO_2 emissions through fuel savings due to, for example, just-in-time arrival at ports, optimum speed profiles and reduced need for onboard energy consumption
- Resilient and predictable operation
- More efficient asset use, less downtime, and reduced human-caused disturbances
- More efficient use of human capabilities

6

How Wärtsilä can help

Wärtsilä Voyage has a long track record and proven expertise in smart marine technologies based on a commitment to practical innovation. We believe that autonomous technology has the power to transform the maritime industry with new levels of safety, efficiency and sustainability.

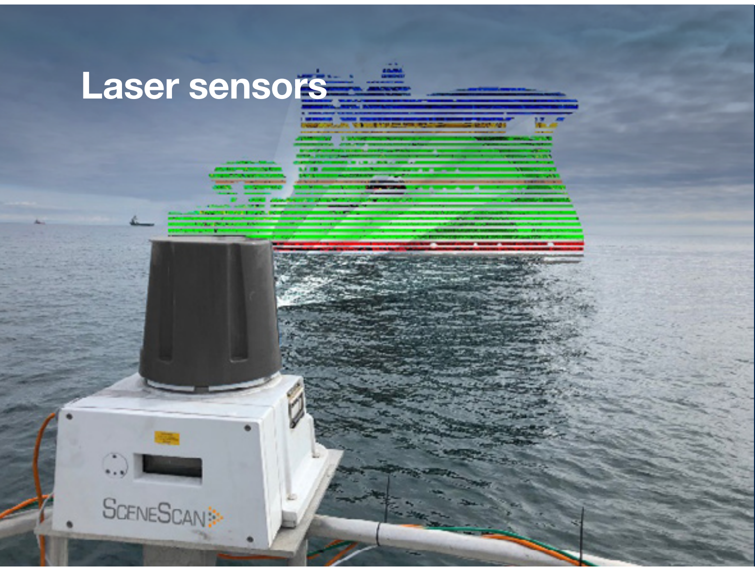
In this section, we look at some of the solutions that Wärtsilä Voyage offers to help customers move towards smart autonomy.



ENHANCING SITUATIONAL AWARENESS WITH SMART SENSORS

Wärtsilä Voyage provides a range of sensor solutions for assisted, autonomous and remote operations. These sensors accurately measure both precise local and global position and provide situational awareness and hazard detection for automated vessel control. Additionally, all the sensors provide outputs that enable them to integrate seamlessly into the ship's navigation systems, whether it be for automating manoeuvres, enabling remote control or for a completely autonomous navigation system. Situational awareness is built on technologies based on:

Laser sensors

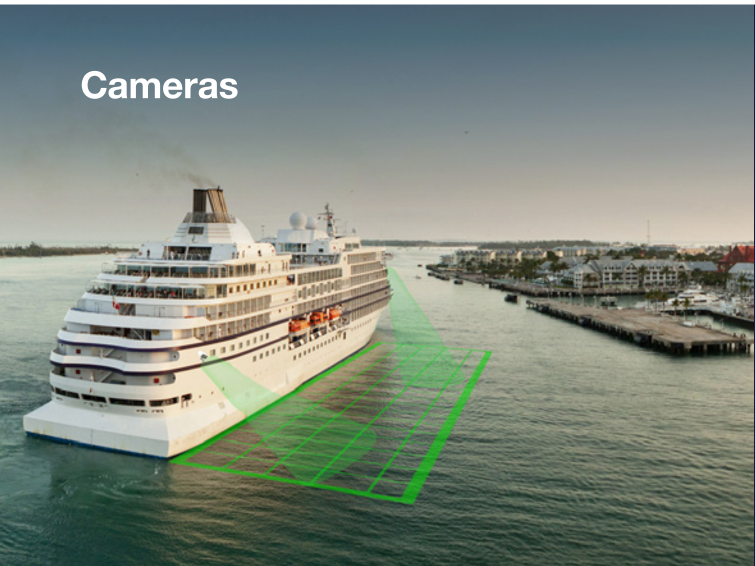


The SceneScan and CyScan AS systems are high-accuracy rotating laser sensors that provide positional information to allow automated approach and/or station keeping relative to a structure, vessel or quayside. SceneScan provides position information relative to man-made structures within the sensor's field of view, meaning that the vessel is completely independent from the infrastructure. CyScan AS tracks phsycial reflective targets on the asset/quayside for long range approches. These state-of-the-art technologies provide precise positioning information to the vessel and remove the dependency on GNSS which is sucepitable to jamming and spoofing.

Microwave (K-band radar) sensors

The RS24 system is the latest generation high-resolution radar and is designed to provide high levels of situational awareness in densely populated marine environments. The RS24 sensor is a high-speed, high-resolution FMCW K-band dome radar. K-band (24GHz) radar has an inherently higher resolution and sensitivity than the S or X bands typically used for marine radar. It detects objects from 0.75 m in size, from a range of 1 m up to 1.5 km, that typical S or X band radars cannot. This kind of capability is critical for small-object detection around the vessel.

Cameras



Wärtsilä Voyage is working on a smart panoramic edge camera system (SPECS) to enable a bird's eye view of the vessel and its surroundings for docking and close-range manoeuvres. A "smartQuay" option provides assistance with docking by offering a superimposed grid on the real-time camera feed to give live distance indications. An augmented reality feature takes information from the bridge navigation systems and sensors and displays this information in real time on a live video feed to provide additional situational awareness, particularly during the voyage.

INTEGRATED VESSEL CONTROL WITH NACOS PLATINUM

The Wärtsilä NACOS Platinum system is a navigation automation control system that offers a unique combination of control systems for navigation, automation and dynamic positioning, as well as power and propulsion. By integrating all these functions into a single system, the vessel can be navigated, controlled and monitored from various onboard positions. Wärtsilä NACOS Platinum provides top-level scalability, flexibility and extensibility, which enables tailoring of the system to meet diverse and individual requirements.

The integrated nature of Wärtsilä NACOS Platinum makes it a central hub for access to insights, data, knowledge and intelligence—and can serve as part of the critical infrastructure for expanding autonomy solutions in the future. NACOS and automation helps to reduce complexity and can enable an unmanned control room, helping to reduce crew requirements and enable future bridge systems. NACOS also enables remote guidance and support for maintenance troubleshooting, which in many cases can remove the need for a visit by maintenance personnel to solve issues onboard.

TRACK PREDICTION AND ANTI-COLLISION SUPPORT WITH WÄRTSILÄ ADVANCED INTELLIGENT MANOEUVRING (AIM)

AIM, part of Wärtsilä Voyage's Fleet Operations Solution (FOS), is a track prediction system and anti-collision support tool designed to improve situational awareness and reduce the probability of officer inattention or poor judgement leading to an incident. It anticipates that vessels will move in compliance with collision regulations, but also needs to account for how humans interpret those regulations in various situations. The system provides a ship trajectory prediction for 15-20 minutes ahead for the area (with 98.5% accuracy) along with recommendations for safe and efficient manoeuvres to avoid collisions. There is also prediction of potential collision and grounding events. AIM is also useful for Wärtsilä Ship Traffic Control (STC) which provides tools for a coordinated global approach to maritime traffic control, monitoring and decision support. AIM is also part of the the Steering Control and Autonomy Lab simulator (SCALab), which allows users to test autonomous navigation solutions using a highly accurate digital twin of the vessel in a digital environment.

NEXT-GENERATION VESSEL CONTROL WITH THE WÄRTSILÄ SMARTMOVE SUITE

Wärtsilä Voyage has a long history in the development of advanced vessel control systems, including technologies such as dynamic positioning. This expertise provided a solid foundation for the development of our next-generation autonomous vessel control systems.

Wärtsilä's SmartMove Suite assists crews with challenging manoeuvres such as harbour entry, docking or-quay-to-quay transit. Full manoeuvring of the vessel is automatically controlled by the software; however, manual intervention and control is possible at any time. The automatic function allows the ship's officers to focus on situational awareness outside the wheelhouse, improving the reliability of operations. By providing consistent and repeatable operations, SmartMove helps to increase safety and reduce fuel consumption.

The **SmartMove** Suite is based around one of the two following solutions:

Wärtsilä SmartDrive

Wärtsilä SmartDrive unifies multiple controls into a simplified joystick, which provides control of vessel movement and basic station-keeping ability. Vessel speed and rate of turn are controlled, which allows the vessel to stay in one position when the joystick is centred—even in the presence of wind and currents. With fewer control handles, the operator can focus more on the situation surrounding the vessel and less on which handle does what, improving operational safety.

Wärtsilä SmartDock

Wärtsilä SmartDock provides docking, undocking and transit on repeat voyages. By providing consistent and repeatable docking, the system increases safety and reduces fuel consumption and vessel wear and tear. Wärtsilä SmartDock relies on docking sensors, dynamic positioning technology and automation to create an autonomous mooring operation.

Once configured in the system, the approach and departure from the same berth becomes repeatable. The system automatically follows the same track of waypoints, resulting in safer, repeatable docking that allows the crew to focus on other tasks.

The result is a mitigation of potential human errors resulting from ship's officers having to perform the same technical manoeuvres several times a day. This is especially important on, for example, larger ferries that must enter and leave tight docking spaces, where significant damage can be caused by forceful collisions with the dock walls.

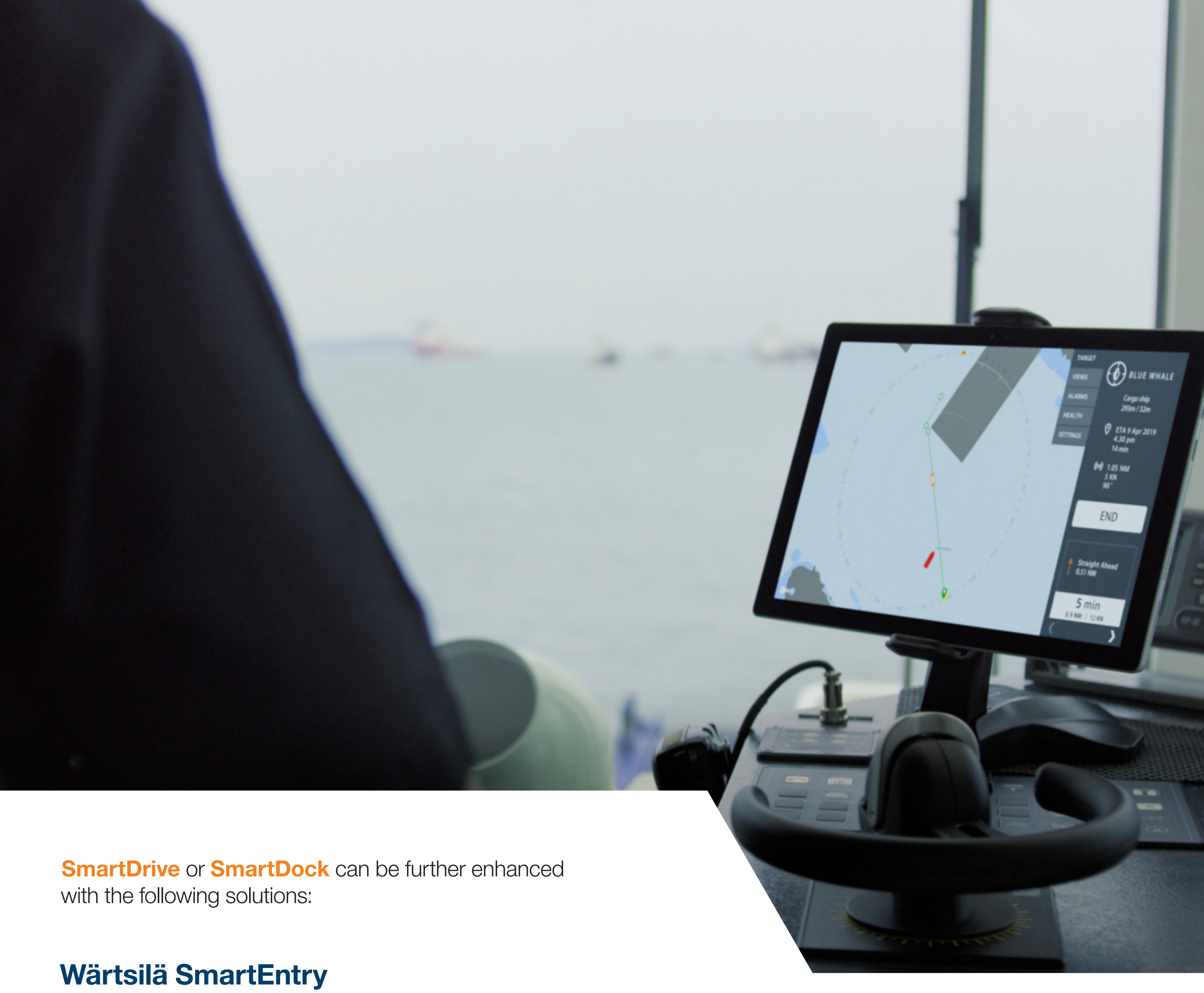
CASE EXAMPLE: THE AMERICAN STEAMSHIP COMPANY

The American Steamship Company (ASC) will be the first company to install the Wärtsilä SmartMove Suite for autonomous transit along the Cuyahoga River in Ohio, USA. ASC operates 12 carriers that traverse the winding, often narrowing, waterways and locks around the clock. SmartMove will help to solve the key issues affecting the Great Lakes shipping industry today, including tightening environmental regulations, increasing commercial traffic volumes and visibility restrictions.

Wärtsilä is providing a standard hardware setup with redundant controllers and displays, along with a sensor suite (comprising gyro, MRU, wind, GNSS and laser position sensors). This is connected to a single digital platform through which five software products are available: SmartDock, SmartTransit, SmartEntry, SmartPredict, and SmartDrive. The core blocks of software (including controllers, sensor processing, TAL, and track follow) are based on Wärtsilä's Dynamic Positioning portfolio, which has been in use over many years in some of the world's harshest environments.

CASE EXAMPLE: FOLGEFONN

In 2018, Wärtsilä Voyage successfully completed testing the SmartDock system on the Norwegian ferry Folgefonn. Autonomous operation was utilised uninterrupted for the entire route, visiting all three ports serviced by the ship. Once the operator selected the next destination berth, the operation was started by simply selecting "Sail", which authorised the autonomous controller to take control of the vessel. The ferry was able to leave the dock, manoeuvre out of the harbour, sail to the next port of call, manoeuvre through the harbour entrance and dock alongside the terminal—all without human intervention.



SmartDrive or SmartDock can be further enhanced with the following solutions:

Wärtsilä SmartEntry

By combining advanced manoeuvring software and positioning sensors, Wärtsilä SmartEntry provides automated alignment for lock and restricted harbour entrances. This reduces the potential for vessel contact with the lock and improves entry efficiency and repeatability.

Wärtsilä SmartPredict

Wärtsilä SmartPredict offers the latest advances in vessel motion prediction. Incorporating a full mathematical model of the ship into the software allows more precise prediction of vessel movement. Operators can see the impact of their actions on screen, enabling safer manoeuvring.

Wärtsilä SmartCommand

Wärtsilä SmartCommand allows true remote control of vessels from connected locations using existing network connectivity including cellular, Wi-Fi and satellite communications. Using a land-based operator terminal, remote vessel control is virtually the same as being onboard.

CO-CREATION OF A SMART NAVIGATION SYSTEM WITH THE WÄRTSILÄ INTELLITUG PILOT PROJECT

Wärtsilä teamed up with PSA Marine in Singapore for the IntelliTug project to create a smarter tug. The project is a co-creation project where all the partners work closely together. The system will perform a range of routine missions and is designed to further improve tug safety and efficiencies while reducing operator workload and the pressures of working in one of the world's most demanding harbour environments.

IntelliTug is an example of a project where autonomous development benefited from a strong co-creation approach as it helped bring many internal and external stakeholders together through an iterative and consultative process. Each stakeholder was brought in at different phases of the project to provide inputs and concerted effort that helped push the project forward to real-world adoption. The stakeholders included:

- PSA Marine, which provided operational and usability insights through their operations team and tug masters and their extensive experience working in the busy port.
- Maritime and Port Authority of Singapore (MPA), which provided some funding, a Maritime Autonomous Surface Ships (MASS) regulatory sandbox for physical testing, and appropriate test cases for vessel manoeuvres based on Singapore's port culture, as well as regulatory oversight.
- Technology Centre for Offshore and Marine, Singapore (TCOMS), which carried out further validation of the various data gathered from the sensor suite, as well as real-world performance of the tug through a physics-based digital twin that incorporated the effects of the physical environment faced in the sea trials.
- Lloyd's Register (LR), which has been closely involved throughout the project to support the development of the trials' safety case, while collaborating on the human factors and technology design processes.

The key capabilities of the **IntelliTug** include:

Enhanced situational awareness, smart navigation and SmartDrive

In this project, Wärtsilä combined a range of sensors and positioning technologies, including AIS, GPS, thermal and daylight video cameras, an AIS receiver, a motion reference unit and our RS24 radar. Combining the data from these different sensors using our sensor fusion engine allowed us to provide a far more accurate and reliable digital picture of what was going on around the IntelliTug.

The smart navigation system comprises Wärtsilä's SmartDrive system and the sensor suite, which uses sensor fusion to track objects and collision risks. The sensor fusion technology behind the IntelliTug will also provide the crew with an extra set of eyes, enhancing situational awareness and improving visibility in challenging conditions.

The tracked objects are then provided to a path-planning algorithm which plots an optimised route that avoids the detected collision risks by dynamically maintaining safe distances during navigation. These instructions are then sent to the SmartDrive system which executes the commands by navigating to the set waypoint. The SmartDrive system also enables the vessel to hold position without the need for a physical anchor or constant input from the vessel operator. When holding position, the sensor suite will alert the operator to any potential collision risks entering the vicinity of the vessel.

SIMULATION AND TESTING OF AUTONOMOUS OPERATIONS WITH WÄRTSILÄ SCALAB

Wärtsilä Voyage has developed one of the world's first simulators designed specifically for testing autonomous vessels, the Steering Control and Autonomy Lab simulator (SCALab). SCALab allows users to test and refine their autonomous navigation algorithms using a highly accurate digital twin of the vessel and its sensors in a safe digital environment. Proof of successful results from digital testing will make it possible to move on to sea trials within months rather than years, with the confidence and support of regulators and classification societies. SCALab also provides a platform for operators and crew to familiarise themselves with new interfaces and system components. The SCALab was used, for example, in the IntelliTug project to conduct digital testing of hundreds of test cases and first person-user tests of the smart navigation system.

7

Looking to the future

In this paper, we discussed how autonomous shipping solutions can be attained through three key enablers:

- Situational awareness based on a range of sensor technologies including radar, laser and cameras
- Decision making and logic capability based on AI-based methods like machine learning and smart algorithms
- Action and control systems that allow the safe and efficient manoeuvring of a vessel

As part of the journey towards autonomy, players in the maritime industry can already begin implementing targeted autonomous solutions that solve specific problems—a pragmatic, stepwise approach towards autonomy. At the moment, this includes helping people to do things better, more safely and more efficiently as well as enabling autonomous vessel control. It's also important to remember that the decision support systems of today can form the basis for the autonomous solutions of tomorrow.

WÄRTSILÄ AS A LEADER IN THE SMART MARINE ECOSYSTEM

Wärtsilä is at the forefront of harnessing the changes taking place in the shipping industry to deliver value and optimisation for its customers. By orchestrating these developments through the use of high levels of connectivity, digitalisation, automation and autonomy, Wärtsilä intends to lead the industry's transformation towards a Smart Marine Ecosystem.

Smart Marine is about ensuring that the industry can work together to tackle critical business and environmental challenges and collaborate on solutions that will achieve a more sustainable future for shipping. To this end, Wärtsilä provides energy, asset and voyage management systems that can help reduce emissions, increase safety and improve operational efficiency across the lifetime of our customers assets.

Autonomy solutions will undoubtedly play their part but as the Smart Marine Ecosystem becomes the industry's preeminent operating model there will be a myriad of other developments too: shared capacity will improve fill rates and reduce unit costs, big data analytics will optimise both operations and energy management, intelligent vessels will enable automated and optimised processes, and smart ports will deliver smoother and more efficient port operations.

Wärtsilä Voyage is focused on transforming how vessels perform their voyage by leveraging the latest digital technologies, to deliver a step-change in safety, efficiency, reliability and emissions. We are developing a unique integrated infrastructure that combines the bridge systems, vessel control systems, cloud data management, data services, decision support tools, and access to real-time information. We look forward to collaborating with you in creating the smart marine ecosystem of the future!

Get in touch and let's discuss how you can successfully move forward on your journey to smart autonomy

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WÄRTSILÄ

Wärtsilä Voyage radically transforms how vessels perform their voyage by leveraging the latest digital technologies, to deliver a step-change in safety, efficiency, reliability and emissions.

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