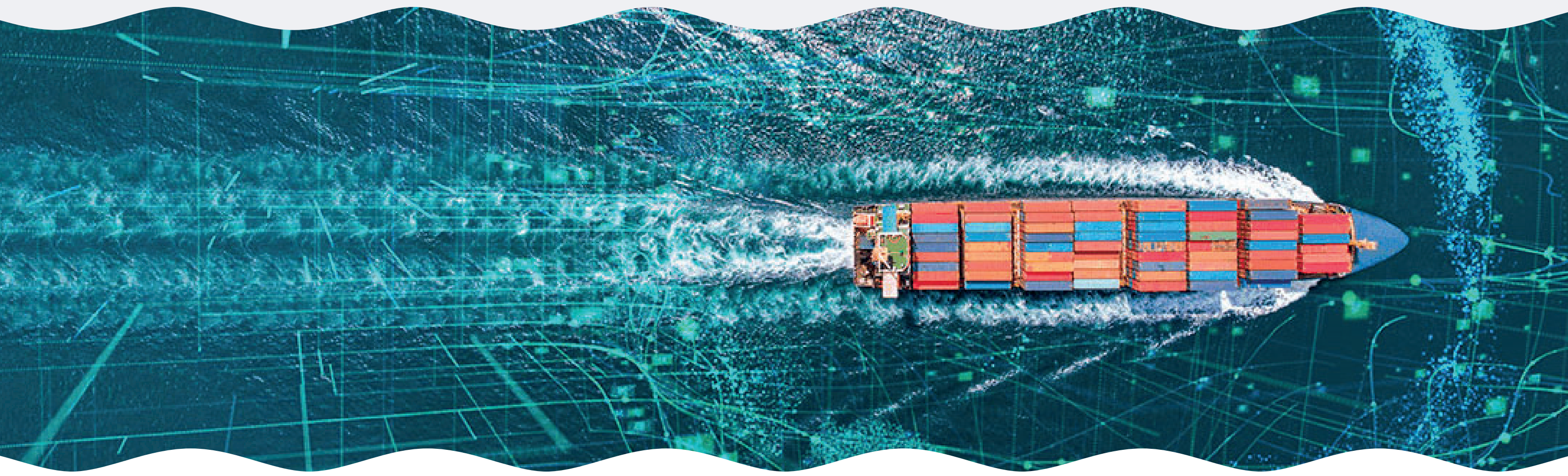
SEAMLESS

SAFE, EFFICIENT AND AUTONOMOUS: MULTIMODAL LIBRARY OF EUROPEAN SHORTSEA AND INLAND SOLUTIONS

Innovation flame: focus on the preliminary versions and specifications of building blocks, and the SEAMLESS Uses Cases

SEAMLESS aims to develop and adapt missing building blocks and enablers into a fully automated, economically viable, cost-effective, and resilient waterborne freight feeder loop service for Short Sea Shipping (SSS) and Inland Waterways Transport (IWT). The SEAMLESS building blocks will be verified and validated through full-scale demonstrations in selected real-world scenarios. These building blocks will support a 24/7 waterborne freight feeder loop service. They will be developed within the project as 'plug-and-play' modules that can be applied as required depending on the use case. They are classified into categories addressing autonomous vessels, port infrastructure, ship-port interactions, and the digital domain. All SEAMLESS building blocks, as well as the fully integrated version of the technological ecosystem, will be verified and validated through the SEAMLESS Use Cases.



Building Block #1 (DockNLoad)

1. Autonomous Mooring

A key part in creating a fully autonomous waterborne freight feeder loop service is making sure the vessels can moor themselves autonomously. MacGregor is further developing its autonomous mooring system (Figure 1) using a seven axis fully electric long range robot arm and fully electric automated tensioning system to place conventional mooring lines on ordinary bollards. The autonomous system must be able to always avoid collision while at the same time locate the correct bollards to use. For safe operations close to the quay, it must also compensate for the ship motions in all six degrees of freedom. The development in the SEAMLESS project is focused on perception technology to fully enable autonomous operation. A full-scale demonstration of the innovation will take place in WP7 also showcasing the integration with other building blocks.

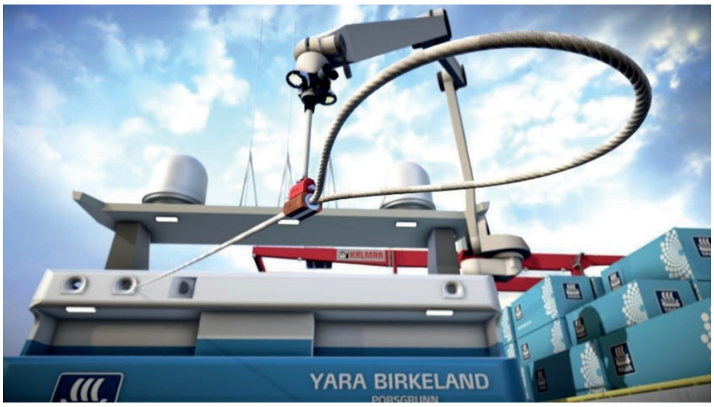


Figure 1: Illustration of the autonomous mooring system

2. Autonomous Cargo Handling

To analyse the efficiency of an on-board crane in an autonomous environment, MacGregor plans within the WP3.1 to design a new triple joint crane (Figure 2). So far, the output from Aegis and Moses has been evaluated. As part of this design, a concept for the spreader and crane interface, a head block will be designed, simulated and analysed. To speed up the development MacGregor can use, as a starting point, the simulation and graphics software developed in Aegis and Moses projects. With this software MacGregor can simulate different load cycles and operational limits. Further within the SEAMLESS project the newly created crane will be simulated in a relevant environment together with other SEAMLESS building blocks.

Figure 2: MacGregor vision of autonomous triple joint crane

3. VCOP

The development of the VCOP platform was initiated within the AEGIS and MOSES projects. Within these projects the system proofed its' necessity by aggregating required data for autonomous operations. All in all, the purpose of the VCOP is to provide a platform to assist vessel operators to create stowage plans together with loading and discharging sequences. The purpose of the development in more detail is to be able to create machine to machine connections to vessel and port operating systems. This enables reliable change management in a transparent way. Ideally the platform can create stowage plans directly from cargo bookings in a way that the information can be passed onwards to the autonomous crane and the autonomous horizontal equipment at the port. It is of utmost importance that the newly created features into VCOP are tested with a real supply chain information with other SEAMLESS building blocks within WP7 (Figure 3).

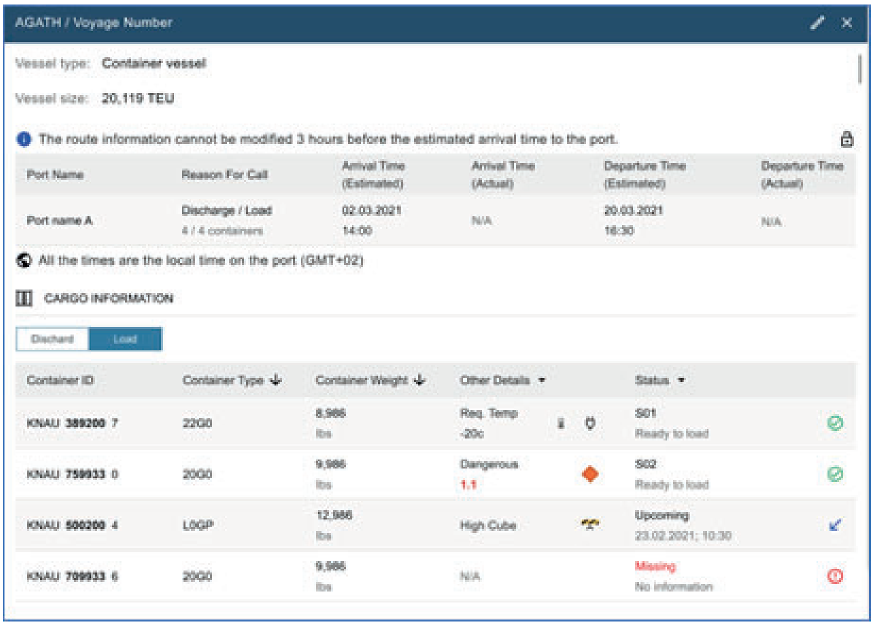


Figure 3: A view from VCOP: Operations, showing the status for each container to be loaded, in the current loading port.

4. AVSPM

The Autonomous Vessels Smart Port Manager (AVSPM) is a cutting-edge software tool designed to facilitate safe and efficient port calls for autonomous vessels. Operating within a sandbox environment at the smart port, AVSPM integrates seamlessly with both current and future smart port systems. This includes systems for port call bookings, traffic control and monitoring, environmental sensors, and traffic situational awareness, as well as adherence to traffic rules and notices. The AVSMM sandbox acts as a virtual representative of the smart port, interfacing directly with autonomous vessels and their respective remote operation centers (ROCs). Its primary goal is to enable safe, optimized, and crewless port calls for ocean-going, inland, and near-shore autonomous vessels. Key objectives of the AVSPM sandbox include managing the entire port call process—pre-booking, booking, execution, change management, and closure. It allows autonomous vessels to negotiate and execute port calls, perform navigation and maneuvering, plan and optimize routes, share situational awareness, and maintain a safe state throughout the port call. Additionally, AVSPM monitors the safe state from the smart port perspective and handles selected emergency situations. The system also meets basic non-functional requirements, including availability, performance, and security aspects. By integrating AVSMM into smart ports, we pave the way for a new era of autonomous maritime operations, ensuring safety, efficiency, and innovation in port logistics.

Building Block #2 (Modular vessel and operations concepts)

1. Further development of the AEGIS/AUTOSHIP rapid prototyping tool

SINTEF Ocean developed a tool named SIMPACT in the Horizon 2020 projects AUTOSHIP and AEGIS. It supports rapid prototyping of ship concepts by enabling early phase evaluations of cost, environmental, and logistical performance of the concepts in their intended operational environment. The performance evaluations are based on logistics simulations combined with hydrodynamic models. Ongoing developments are focusing on extending the hydrodynamic simulation framework to include the shallow and confined water effects for power predictions in inland waterways. In addition, a paper presenting the method behind the SIMPACT cost and emission predictions is being written. Going forward, the demonstration use cases will be modelled and evaluated using SIMPACT.

2. Methodology for selecting optimal green machinery and propulsion powerplants

ESI will assess and offer alternative zero emission power plants for the suggested ships and use cases. In this sense, based on simulations of suggested vessels and following the requirements (distance, usage, load conditions, sea state, etc.) zero emission power plants will be suggested that will meet the power needs of the ships. The zero emission power plants that will be studied are Batteries, Fuel cells (PEMFC and SOFC), selected for the level of maturity of the technology (PEMFC) and the efficiency (SOFC). For the FCs different fuels will be also assessed, such as CGH2, LH2, LOHC and ammonia. The methodology will begin with the evaluation of the naval characteristics of the ships, such as stability, load capacity, resistance (in different sea states), etc. At the next stage, the proposed zero emission power plants will be studied, to deduce which is the best candidate for fitting on board the ships, through multiple criteria, such as volumetric and gravimetric energy density, meeting the power requirements, vessel power plant arrangement, fuel storage, etc.

3. Development of a risk-based approval framework for autonomous ships

Guidelines for the approval of autonomous ships are focused on the development of concepts of operation, encompassing minimum risk conditions, safety philosophy, and hazard analysis. We are currently engaged in formalizing a concept of operation (ConOps), which includes delineating essential components like fallback strategies. Moreover, we are developing a formal process for hazard analysis based on the formalized ConOps. This research aims to simplify the process associated with the regulatory framework surrounding autonomous ships, while also ensuring a high level of safety. Results of an initial study, aiming to identify and understand potential hazardous scenarios related to autonomous ship operations, assessing safety implications across various operational phases and autonomy levels, will be presented at the upcoming ESREL conference.

4. Fault Tolerant COLREG-compliant GNC scheme

The Guidance, Navigation and Control scheme has become essential for rendering a vessel autonomous. To reach higher levels of autonomy, the vessel should be able to handle undesired, dangerous situations such as collisions with other ships, or grounding, or stranding. These situations are more possible to happen during inland-waterways and short-sea navigation. To this end, we are developing Guidance & Control methods that enable the autonomous vessel to navigate in confine waters while adhering to traffic regulations, even when faults or unauthorized actions affect the navigation system (i.e. sensors, automatic identification system (AIS)) and the actuators. These methods are developed by transforming traffic rules into a mathematical framework, and by using physical models together with input and sensor data to assess the healthy behavior of the vessel and to control it. Preliminary results of this research will be presented in the IFAC SAFEPROCESS Symposium in June 2024 and the IFAC FAC Conference on Control Applications in Marine Systems, Robotics and Vehicles in September 2024.

5. Development of the SEAMLESS ROC

In an automated, economically viable, cost-effective, and resilient waterborne feeder loop service as demonstrated in SEAMLESS, KONGSBERG will continue developing autonomous vessels and the Remote Operation Center from AUTOSHIP. The control system for an R&A vessel consists of several subsystems that together form the necessary functionality for autonomous operation. In an autonomous setting, we have defined three roles: Digital Master, Digital Navigator, and Digital Chief, representing the master, navigator, and chief on a manned vessel. Together, these roles form the digital orchestration of an autonomous vessel. In SEAMLESS, these digital roles will be further developed. The Remote Operation Centre (ROC) is a comprehensive workspace capable of monitoring and controlling remote and autonomous vessels. It supports both vessel navigation officer duties and chief engineer duties. The remote operation of the R&A vessel is performed from Remote Operation Workstations (ROWS), with Navigation ROWS for mission control, navigation, and maneuvering, and Engineering ROWS for monitoring the vessel's technical status and providing technical assistance (Figure 4). In AUTOSHIP, one operator monitored and controlled one vessel. In SEAMLESS, KONGSBERG will enable operators to manage more than one vessel, facilitating multi-vessel operation from the ROC.

Figure 4: Illustration of the navigation ROW (left) and the engineering ROW

Building block #3 (ModalNET)

1. ModalNET platform

ModalNET is one of the three building blocks that conform a fully integrated version of the technological ecosystem that is verified and validated through the SEAMLESS for a fully automated and economically viable, cost-effective, and resilient waterborne freight feeder loop service for Short Sea Shipping (SSS) and/or Inland Waterways Transport (IWT).

2. Platform's architecture for cyber-secure communication

Ensuring cyber-secure communication is of paramount importance for the implementation of ModalNET and its communication with the other building block components. Therefore, the adopted architecture supports the demonstration of preventive, protective, reactive and coercive measures against the identified misuse cases and threat scenarios. This approach is based on two pillars: a) the application of a risk management methodology to obtain a deep and accurate assessment of the maritime cyber environment, the risk it faces and to select the appropriate mitigation measures; b) the adoption of the Zero Trust paradigm to implement the deployment of the solution and its components.

3. Platform's computational engine for resilient logistics

The computational engine for resilient logistics (CERL) provides the methods and algorithms required for ModalNET to facilitate synchro-modal dynamic management of the supply chain. CERL will use advanced data analysis algorithms to align cargo demand and supply, supporting logistics planning and the timely identification of disruptions, faults and failures, and the optimization of supply chain services. Interacting with ModalNET, CERL will receive data from all entities in the supply chain, to provide optimal route alternatives and tangible benefits through optimization and collaborative matchmaking analyses - transpiring behind the scenes. The system orchestrates an intricate dance of data, culminating in an analytic compilation of the best available routes. These routes are discerned based on the individual preferences and search criteria posed by end users. CERL's integration with ModalNET not only streamlines operations but also enhances the overall efficiency and resilience of the supply chain, paving the way for the SEAMLEESS feeder loop service.

SEAMLESS Uses Cases

While the technical development of the building blocks is challenging in itself, the strategic aspirations of the project go far beyond this. What is needed from a logistics perspective is the seamless and economically viable integration of autonomous waterborne concepts into multimodal transport and logistics chains. To ensure this, the SEAMLESS use cases play a central role in gathering requirements and physically or theoretically testing the validity of the project's technological and organizational concepts. The use case landscape consists of a variety of relevant scenarios for automated and autonomous waterborne operations in short sea shipping and inland waterway transport in Europe. Physical demonstrations will take place in the **Northern European Use cas**e, which integrates the SEAMLESS building blocks into an emission-free feeder loop in the Bergen region, and in the **Central European Use Case** which elaborates on highly automated inland waterway transport in the hinterland of the Port of Antwerp connecting it to the Belgian and French canal network as well as to the port of Duisburg as Europe's largest inland port. To assess the transferability of the SEAMLESS components to other corridors and to explore further deployment opportunities and sustainable business models, six transferability use cases will be subject to a conceptual analysis. A first analysis of all SEAMLESS use cases can be found here. The next phase of the project will see the preparation of the physical and digital demonstrations as well as the conceptual evaluations – stay tuned!

Figure 5: SEAMLESS demonstration Use Cases

Consortium

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