ANNUAL REPORT 2025

SFI · AUTOSHIP

Autonomous ships for safe and sustainable operations

Norwegian Centre for Research-based Innovation

SFI · AUTOSHIP

NTNU | Norwegian University of Science and Technology

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Kystverket

HOST

NTNU
Faculty of Information Technology
and Electrical Engineering
Department of Engineering Cybernetics

Grafisk design og produksjon: NTNU Grafisk senter

CONTENTS

VISION

Our vision is to leverage the competencies of the complete Norwegian maritime cluster and consolidate Norway as a leading global actor within autonomous ships.

OBJECTIVE

The Centre for Research-based Innovation within Autonomous Ships will develop and manage technologies, systems and operations for safe, sustainable, secure and cost-effective autonomous sea transport operations.

The focus areas include:

- Enabling technologies like situational awareness, artificial intelligence, autonomous control and digital infrastructure.
- New business models and operational concepts like the adaptation of remote operation centres (ROC) and the development of cost-efficient logistical concepts and port solutions.
- Methods and models for monitoring risk and the clarification of the legal aspects of liability when a captain is not on board.

Sea trials with milliAmpere1. Left-right: Anastasios M. Lekkas, Miguel Hinostroza and Alexander Sandberg. Photo: Simon Lexau/NTNU

Anastasios M. Lekkas
Centre Director SFI AutoShip

Centre Director

SFI AutoShip has now crossed the midpoint of its lifecycle (2020–2028). In 2025, the Centre successfully concluded its mid-term evaluation, confirming the quality, relevance and progress of our research activities. The mid-term evaluation also provided us with the opportunity to summarize and reflect on our results by that time.

Between 2021-24, five researchers (three postdocs and two PhDs) completed their work in the Centre, all of whom remain in Norway and continue contributing to autonomous systems, with three now employed by SFI AutoShip partners.

By the end of 2024, 90 MSc theses had been registered, and the Centre's research had resulted in 77 journal articles, 56 conference papers, 158 dissemination activities, four reports, 18 innovation leads, five DOFIs and one patent application.

In 2025 alone, we added 23 journal articles (six co-written with user partners) and 17 conference papers (three co-written with user partners). Eight new innovation leads were generated, bringing the total to 26. Three PhD candidates successfully defended their theses this year, increasing the total number of graduates to eight. The number of associated MSc students now exceeds 100, and three additional webinars were organized, for a total of 18 webinars.

The three PhD candidates who completed their work in 2025, Daniel Menges, Luka Grgičević and Lukas Herrmann, addressed issues such as digital twins for situational awareness and optimal control, game-theoretical maritime guidance algorithms, and maritime radar detection and tracking of low-observable targets. These contributions encompass perception, decision-making and control, reflecting the breadth of the Centre's research. At the same time, we welcomed our final two PhD candidates Johannes Skarø and Mikkel Bergstrand and the final postdoc, Martin Baerveldt, who will strengthen significantly our ongoing work within situational awareness and mission planning.

International collaboration remains active, with exchanges involving the University of Genoa, University of California, Berkeley, and the National Institute of Standards and Technology (NIST).

Our user partners continue to participate actively in publications, innovation activities and Centre events.

I wish to thank all members for their continued dedication to SFI AutoShip's objectives. As the Centre moves toward its final phase, several researchers are expected to complete their work in 2026, and the overall research capacity will gradually decrease. At the same time, the activities will become increasingly focused, and the results more mature, building on the foundations established in the first half of the Centre's period. I look forward to the continuation of collaboration in 2026!

From the SFI AutoShip Days 2025. Photo: Kai T. Dragland/NTNU

Øystein Engelhardtsen
Group Leader Ship Autonomy -
Group Research and Development
DNV

Chairman of the Board

As Chairman of the Board, I am pleased to present the 2025 Annual Report of SFI AutoShip. With the Centre now well into its final phase, 2025 has been a year of increasing maturity and a focus on delivering impactful research results.

SFI AutoShip continues to bring research and industry together in a constructive manner. Across the work packages, results are steadily moving from early concepts towards solutions that address real operational challenges, supported by a structured, crosscenter overview of result maturity and innovation potential. The Centre's broad scope, spanning autonomy technologies, digital infrastructure, human factors, safety, and operations, remains a core strength. At the same time, SFI AutoShip has established itself as a recognized knowledge hub for autonomous ship research, both nationally and internationally, reflected in the volume and visibility of peer-reviewed publications in international journals and conferences.

A defining characteristic of the Centre is a strong focus on safety, assurance, and regulatory relevance. Safety considerations are embedded throughout the research, from technology development and human factors to testing, verification, and validation. This close link between research, safety, and regulatory needs is essential for building trust and will be instrumental in enabling a responsible and wider adoption of autonomous and remotely operated maritime systems.

Competence development is another important outcome. In 2025, several PhD candidates and postdoctoral researchers completed or reached key milestones in their work, and many are now contributing directly to industry, research or public organizations. More than one hundred master's students have now been involved in SFI AutoShip, many working on concrete use-cases and real data, creating value and competence that extends well beyond the Centre's lifetime.

On behalf of the Board, I would like to thank the Centre Director and Centre Management for their commitment and leadership, and all partners for their engagement. The Centre is well positioned to deliver valuable results also in the final phase, with a clear focus on research, implementation and impact.


Illustration: Bjarne Stenberg/NTNU

SFI AutoShip Facts 2025

8
WORK PACKAGES

23
PARTNERS

17
CONFERENCE PAPERS
(3 CO-AUTHORED WITH INDUSTRY PARTNERS)

23
JOURNAL PAPERS
(6 CO-AUTHORED WITH INDUSTRY PARTNERS)

PhD

Postdoc/researcher

COMPLETED ONGOING

Organisation

The Centre is hosted by the Department of Engineering Cybernetics (ITK) at the Faculty of Information Technology and Electrical Engineering (IE), NTNU. The Centre organisation includes the Centre Board, Centre Management, eight Work Packages (WPs), and two advisory committees.

In total, NTNU is involved with six Departments in three Faculties. IE Faculty: ITK, Department of Electronic Systems (IES), and Department of ICT and Natural Sciences (IIR). Faculty of Engineering (IV): Department of Marine Technology (IMT) and Department of Ocean Operations and Civil Engineering (IHB). Faculty of Architecture and Design (AD): Department of Design (ID).

The other research partners are SINTEF Ocean, SINTEF Digital, Institute for Energy Technology (IFE), and the University of Oslo (UiO).

Board meeting in June 2025, hosted by Equinor. Photo: Ingeborg Guldal/NTNU

Scientific Advisory Committee Leader
Thor I. Fossen, NTNU

SFI AutoShip Centre Board Chairman
Øystein Engelhardtsen, DNV

Innovation and Commercialisation Advisory Committee Leader
Kjetil Skaugset, Equinor

Anastasios M. Lekkas, NTNU**, Centre Director**

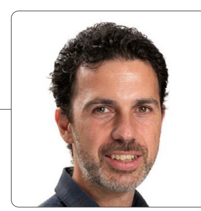
Roger Skjetne, NTNU, **Centre co-director**

Svein Peder Berge, SINTEF**, Centre co-director**

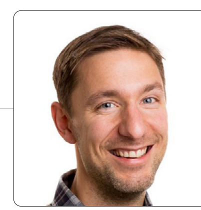
Ingeborg Guldal, NTNU, **Administrative Coordinator**

Frank-Robert Horgmo, NTNU**, Financial Adviser**

Edmund Førland Brekke, NTNU
WP 1 - Autoremote



Pierluigi Salvo Rossi, NTNU
WP 2 - Digital Infrastructure



Ole Andreas Alsos, NTNU
WP 3 - Human Factors

Ingrid B. Utne, NTNU
WP 4 - Safety and Assurance

Pauline Bellingmo, SINTEF
WP 5 - Sustainable Operations

Svein Peder Berge, SINTEF
WP 6 - Use Cases

Kjell Olav Skjølsvik, NTNU
WP 7 - Innovation and Commercialisation

CENTRE MANAGEMENT		
Name	**Institution**	**Role**
Anastasios Lekkas	Dept. of Engineering Cybernetics, NTNU	Centre director
Roger Skjetne	Dept. of Marine Technology, NTNU	Co-director
Svein Peder Berge	SINTEF Ocean	Co-director
Kjell Olav Skjølsvik	Dept. of Marine Technology, NTNU	Innovation manager
Ingeborg Guldal	Dept. of Engineering Cybernetics, NTNU	Administrative coordinator

CENTRE BOARD		
Name	**Institution**	**Function**
Øystein Engelhardtsen	DNV	Chairman of the Board
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Kjetil Skaugset	Equinor	Board Member
Jonathan Laporte	Fugro	Board Member
Jarle Fosen	Gard	Board Member
John Gabriel Östling	Grieg Star	Board Member
Torbjørn Pedersen	Idletechs	Board Member
Bjørn Axel Gran	IFE	Board Member
Sverre Rye Torben	Kongsberg Maritime	Board Member
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Vegard Evjen Hovstein	Maritime Robotics	Board Member
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Trond Solvang	UiO	Board Member

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Representing partner	**Institution**	**Function**
Kjetil Skaugset	Equinor	Leader
Are Jørgensen	DNV	Permanent member
Oda Ellingsen	Kongsberg Maritime	Permanent member
Vegard Evjen Hovstein	Maritime Robotics	Permanent member
Trond Johnsen	SINTEF Ocean	Permanent member
Kjell Olav Skjølsvik	NTNU	Permanent member
Ivar de Josselin de Jong	Fugro	Member (2024-2025)
Kenneth Johanson	NCL	Member (2024-2025)

SCIENTIFIC ADVISORY COMMITTEE		
Name	**Institution**	**Function**
Thor I. Fossen	Dept. of Engineering Cybernetics, NTNU	Leader
Paolo Braca	Centre for Maritime Research and Experimentation (CMRE), NATO Science and Technology Organization	Member 2022-2025
Nikolaos P. Ventikos	School of Naval Architecture and Marine Engineering, National Technical University of Athens (NTUA)	Member 2022-2025

Illustration: Bjarne Stenberg/NTNU

Research and Work Packages

Based on the Centre's objectives two overarching research questions have been identified:

- How can society benefit from autonomous shipping, in terms of reduced environmental footprint, economy, safety and sustainability?
- How can new standards, methods, regulations, digital twins and digital infrastructure be used to assure the required safety and security for autonomous shipping?

Answering these questions relies on a multi-disciplinary effort, multiple perspectives from different autonomy concepts, industrial and commercial applications, and the Centre stakeholders' interests, theory development, and experimental testing. This is best approached by framing and aligning Centre research according to use cases, where each use case represents a relevant context for autonomous ships.

We have 8 Work Packages in SFI AutoShip, 7 of which are devoted to research, use cases, innovation and commercialization, and 1 to management, communication, and dissemination. The 7 first Work Packages are presented on the following pages and show the ongoing research activities in the Centre. Some highlights from the final Work Package can be found in the subchapter on Events and Communication.

1 AutoRemote

WP Leader: Professor Edmund Førland Brekke
NTNU, Department of Engineering Cybernetics

Our objective is to develop perception and decision-making systems that will enable maritime autonomous surface ships (MASS) to accomplish their mission, including fallbacks for extraordinary events.

The work in WP1 has focused on the fundamental capabilities that are required to improve the safety and efficiency of the state of the art in maritime surface autonomy. This includes the design of algorithms suitable for detection, tracking, localization, docking and collision avoidance in coastal waters. In 2025, the research in WP1 has made advances both towards real-time applicability and how data and decisions can be interpreted in optimal or explainable manners. Regarding real-time applicability, highlights include closed-loop docking experiments with lidar-based collision avoidance, and the development of a CUDA accelerator for symbolic programming, which has vast potential to speed up solutions to the localization and mapping problems that are fundamental in robotics. Both these results will be presented at the International Conference of Robotics and Automation in Vienna this spring. Regarding the fundamental interpretation of data in situational awareness systems, focus areas have been radiometric radar odometry, free space estimation using camera and lidar, and extended object tracking (EOT). In particular, EOT methods that estimate the perimeter of vessels using a Gaussian process representation have been combined with environment mapping and refined with various subtleties such as multiple motion models. Furthermore, we are currently making strides towards real-time and closed-loop implementation of these methods. Bridging the gap between optimality and real-time applicability will be a main focus in 2026.

Daniel Menges defended his PhD "Digital Twin for Situational Awareness and Optimal Control of Autonomous Surface Vessels" in May 2025 and presented his results at the SFI Days. Two other PhD positions are finished, and the theses are due to be completed soon.

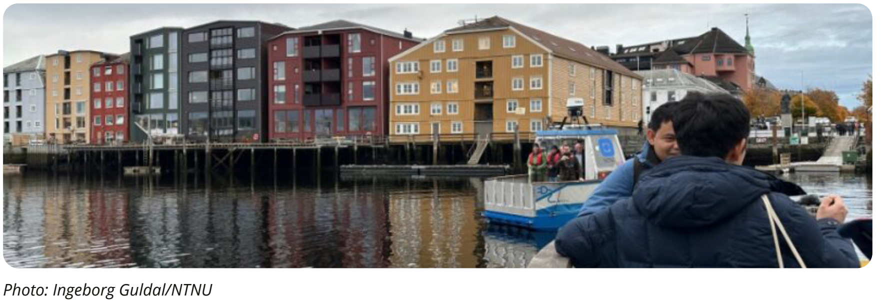


Photo: Ingeborg Guldal/NTNU

Martin Lukas Baerveldt

Combining Extended Object Tracking and Localization to Enhance Situational Awareness

Problem statement

To navigate safely, especially in confined waterways with dense traffic and limited maneuverability, autonomous vessels require situational awareness. This awareness is built from sensor data using models that describe moving vessels, the static environment (shorelines and infrastructure), and maritime-specific disturbances such as wakes. A key challenge is determining which observations correspond to which objects or environmental features, a process known as data association, while properly accounting for uncertainty in all estimates. Many current systems separate object tracking from localization and environment mapping, despite relying on the same sensor data. This fragmentation can cause errors in data association, inconsistent uncertainty handling, and reduced situational awareness. These issues increase the risk of collisions, reduce reliability of remote supervision, and limit safe deployment of autonomous vessels in complex maritime environments

Proposed solution

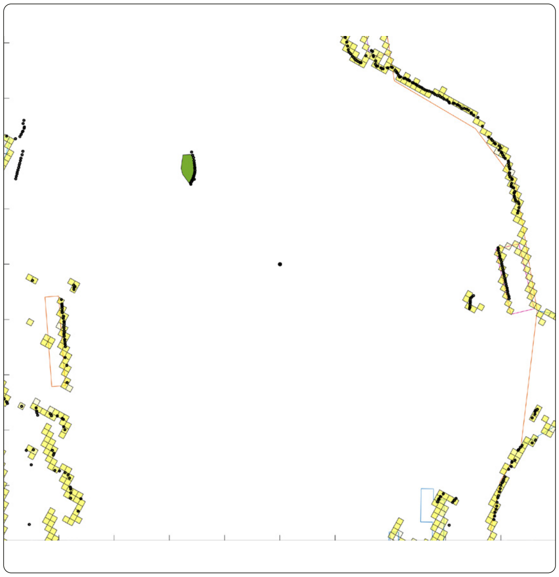
The solution is an integrated situational awareness system that combines vessel tracking, environment mapping, and own-vessel localization into a single framework. All sensor inputs are fused to create a consistent picture of the surroundings, with uncertainty explicitly represented and propagated to allow reasoning about possible errors in the system. Extended object tracking is a key component, representing vessels by their size, shape, and orientation rather than as points, enabling accurate predictions and risk assessment in confined waterways. Equally important is the correct association of sensor measurements with both moving vessels and static features, ensuring that information from extended object tracking is used reliably and supports accurate localization and mapping. The system is designed to support integration of multiple sensors, allowing their respective strengths to be leveraged to improve overall capability.

How can the results be utilized?

Partners developing autonomous vessel systems can use the solution as a framework to enhance sensor fusion, perception, and situational awareness capabilities. As such, it can provide new technical solutions that enable autonomous vessels to operate in more complex environments.

Main activities during 2025

- Conference paper: "Methods to Handle Interior and Boundary Measurements for the Gaussian Process Model | IEEE Conference Publication", FUSION 2025, IEEE Xplore.
- Finished a journal paper "Combining Occupancy Grid Mapping and Extended Object Tracking with the Poisson Multi-Bernoulli Mixture Filter" to appear in IEEE Journal of Oceanic Engineering.
- Co-supervised 2 master students, resulting in 2 submitted publications; started co-supervision of 5 additional master students, 4 engaged with SFI AutoShip partner projects.
- Presented at the SFI AutoShip Days.



A visualization of the system in an inland waterway, a vessel is being tracked as an extended object (green) while the surrounding static environment is incorporated into a grid map. Also shown is the current (LiDAR) sensor scan.

Emil Martens

Caspar (CUDA Accelerator for Symbolic Programming with Adaptive Reordering)

Problem Statement

Many core tasks in robotics, like motion planning, state estimation, and sensor calibration, are naturally formulated as nonlinear optimization problems. While constrained nonlinear optimization requires the solution to satisfy specific equality or inequality constraints (e.g. collision avoidance or robot joint limits), unconstrained optimization seeks to minimize the cost of problems without such restrictions.

The latter is generally preferred in robotics, particularly in real-time systems, due to its relative implicitly and computational efficiency, especially when the problem-specific structure allows constraints to be handled implicitly.

While existing algorithms and implementations exist to solve these types of problems, Caspar offers a new way to generate solvers from symbolic residual functions that leverage the power of the GPU to deliver state-of-the-art performance.

Proposed Solution

Caspar is a library that makes the power of modern GPUs more accessible in robotics and provides a state-of-the-art nonlinear GPU solver for problems such as bundle adjustment and state estimation. Caspar bridges the gap between expressive symbolic programming in Python and high-performance

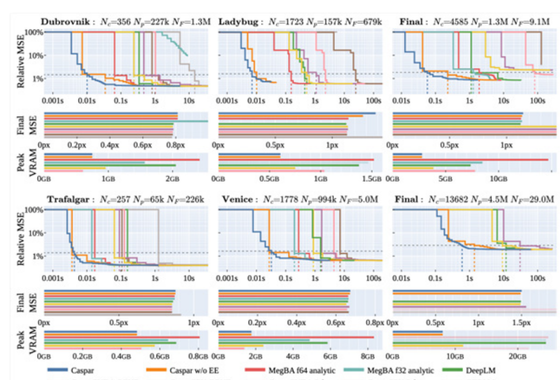
GPU runtimes in C++ by automatically generating optimized CUDA kernels from symbolic expressions. Building on the SymForce library, users can easily define and combine symbolic expressions and Lie group operations to generate custom CUDA kernels.

To use Caspar as a solver, users need only define the residual functions; Caspar then uses symbolic differentiation to generate the necessary GPU kernels and interfaces to perform tangent-space nonlinear optimization.

When compared to other state-of-the-art bundle adjustment solvers, Caspar demonstrates a speedup of 5-20x compared to the best-performing alternative. Caspar is released as part of SymForce under the Apache 2.0 license and is available at https://github.com/symforce-org/symforce.

Main activities during 2025

- Became a dad.
- Wrote Caspar.
- Supervised two master theses.
- Presented Caspar to the consortium at the SFI Days in October.



Relative Mean Squared Error (MSE) over time, GPU memory usage and final MSE for different solvers on multiple BAL datasets, characterized by Nc cameras, Np points, and NF reprojection factors.

Henrik Dobbe Flemmen

Radar based SLAM for autonomous ships

Problem statement
Global Navigation Satellite Systems (GNSS) is the primary technology for positioning for both manned and unmanned ships. Although GNSS is highly available, very precise and has high integrity, it might fail in rare cases.

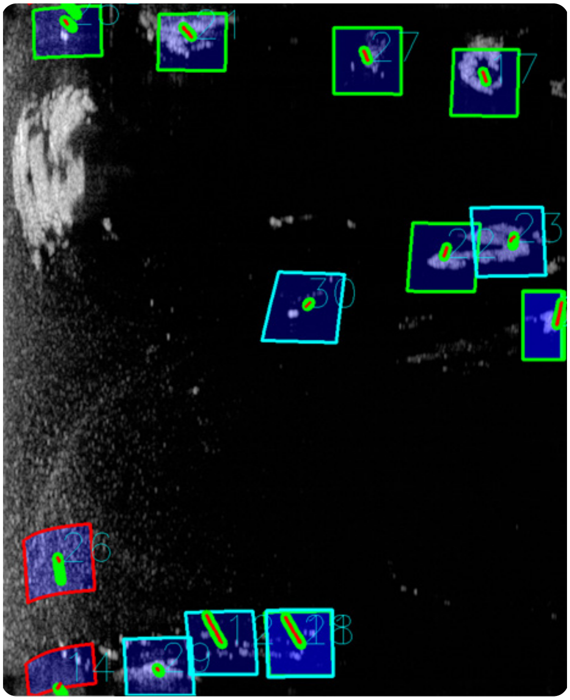
Traditional ships can in those cases fall back to traditional manual navigation methods, but autonomous ships need an automatic fallback. No other technology can fully replace GNSS in all aspects, so we need to compromise on accuracy, operational area, measurement delay and/or robustness. I try to solve the problem of GNSS redundancy for the case when the ship is in vicinity of land.

Proposed solution
Using the navigational radar of the ship to measure the motion of the ship relative to land has the inherent limitation of not working in the open sea, but we expect it to be more accurate than more general approaches.

We do this by scanning the radar image for distinct features, and heuristically filtering out sea clutter. Then we track the features in the consecutive frames, and use the feature tracks to probabilistically estimate the ship's motion.

If we know where the ship was when the GNSS failed, we can use this radar system to know where we are. Measuring the velocity over ground can also be useful even when we don't know the starting point. E.g. if we let the ship stay stationary as a fallback, or as an assistance to more manual remote operation.

Main activities during 2025
- Experimented with temporal averaging of the tracked features.
- Experimented with a motion model in the backend.



An example radar image with the tracked features illustrated. The green ones are considered more reliable than the blue ones and the red ones are considered noise. The green paths are the correct path for the feature, extracted from the GNSS of the ship and the red path is the estimated path from the radar processing algorithm.

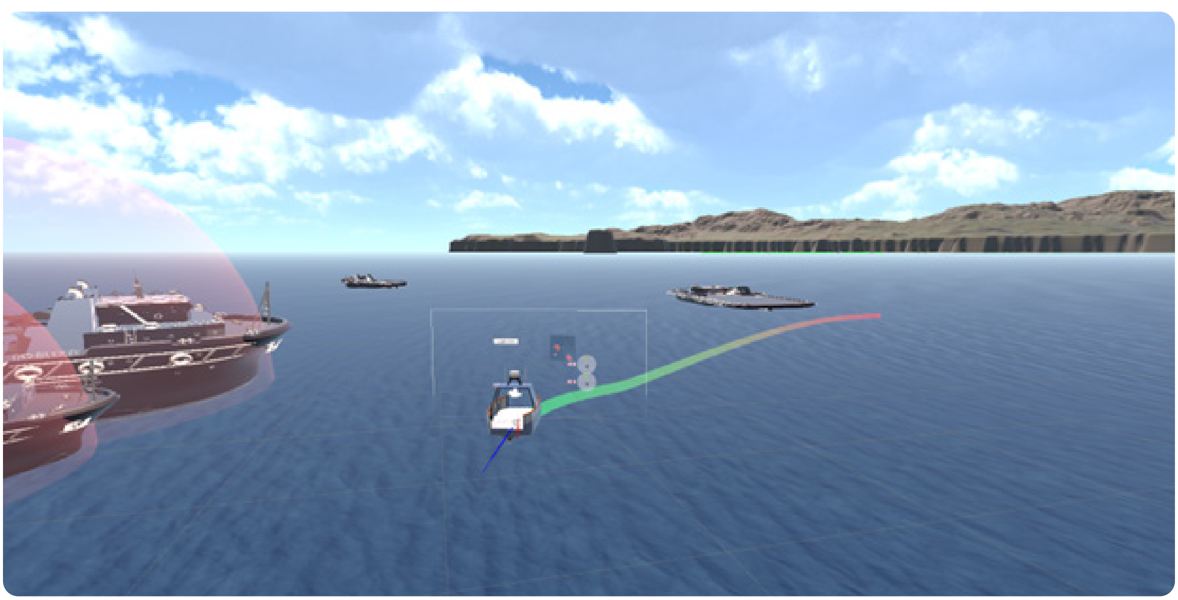
Daniel Menges

Digital Twin for Situational Awareness and Optimal Control of Autonomous Surface Vessels

Problem statement
This PhD project aims to enhance situational awareness for autonomous surface vessels and utilize this knowledge for optimal control by integrating digital twins. Reliable environmental perception and awareness of a vessel's internal state, such as engine conditions, are critical for improving decision-making and preventing outages during operations. Digital twins serve as key enablers, providing a safe environment for testing and training modern algorithms by simulating real-world scenarios. To achieve this, the digital twin must combine accurate models, real-time data streams, and intelligent algorithms to deliver optimal, real-world decisions.

Proposed solution
This research proposes solutions to enhance digital twin capabilities, including scalable frameworks integrating diverse data sources, predictive functionalities, and advanced control techniques. It introduces adaptive tools for estimating environmental forces, proactive control methods for collision avoidance, and efficient algorithms for anomaly detection and big data processing. A focus is placed on creating digital twins for predictive monitoring and utilizing learning-driven frameworks for adaptive control and model identification. In addition, safety-oriented control schemes enable reliable operations, while robust object-tracking techniques, combining LiDAR and AIS data, improve situational awareness. These advancements collectively optimize decision-making and operational efficiency in the context of autonomous surface vessels.

Main activities during 2025
- Daniel defended his PhD thesis, "Digital Twin for Situational Awareness and Optimal Control of Autonomous Surface Vessels" in May 2025.
- Co-authored "Digital twin syncing for autonomous surface vessels using reinforcement learning and nonlinear model predictive control", Nature, Scientific Reports.
- Presented the results from his research to the consortium at the SFI Days in October.



Digital twin demonstration of the milliAmpere ferry on the Trondheim fjord executing the predictive safety filter to generate a safe path.

Simon J. N. Lexau

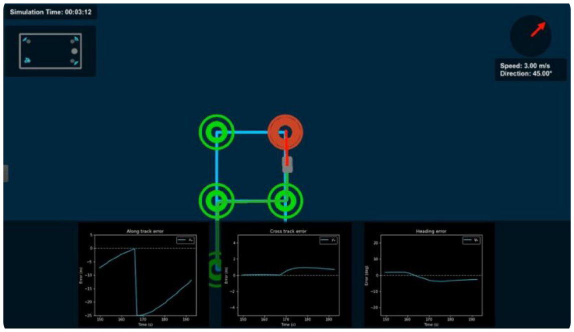
Autonomous docking of marine surface vessels

Problem statement
The development of Autonomous Surface Vessels (ASVs) continues to advance toward practical implementation in maritime operations. My research focuses on autonomous docking systems capable of handling complex port environments through advanced control algorithms and adaptive perception systems that maintain safety and efficiency in dynamic conditions.

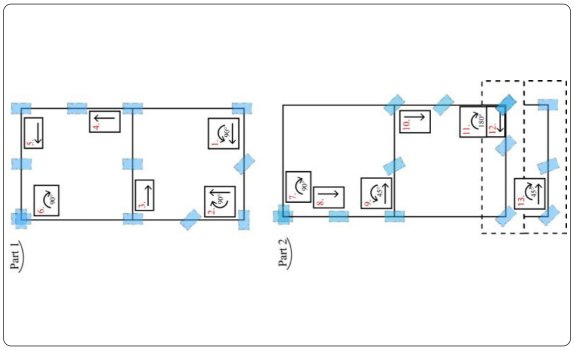
Proposed solution
My PhD research develops planning algorithms and advanced control systems for autonomous vessel navigation, with emphasis on safe trajectory following and energy-efficient operations in challenging maritime environments. As I approach PhD completion, final experiments are planned to validate the RL-NMPC control system on the MA1. The successful integration of adaptive perception with advanced control algorithms represents a significant step toward practical autonomous docking systems.

How can the results be utilized?
The demonstrated technologies show promise for implementation across various vessel types, from research vessels to commercial applications, providing robust autonomous docking capabilities in complex maritime environments.

Main activities during 2025
- Breakthrough Sea Trials: In collaboration with master student August Fors, we conducted what are likely the first adaptive docking experiments for vessels of this class. Using LiDAR-based perception, we successfully demonstrated autonomous docking with adaptive pose selection, enabling the vessel to identify and navigate to safe docking regions in real-time. These groundbreaking experiments were performed on the milliAmpere1 (MA1) vessel.
- Conference Acceptance: The adaptive docking work resulted in the paper "Autonomous Docking Using LiDAR-Based Tracking and Adaptive Pose Selection: Closed-Loop Sea Trials," which has been accepted for presentation at ICRA in Vienna in June 2026.
- RL-NMPC Development: Simulation results demonstrated that the Reinforcement Learning-based Nonlinear Model Predictive Control (RL-NMPC) system performs superior to both PID control and pure NMPC. This work has been submitted to ECC and is currently under review. Sea trials are planned to validate the simulation results on the MA1 vessel.
- Mission Planning Research: Collaborative work with Miguel Hinostroza advanced mission planning capabilities, with all experimental validation conducted on the MA1 vessel.
- Co-authored "Model Identification, Dynamic Positioning, and Thrust Allocation System for the milliAmpere1 Autonomous Ferry Prototype: Field Trial Results", IEEE Access.



Snapshot of RL-NMPC controlling the milliAmpere 1 on the 8-corner test in a simulation environment, under the presence of wind.



A diagram depicting the maneuvers associated with the 8-corner test. The test is designed to capture data necessary to perform system identification, and makes no assumption of hull symmetry.

Joel Jose

Automation transparency during supervisory control of maritime collision avoidance systems

Problem statement
The current era of Maritime Autonomous Surface Ships (MASS) will need to interact and co-exist with humans in the ocean space, both with external actors operating on manned vessels, and with human masters responsible for supervising MASS (according to working reports of IMO MASS Code). However, differences in how humans and machines deal with Situational Awareness (SITAW), risk analysis, decision-making and action execution lead to the necessity in effective exchange of knowledge about these processes, especially for autonomous collision avoidance systems (CAS) during high-risk situations. In addition, human-machine-interaction is a key feature that is overlooked in current CAS, which can greatly improve co-existence and collaboration between MASS and human actors.

Proposed solution
Development of interfaces for existing collision avoidance algorithms to facilitate exchange of knowledge and interaction with humans:
- Highlight relevant decision-making processes of a CAS by designing interfaces that display transparency information with human-centric explanations, aiding a human supervisor in validating the system's reasoning for avoidance maneuvers.
- Use of LLMs as a reliable conversational tool for external actors and human supervisors to interact with the CAS by providing high-level instructions, receiving explanations, and collectively resolving high-risk situations.
- Qualitative and quantitative evaluation of the proposed interfaces through experimental trials with maritime navigators in a supervisory setting.

How can the results be utilized?
The research output from this PhD project is directly linked to enhancing supervisory control of MASS from Remote Operation Centers, or by navigators onboard, and co-existence with conventional ships. Effective monitoring and interaction of autonomous navigation systems forms a crucial intermediary and possibly long-term solution for MASS to be reliably deployed in the ocean space. Industries working on the development, remote operation and bridge design for MASS can greatly benefit from interfaces for communicating with a CAS. Ongoing collaboration with Shore Control Lab, Nyhavna demonstrates this use case.

Main activities during 2025
- Submitted conference paper to ICRA 2026: "Automation Transparency in Maritime Collision Avoidance through Contrastive Explanations".
- Mentored a student team in the development and testing of a competition USV for Autodrone 2025.
- Contributions towards data visualization and simulated data collection in an NTNU discovery project on evaluation and assurance of collision avoidance maneuvers.
- Initiated collaboration with Shore Control Lab, Nyhavna, towards the development and testing of an interactive and explainable interface for collision avoidance systems on a Remote Operating Center.

Concept illustration of Automation Transparency for Autonomous Vessels. Generated by ChatGPT.

Miguel Hinostroza

Mission Planning for Autonomous Surface Vessels

Problem statement
Autonomous surface vessels (ASVs) have become a strategic priority in several countries, and numerous research and industrial initiatives are focused on addressing the associated technological and operational challenges. A central challenge in achieving ASVs autonomy lies in the mission planning system, an architectural layer responsible for interpreting high-level commands, reasoning over spatiotemporal constraints, and generating executable tasks. Although research on ASV mission planning has received increasing attention, systematic validation that integrates both simulation-based studies and real-world experimental evaluation remains limited.

Proposed solution
The solution proposed in this research is a ROS-based mission planning framework for ASVs that integrates simulation and real-world validation within a unified architecture. At its core, the system employs a temporal planner formulated as a Simple Temporal Problem (STP), enabling explicit representation of and reasoning over temporal constraints such as task ordering, durations, and synchronization among mission elements. This formulation allows the planner to generate feasible and temporally consistent mission plans while remaining computationally efficient and suitable for online execution. By combining temporal planning with standardized middleware and real-world testing, the proposed framework addresses key limitations of existing approaches related to robustness, comparability, and practical deployability in maritime mission planning.

How can the results be utilized?
The developed mission planning system has been implemented onboard the milliAmpere 1 research ferry prototype, and provides a practical and flexible platform for researchers and partners in the SFI to develop, test, and validate autonomous navigation, control, and decision-making algorithms under real operational conditions.

Main activities during 2025
- Journal paper: "Model Identification, Dynamic Positioning, and Thrust Allocation System for the milliAmpere1 Autonomous Ferry Prototype: Field Trial Results", IEEE Access.
- Conference paper: "MilliAmpere1 Autonomous Ferry Prototype: Hardware and Software", OMAE 2025.
- Presented research findings at the 44th International Conference on Ocean, Offshore and Arctic Engineering (OMAE 2025), Vancouver, BC, Canada, June 22–27, 2025.
- Delivered an SFI AutoShip webinar titled "Results from Sea Trials with milliAmpere 1."
- Conducted experimental execution supporting three Master's theses on path planning and collision avoidance for autonomous surface vessels.
- Developed a ROS-based mission planning system for the milliAmpere1 autonomous ferry prototype.

milliAmpere1 ferry during mission planning experiments. Photo: Miguel Hinostroza/NTNU

Johannes Robert Skarø,

Safe-Space Estimation for Autonomous Surface Vessels

Problem statement
The research addresses the problem of reasoning about future navigable space for autonomous ships operating in dynamic and uncertain maritime environments.

While existing situational awareness systems estimate vessel states and motion, they do not provide a direct representation of which regions of the environment will remain safe for navigation. Current approaches insufficiently account for vessel interactions, spatial extent, uncertainty in detections, and situations where AIS data are unavailable.

This problem is relevant for parters of SFI AutoShip, as it limits the ability of autonomous ship systems to consistently assess collision risk and maneuver feasibility in complex and high-traffic environments.

Proposed solution
The result of the research is a situational awareness solution that provides a probabilistic estimate of current and future safe navigable space around an autonomous vessel.

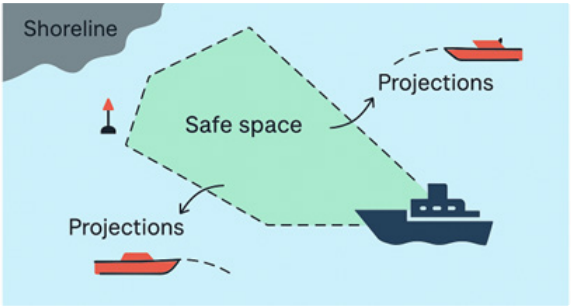
The solution delivers a unified environment representation that integrates dynamic traffic, static obstacles, and navigational constraints, and explicitly identifies which regions remain collision-free over a given time horizon. Target vessel motion, interactions, spatial extent, and uncertainty are reflected directly in the predicted safe space, enabling downstream planners to evaluate risk and maneuver feasibility in a consistent manner.

The solution supports integration between perception, prediction, and planning for autonomous ship operations in complex maritime environments.

How can the results be utilized?
The result can be utilized by partners in SFI AutoShip as a component in situational awareness and collision-avoidance systems for autonomous ships. It can be implemented by technology providers as part of perception and prediction stacks, enabling planners to directly query future safe navigable space rather than relying solely on object-level predictions.

In addition, the solution can be applied in decision-support tools for manned vessels to improve navigational safety in complex traffic environments.

Main activities during 2025
- Conference paper: "Stixel-based Free Space Estimation for USVs using Stereo Camera and LiDAR", FUSION 2025.
- Completed the research plan and most of the coursework.
- Prepared a conference paper for FUSION 2026, titled "Predicting Future Occupancy from Extended Object Tracker Outputs".
- Planning field trials with mA1 to verify the free-space-estimation system in a closed loop during autonomous docking.
- Presented MSc thesis research and PhD plan at the SFI Days in October.



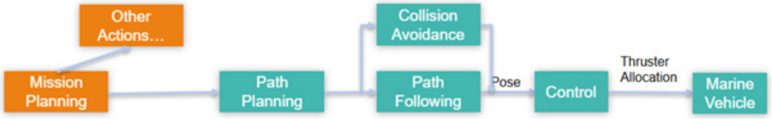
Conceptual illustration of safe-space prediction in a maritime environment. The predicted motions of surrounding vessels and static constraints define the region that remains safe for navigation.

Mikkel Bergstrand

Mission Planning for MASS systems

Problem statement

Mission planning seeks to fill a void in the MASS autonomy stack by acting as a high-level decision-making module. Its role is to guide low-level systems in carrying out abstract tasks and to manage contingency scenarios in a structured and predictable way.



The figure above illustrates where the mission planning module fits in alongside the rest of the ship. The mission planner is responsible for informing the path planner where to go. It assumes that the path planner finds a feasible path from point A to point B, including generating intermediate waypoints. In addition to navigation, the mission planner coordinates actions such as loading, unloading, docking, or switching between operational modes.

The module also behaves as a high-level state machine. It can transition the vessel into operational states like docking, transit, or dynamic positioning. When contingencies arise—such as sensor faults or communication failures, the mission planner can instruct the vessel to enter fallback modes. Examples include holding position or navigating to the nearest safe harbour.

Proposed solution

As outlined in the research plan, the work will proceed along three main tracks:
1. Evaluate existing AI planners for suitability in real-time MASS operations. This includes formulating planning problems to test on NTNU's experimental vessel, the milliAmpere. The initial focus is the Simultaneous Temporal Planner (STP).
2. Discuss and collaborate with partners to create and solve planning problems that are industry relevant.
3. Assess the need for a new planner tailored for real-time MASS applications. Possible research directions include:
- Improving classical and temporal planners.
- Incorporating uncertainty in actions, by means of Markov Decision Processes.
- Incorporating Reinforcement Learning to improve the planner.
- Using Large Language Models to generate planning domains and problems, reducing reliance on PDDL.

How can the results be utilized?

AI-based mission planners can support a range of domain-specific tasks:
- Ferry operations: Efficiently manage passenger loading/unloading and route planning while maintaining fuel constraints.
- Cargo operations: Automate loading and unloading in ways similar to classical BLOCKSWORLD domains, making the problem well-suited for AI planning.
- USV missions: Plan visits to multiple locations, incorporate mission-specific actions such as imaging or surveying, and optimize routes under fuel constraints.

Main activities during 2025
- Researching and understanding AI planning algorithms.
- Getting familiar with existing AI planners, the main ones being the Simultaneous Temporal Planner (STP) and the DiNO planner, which are temporal planners suited for mission planning for the real-time maritime domain.
- Getting familiar with and modifying the milliAmpere source code, which is built on ROS (Robot Operating System). The modifications to the code have the goal of better facilitating real-time mission planning on the milliAmpere.

2 Digital Infrastructure

WP Leader: Professor Pierluigi Salvo Rossi, NTNU, Department of Electronic Systems

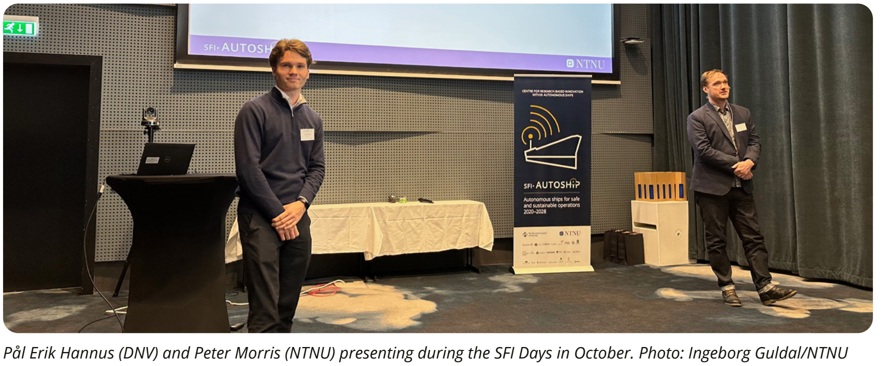
Our objective is to develop reliable and secure data transfer among the ship, the RCC and other marine traffic, allocated according to operational needs.

The digital infrastructure behind autonomous maritime systems is an IoT system, where nodes are sensors on ships or on-land centres, each with different partial view, different equipment, asymmetric links, and operating in non-stationary local and global conditions.

Understanding and comparing effective ways to collect and combine the information and provide a coherent scenario is challenging.

In 2025, advanced methods for object detection and tracking based on the "track-before-detect" principle were developed and validated in maritime scenarios. The simulator to test the robustness of collision and grounding avoidance systems in presence of situational awareness system noise, degradation, and breakdown, is being further developed in collaboration with DNV. New channel models for the phase distribution and correlation of the scattered field from the sea have been developed and verified numerically. Gaussian mixture models have been exploited to design methods for channel quality prediction in presence of spatially-correlated small-scale and large-scale fading.

Lukas Herrmann defended his PhD "Marine Radar Detection and Tracking of Low-Observable Targets" in December 2025 and presented his results at the SFI Days.



Pål Erik Hannus (DNV) and Peter Morris (NTNU) presenting during the SFI Days in October. Photo: Ingeborg Guldal/NTNU

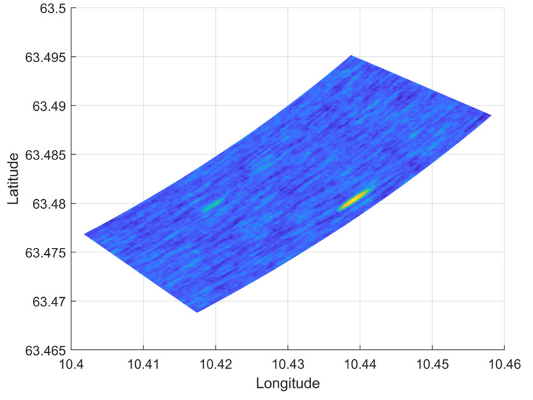
Lukas Herrmann

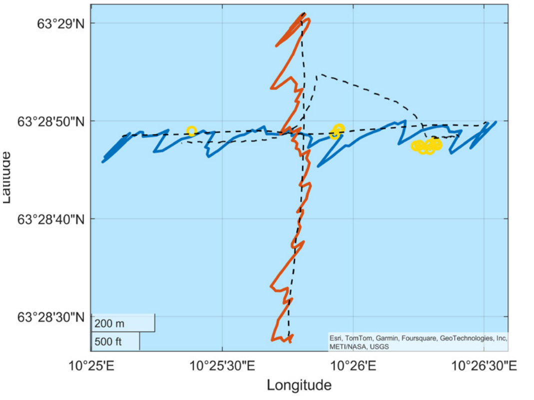
Maritime Radar Detection and Tracking of Low-Observable Targets

Problem statement
In recent years, the idea of autonomous shipping has become more concrete since autonomy has the potential to revolutionise the maritime industry by enhancing safety, reliability, sustainability, efficiency, and ultimately cost optimisation. For the whole concept to work, every vessel must know its own position and the position of all the other vessels in its vicinty to avoid collisions and effectively enable optimal path planning. To realise the full potential of autonomous operations, every vessel must possess this comprehensive situational awareness. This becomes particularly interesting in harbours and close-to-shore areas since they are busier, less predictable, and vessels such as small boats or kayaks can appear. These low signal-to-noise ratio scenarios with low observable targets are challenging especially paired with unwanted sensor disturbances caused by the sea surface under different weather conditions. Further, not all vessels are equipped with sensors or enough of them. This can be due to various reasons. Sensors are expensive, they take up space, they require special knowledge, and sometimes they are just not accurate enough which eventually makes it difficult for the vessels to be aware of their surroundings.

Proposed solution
The main focus of this PhD project is to develop a shore-based radar network, consisting of several radars at multiple sites which is capable of detecting vessels within the observed area and distributing the position information of all the tracked targets. The land-based hardware of the system is more powerful than standard hardware on ships and is additionally combined with complex algorithms. Those new methods and algorithms are focused on sensor fusion and track-before-detect techniques to tackle the challenges of the detection and tracking of targets in low signal-to-noise ratio maritime scenarios including considerations regarding real-time capabilities.

Main activities during 2025
- Lukas defended his PhD thesis "Maritime Radar Detection and Tracking of Low-Observable Targets" in December 2025.
- Journal papers: "Target Detection in Maritime Radar Tracking Based on Spatial Image Gradients", IEEE Sensors Journal. "Histogram-Probabilistic Multi-Hypothesis Tracking with Integrated Target Existence", IEEE Transactions on Aerospace and Electronic Systems.
- Conference paper: "Track Initiation and Adaptive Target Birth in Existence-Based Poisson Histogram-PMHT", 2025 IEEE Radar Conference.





A single radar scan (left) observing parts of the Trondheim fjord and corresponding track-before-detect tracking results compared to GNSS ground truth (right).

Peter Morris

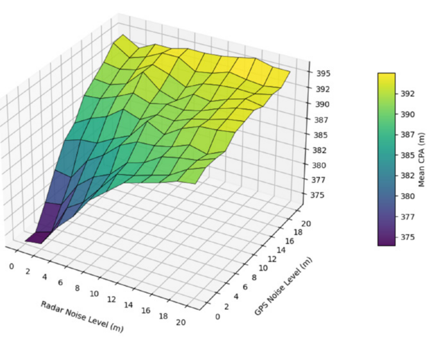
Data Fusion in Maritime IoT

Problem statement
The transition to autonomous vessels promises significant benefits, but designing and validating these systems is a difficult task. There are an immense number of variables, from geographical location, weather and sea conditions, sensor limitations, and the behavior of other vessels. Physical testing at sea is costly, time-limited and difficult to control and reproduce. Autonomous vessels consist of many tightly integrated systems and components that depend on each other for safe operation. To develop reliable systems, it is necessary to understand how faults are handled and how failures can propagate across system boundaries. Testing these behaviors is not easy to do in a live environment, as failures can be inherently dangerous, and there is an enormous variety of scenarios that should be tested. Meanwhile, there is a strong interest in investigating and expanding the capabilities of autonomous vessels. Developing systems that can allow them to collaborate and coordinate effectively can give them increased usefulness.

Proposed solution
To address these challenges, we are developing a simulator that can model a wide variety of sensors, systems and environmental conditions. The simulator will support systematic testing of the overall behavior of autonomous vessels in controlled and repeatable scenarios. The simulator models vessel sensors (including realistic noise and failure modes), the situational awareness (SA) systems that rely on these measurements, and the navigational and collision avoidance (CA) systems that make decisions based on the output of the SA systems. This framework allows flexible configuration of sensor availability, noise characteristics, failure behaviors across one or more vessels, all in a simulated geographical and bathymetric environment. This allows testing of general performance of autonomous systems, while also enabling in-depth review of noise and failure propagation.

How can the results be utilized?
By simulating a broad set of complex scenarios, the framework supports the development and evaluation of SA and CA systems. It enables systematic study of how sensor noise, data degradation, and failures affect system performance and helps identify critical failure conditions. This simulator could also be a tool in the validation of third-party SA or CA systems. With reliable SA and CA systems in place, the simulator can be used to test higher-level functions such as vessel collaboration and coordination. It also enables analysis of interactions between cooperative and non-cooperative vessels in complex environments, including the assessment of system robustness against adversarial or malicious behavior.

Main activities during 2025
- Conference papers in collaboration with DNV, "Leveraging Collision Avoidance Robustness to Establish Situational Awareness Requirements: A Closed Loop Simulator Approach", ESREL 2025 and "From COLREG compliance to performance requirements for situational awareness systems in autonomous navigation systems", ICMASS 2025.
- Additionally, development has been initiated on the development of collaborative and cooperative autonomous vessel systems based on the simulation framework.
- Co-presented with DNV at the SFI Days: "Simulating the Effects of Sensor Noise on Situational Awareness and Collision Avoidance Systems".
- SFI AutoShip webinar: "Simulating Situational Awareness for Performance Requirements and testing Collision Avoidance Systems using Signal Temporal Logic", in collaboration with DNV.



The "real» variation of mean CPA (Closest Point of Approach) as an autonomous vessel's radar noise levels and GPS noise levels are increased.

Giacomo Melloni

Radio channel measurements and modelling in maritime scenarios

Problem statement

Nowadays, we are surrounded by all kinds of technology that operates thanks to wireless connectivity. In particular, 5G requires the exchange of an enormous amount of data, which is why reliability, latency and capacity of the links must be optimized, even for next generations. The only possibility to improve our technologies is to have a better understanding of the wireless communication channels, which varies by scenario on which the communication link operates. Until few decades, channel models for mobile applications were just supported by stochastic behaviours, which were sufficient to attain a sufficient quality of the service. However, we face a new generation of smart connectivity that needs more context awareness, which makes simple stochastic models no longer suitable to attain the required efficiency. Moreover, we need new solutions to make the network scalable for more connected devices. One way is to reduce the number of resources allocated for typical radio applications, such as communication and radar.

Proposed solution

During my PhD, I am developing channel models for diverse use cases, including maritime communications and indoor/outdoor JCAS. I focus on how diffuse scattering, depolarization, and reflection behave in representative reference scenarios. I defined two work packages: (1) Maritime communications: I am investigating how sea-surface roughness impacts received signal strength. I leverage Geometrical-Based Stochastic Models (GBSM) and two-scale approaches to study how wave shadowing, wave patterns, and antenna geometry shape the channel. (2) Outdoor/Indoor JCAS: during my research stay at the National Institute of Standards and Technology (NIST), I am developing methods to predict EM interactions with materials (plexiglass, brick, drywall, asphalt, etc.), and I validate my models using NIST high-resolution datasets combining digital twins and RF measurements.

How can the results be utilized?

These models can be embedded in on-board devices to emulate the channel and adapt the link to maximize available resources. In JCAS, they can improve propagation prediction and resource allocation for applications such as WiFi-based localization, gesture sensing, and sensing-assisted collision avoidance.

Main activities during 2025

- Conference paper: "Phase Distribution of the Large-Scale Scattered Field from the Sea Surface", EuCAP 2025.
- Submitted and had accepted two EuCAP 2026 papers on a closed-form main-lobe model for coherent scattering from finite Gaussian surfaces and on shadowing-aware mean/variance prediction.
- Submitted a TAP communication letter introducing a directive, reciprocal diffuse scattering model that reduces computational cost by an order of magnitude with no loss in accuracy.
- Started working on journal paper on complete validation of the proposed model in the communication letter, and a propose novel model to predict the cross polarization discriminations based on the material properties of the reflecting surface.

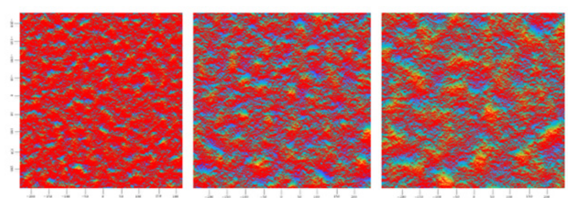


Figure 1: Impact of wave shadowing in a bistatic setting. The red area is the visible surface by both TX and RX. From left to right the sea surface is rougher, impacting the scattered/reflected power.

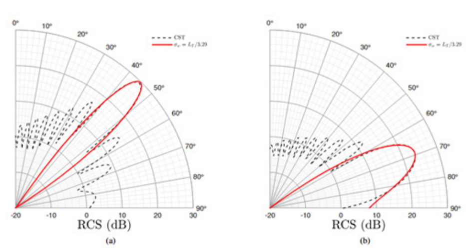


Figure 2: Model validation of the coherent scattered field from a finite rough surface. The proposed model is validated using electromagnetic simulations.

Manju James

Radio Twin: Digital twin for maritime communication system performance prediction

Problem statement
Radio wave propagation in maritime environment is affected by sea state, ship movements, and sea surface scattering and reflection. Deterministic channel modelling will be computationally intense in maritime environment with deep fading phenomena. This makes the channel performance prediction difficult.

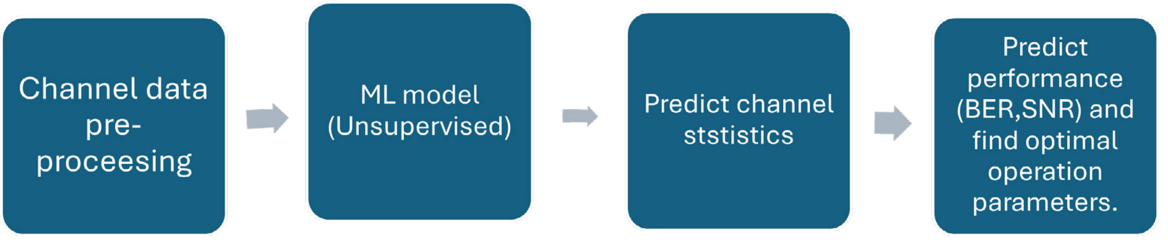
Proposed solution
Utilize machine learning algorithms to learn the varying channel probability density function. From the predicted channel statistics find the best possible physical layer parameters for the communication channel. The performance of a communication system can be analyzed from the signal to noise ratio (SNR) of the communication link. Learning channel statistics helps to predict the SNR and to choose optimum parameters for the communication system depending on the predicted data rate and latency from the SNR.

This work uses machine learning algorithm to learn the channel statistics to predict the SNR and thus to gain an understanding of optimum operation parameters for the communication system. In the case of remote-controlled operations, a degraded communication channel can result in poor video quality while monitoring, delayed or missed commands/instructions during operation, or even lost connectivity. Channel performance prediction enables switching to alternate communication methods on time, while a poor channel is predicted.

How can the results be utilized?
A remote-controlled operation system with capability to adjust its behavior to match the predicted communication physical layer parameters will enable graceful degradation rather than sudden sharp decay of communication channel performance or the link totally. The result can be utilized to support graceful maritime communication link maintenance by the communication service providers in marine environment. The solution can help in decision-support for communication channel selection in situations of degraded maritime communication channel mainly due to local weather and other unpredictable events.

Main activities during 2025

- Deduced algorithm using Gaussian mixture for density estimation for wireless communication channel.
- Currently working on implementation of the algorithm.
- Completed PhD coursework.
- Attended several SFI AutoShip events.



3 Remote Operation Centres (ROC) and Human factors

WP Leader: Professor Ole Andreas Alsos
NTNU, Department of Design

Our objective is to develop safe and efficient human-machine interfaces and interaction for remote operation centres (ROCs).

Maritime Autonomous Surface Ships (MASS) will for the foreseeable future be dependent on a land-based remote operation centre (ROC). The role of the ROC will be to monitor the status of the ship, and to intervene if the automation fails. The location, removed from the context of the vessel, will be a great challenge in order to give adequate situation awareness to the ROC operators. The interaction between MASS-ROC and conventional ships will depend heavily on sensor and AIS information, as well as cooperation with the vessel traffic service (VTS).

Topics that we have conducted research on in 2025 include improved decision support systems, seamless transition between human and autonomy control, conversational user interfaces for MASS, multimodal presentation of sensor data from the MASS, improved video transmissions and sensor data presentations from MASS to ROC, remote control over 5G network, improved automation transparency, and improved design of remote operator stations and remote operation centers.

In 2025, WP3 published 11 papers, carried out more than 50 popular science dissemination activities, and graduated one PhD. All these activities have contributed to reaching the Centre's objectives in 2025.

Luka Grgičević defended his PhD "Game-Theoretical Maritime Guidance Algorithms" in September 2025 and presented his results at the SFI Days.

Currently all the PhD positions in WP3 are finished or are awaiting defense, and the remaining activity is directed to create and establish new and associated projects that can contribute to the SFI AutoShip goals.

The control room at the NTNU Shore Control Lab where two operators monitor an autonomous ferry operation with multiple vessels.
Photo: Jooyoung Park/NTNU

Felix-Marcel Petermann

Designing Interaction for Safe and Comprehensible Human-Autonomy Collaboration in Autonomous Passenger Ferries

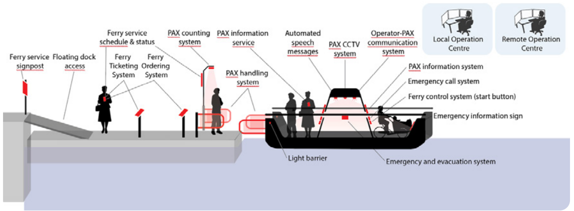
Problem statement
Autonomous and remotely operated maritime systems remove the human crew from the vessel, creating new interaction challenges for both operators and passengers. Key issues include operator challenges such as loss of embodied situational awareness, fragmented displays, high cognitive load in ROCs, and difficulty coordinating during abnormal events. Furthermore, passenger challenges include a lack of standardised information, uncertainty about system state and intent, inaccessible touchpoints, and unclear help paths.

These challenges lead to potential breakdowns in **sense-making, trust, and safe action**, highlighting the need for interaction design that is **grounded in the socio-technical context**, not just technology deployment.

Proposed solution
The solution for this problem is a **practice-driven HCI and Interaction Design framework** for autonomous ferry systems, combining:

1. Spatial coupling for operators and legible threshold cues for passengers (e.g. mHUD, immersive operator chair), shared coordination surfaces to support distributed teams (e.g. Digital Fire Central), and multimodal, intelligible, and accessible interfaces to support safe and confident use (Operator station, passenger access gates and information displays).
2. Boundaries under which guidelines hold (operational, environmental, and organisational), and identifying conditions where breakdowns occur and interaction qualities degrade.
3. Legibility, comprehensibility, trustworthiness, and actionability. Designed to support understanding, decision-making, and safe behaviour in both routine and exceptional conditions.
4. Prototypes tested in simulators, real-world trials, and observational studies. Observable outcomes include head-down time, hesitation, comprehension, trust, and accessibility metrics.

Main activities during 2025
- Completion of PhD thesis.
- Journal paper: "Maritime Head-up Display (mHUD): a safety-enhancing navigational tool for ship bridges and remote operation centres", Journal of navigation.
- Conference papers: "Mind the Kayak! Informing UX Design of Autonomous Vehicles through Edge Case Testing in the Field", Proceedings of the 2025 CHI Conference on Human Factors in Computing Systems, "Guided by the Light: The Human-Centred Design of a Navigation Support Tool for Ships", Proceedings of Interact Conference 2025.
- Conference lectures: "From Helm to Screen: Navigator and Gamer Insights for Designing Multi-Vessel Control Interfaces" and "Guided by the Light: The Human-Centred Design of a Navigation Support Tool for Ships", Interact Conference 2025, Brazil. "The unseen helm: Potential human-factors issues in monitoring and operating MASS", Autonomous Sea Navigation, Georgia. "Human in the maritime operations of the future", IMO MASS Symposium, UK.
- Received the Brian Shackel Award and the Best Doctoral Student Paper Award at the Interact Conference 2025.
- Several presentations of the Shore Control Lab, Nyhavna.



Different touchpoints a passenger might encounter when travelling with an autonomous passenger ferry.

Luka Grgičević

Game-Theoretical Maritime Guidance Algorithms

Problem statement

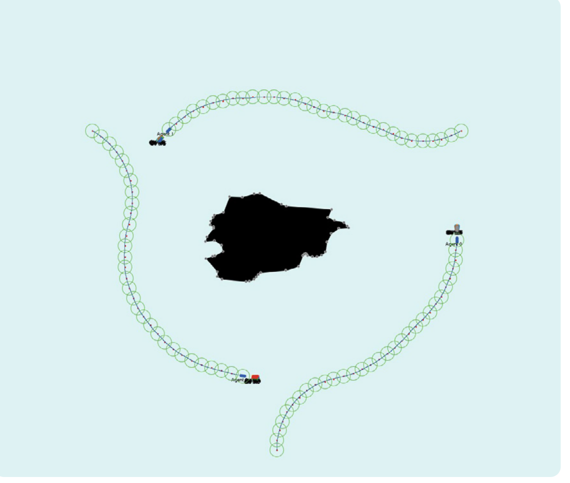
Vessels navigating in high-density traffic aim to achieve objectives such as effective collision and grounding avoidance while adhering to international, regional, and port regulations. The increasing traffic density poses a significant challenge for decision-makers, whether human navigators or autonomous intelligent systems. It is a complex system which is lacking standardised communication protocol. The information exchange is slow and unreliable which makes a fast decentralised solution suboptimal. Centralised actuation methods via the route suggestion to vessels from Vessel Traffic Service (VTS) is a practical traffic management method.

Proposed solution

This thesis is focused on algorithms for centralised decision support in traffic management that is meant to be provided by the VTS or other centres for coordination, such as Remote Operating Centres. Vessels (agents) are embedded in polymatrix game that requires a strategy set for each player, a computationally light models that evolve the strategies resulting in different trajectories, an evaluation metric and a method to find the game solution. The algorithm we developed is based on evolutionary game theory and the adopted solution is a pure Nash equilibrium.

Main activities during 2025

- Defended PhD thesis "Game-Theoretical Maritime Guidance Algorithms" in September and presented his results at the SFI Days in October.
- Journal paper published: "Centralised Decision Support in Maritime Vessel Traffic Services: A Polymatrix Game Solution", IEEE Access.



Central coordinator constructs a series of waypoints for each vessel using a game-theoretical model predictive control planner. The agent utility function is considering collision and grounding risk, operational efficiency, and a level of compliance with the (International Regulations for Preventing Collisions at Sea, 1972 (COLREG).

Eirik Fagerhaug

Explainable AI for Autonomous Ships

Problem statement
The project aims to address some issues related to data management in autonomous maritime operations. There is a need to effectively handle and interpret a very large and diverse collection of data, this includes publicly available information, such as weather conditions and details about coastal facilities, but also specialized data generated by the ships themselves and various onshore installations such as Remote Operating Centers, coastal sensor arrays, and Vessel Control Centers.
The core issue stems from the requirement to integrate and understand these varied data streams in real-time, ensuring that both machines (for operational efficiency and decision-making) and humans (for oversight, intervention, and understanding) can make sense of the information.

Proposed solution
The solution our project has developed is a data model that uses spatial graphs or networks to enhance data integration and accessibility. This model organizes data in a way that emphasizes the connections and relationships between different data points, and with tools that can be used for better visualization and comprehension. It's designed to serve as a foundation for both AI training and data analysis, supporting the development of AI models with a focus on explainability for operators at remote operating centers.

Main activities during 2025
- Journal paper: Oceanscape: A graph-based framework for autonomous coastal navigation, Ocean Engineering.


Representation of a graph-based platform for AI based navigation. Illustrations generated by DALL-E.

4

Safety and Assurance

**WP Leader: Professor Ingrid Bouwer Utne,
Dept. Of Marine Technology, NTNU**

Our objective is to research and develop novel methods, models and tools for risk management and safe design and operations of autonomous ships.

This work package focuses on risk reduction, mitigation strategies, and safe solutions for the design and operation of autonomous ships. This achievement relies on the ability to identify the new risks and incorporate necessary (technical, software, security, human and organisational) measures into the systems, the operation, and the associated infrastructure. Since 2021, we have consolidated the work of the PhDs and Post Doc and conducted webinars together with industry related to topics on Risk of Autonomous Ships, hosted by NTNU. The PhD student Spencer Dugan submitted his thesis in 2025, which he will defend in Feb. 2026. Dugan will be the first PhD student finished with his project in WP4, but more PhDs are expected to complete their theses in 2026.

Paul Lee (NTNU) presenting durng the SFI Days in October. Photo: Kai Dragland/NTNU

Susanna Dybwad Kristensen

Online risk modeling of autonomous ships

Problem statement
Highly autonomous ships are expected to be able to operate independently from human operators. This means that the autonomous system itself must be able to analyze and evaluate the risk related to the operation it is performing, to make safe and efficient decisions.

Proposed solution
Supervisory risk control, which includes developing and using online risk models to inform the autonomous system about risk during operation, can be an approach to developing risk-aware autonomous systems. Online risk models mean risk models that can utilize different sources of data and provide updated estimates of risk, reflecting the state of the system and environment during operation.

Two studies have focused on how hazards and failures related to autonomous surface vessels (ASVs) can be identified and described. An extended Systems-theoretic process analysis for hazard identification for a small unmanned surface vehicle has been proposed, and a new software failure taxonomy has been developed. Bayesian network online risk models for ASV operations have been developed, with a focus on navigation risk. The online risk models have been integrated into the control system of ASVs and have been used for risk-based path planning in simulation and field trials. Results show that the online risk models can contribute to transparent, safe, and efficient path planning by ASVs, and that the choice of risk metric should be considered when implementing risk metrics from risk models in ASV planning and decision-making.

How can the results be utilised?
The results are relevant for developers of ASVs. The proposed methods and models can be used as a basis for implementing online risk models in control systems of ASVs, and in this way enhance the risk-awareness of the systems. The proposed methods and models can also be used to analyze the risk during operation, and in this way be relevant for the assurance and approval process for autonomous ships.

Main activities during 2025
- Journal article: "Evaluating the effect of risk metrics for supporting operational decision-making by autonomous surface vehicles", Ocean Engineering.
- Co-authored journal article: "Multi-level risk classification of distributed embedded software failures for autonomous systems", Proceedings of the Institution of Mechanical Engineers, Part O: Journal of Risk and Reliability.
- Presented results from the PhD research at the SFI AutoShip days in October.

The Grethe ASV used in case studies and field trials as part of the PhD project.

Raffael Wallner

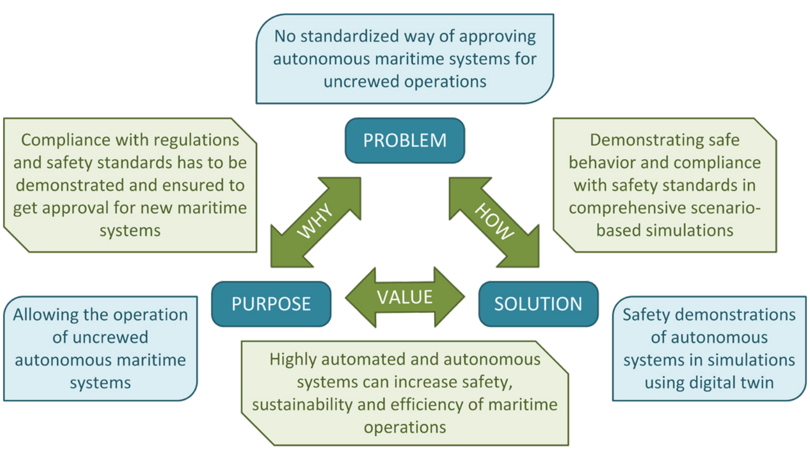
Safety Demonstration of Autonomously Controlled Ships using Digital Twin

Problem statement
The maritime industry is undergoing major change as highly automated and autonomous ships promise more efficient, sustainable, and safer sea transport. However, these advanced systems are complex and difficult to understand, making it challenging to test and demonstrate their safety using current methods. This creates a barrier to adoption and slows progress in the Norwegian maritime cluster. Stakeholders in SFI AutoShip include technology providers seeking approval for their solutions, as well as authorities and class societies responsible for validating and certifying new technology. All parties must agree on criteria, tools, and methods that ensure test results are trustworthy and suitable for authorization processes.

The research therefore focuses on three main objectives:
- RO1: Demonstrate and verify the safety of automated and autonomous systems in simulations
- RO2: Identify test scenarios for safety simulations to gain confidence about system safety
- RO3: Utilize digital twins in safety simulations and choose appropriate models and environments

Proposed solution
To enable broader adoption of highly automated and autonomous maritime systems, new safety demonstration and verification processes are needed. These must handle many possible scenarios and show that systems operate safely across a representative selection. Simulations make this possible by enabling extensive testing without real-world risks. This research proposes a scenario-based simulation approach for testing complex maritime systems. Both the system and its operational environment are modeled virtually, supported by appropriate simulation models and digital twins that reflect real control units. This makes it possible to expose the system to any relevant situation, from normal operations to critical edge cases, in a safe environment. Such comprehensive testing can support design verification, certification processes, and operational planning.

How can the results be utilised?
Authorities and class societies may use these methods when updating guidelines and standards. Manufacturers can incorporate them to streamline approval and ensure regulatory compliance. End users may apply the methods in mission planning to ensure safe operations under all conditions.



Spencer A. Dugan

Methods and tools for the analysis and mitigation of drift grounding risk

Problem statement
The widespread introduction of autonomous ships is still limited by RAMS related issues. There are several differences in the operation of machinery systems when compared to conventional ships – most notably prognostics, maintenance scheduling, and repairability.

The thesis focuses on losses of command, i.e., a failure of the propulsion, electrical generation, or electrical distribution systems. This type of failure can lead to serious consequences if command is not restored, or appropriate mitigation actions do not occur.

Furthermore, novel machinery configurations, often introduced for decarbonization or operational efficiency, are increasingly interdependent; equipment for power generation and distribution require auxiliary systems, yet these auxiliaries are dependent on power to operate. This tanging and nesting of systems increases the susceptibility to both cascading and common-cause failures.

The objective is to develop knowledge and methods for reliability assessments for propulsion systems of autonomous ships. The three main tasks are outlined below:
- Improve understanding of the frequency, duration, consequences, and risk influencing factors of machinery failures for existing ships by analyzing incident databases
- Identify and analyze design solutions for machinery systems onboard autonomous ships
- Investigate operational requirements for power management and maintenance procedures considering crew reduction

Proposed solution
The first phase of the work has focused on establishing failure rates for losses of command failures occur and identifying factors associated with their occurrence. The second phase focuses on design solutions for risk-based operational guidelines to reduce the frequency of this failure mode and consequence mitigation.

The work has focused on understanding the repair times for failures of traditional ships, and the risk perception of drift groundings for autonomous ships. The last part of the work investigates risk-based modifications to guidance and the power management system, e.g., start-stop of generators and risk-based decision making.

Traffic monitoring by the coastal authorities can be improved by the method to identify factors associated with loss of command. This would allow for targeting of high-risk ships and allocation of emergency response resources. Such a tool is also useful for insurance providers.

Assessing the reliability and safety of design topologies is necessary for ship designers as well as regulators. It may lead to insight for the development of guidelines and standards related to autonomous ships.

Main activities during 2025
- Submitted the PhD thesis "Methods and tools for the analysis and mitigation of drift grounding risk", and successfully defended his PhD in February 2026.
- Journal article: "Improved identification of maritime risk-influencing factors using AIS data in regression analysis", Reliability Engineering & System Safety.

Spencer Dugan during his PhD defence in February 2026.
Photo: Ingrid B. Utne/NTNU

Ayoub Tailoussane

The Application of the COLREGS to Autonomous Vessels: A potential solution to the legal challenges

Problem statement
The goal of the research is to see how autonomous vessels can be integrated into the framework of the regulations for collision prevention without or with very minimal amendments.

Proposed solution
Autonomous vessels must be distinguished from conventional vessels. It is important to recognize that many aspects of the collision regulations (COLREGS) cannot be fully complied with by autonomous vessels. Therefore, it is proposed that autonomous vessels be required to follow only a limited/specific part of the COLREGS in order to reduce the number of legal barriers and facilitate/support the development of autonomous navigation systems that are, not just compliant, but actually safe.

Main activities during 2025
- Working on the completion of the PhD thesis (monograph), which is focused on two major goals: (i) To propose a legal definition of "autonomous vessels" and (ii) to provide an in-depth legal analysis of a small selection of rules in order to show why it is difficult, if not impossible, to transform certain rules of the COLREGS into machine-executable algorithms.
- Co-authored and submitted for review the paper "Sailing into the Future with Periodically Unmanned Bridges - a Viable Concept for Mitigating Seafarer Shortages?", Ocean Engineering.

Illustration: Colourbox

Emir Cem Gezer

Risk-aware and safeguarding control for autonomous ships

Problem statement
The maritime industry is increasingly focusing on autonomous vessels to enhance efficiency, safety, resilience, and reliability across diverse operational scenarios. Designing vessel control systems capable of adapting to dynamic internal and external environmental factors is essential. Understanding the interactions between ship systems is key to developing risk-aware and safeguard-oriented marine control solutions. This research addresses safety by exploring behavior-based vessel control design strategies and formulating risk-informed operational modes.

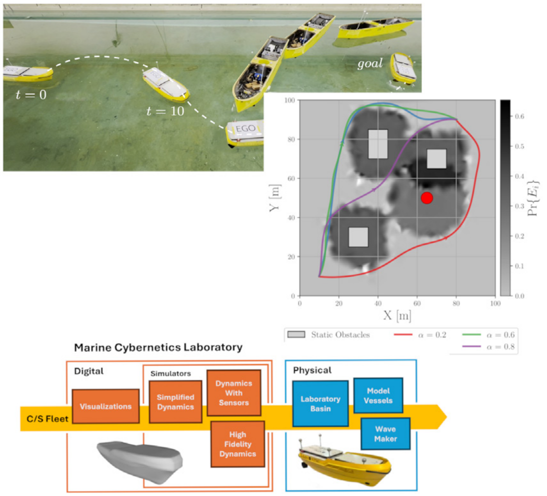
While earlier work on marine autonomy has focused on single-mode operations such as path-following with anti-collision or safe auto-docking, separately, we aim in this project to extend our focus by addressing safe autonomous multi-mode operation of a vessel where switching between a defined set of nominal operating modes and relevant safety fallback modes should occur safely and seamlessly in accordance with the vessel mission plan.

Proposed solution
This project focuses on developing risk-aware safeguarding controllers for autonomous marine vessels, emphasizing hierarchical symbolic control, nonlinear dynamics, and system integration. The work includes real-time controller synthesis for safe maneuvering, the development of a modular testbed with small-scale robotic vessels for cost-effective validation, and risk aware planning. The goal is to create a mode-based control architecture that minimizes risk and enables safe, robust autonomy in complex environments.

As part of the project, we explored several control and decision-making frameworks for autonomous systems, including symbolic control, signal temporal logic for short-horizon decision making, nonlinear model predictive control, control barrier functions for safeguarding control inputs, and Bayesian belief networks for generating risk-aware navigation paths. Together, these approaches aim to ensure safety while enabling real-time decision making.

Beyond the theoretical work, we developed both digital and physical testbeds to address challenges associated with testing autonomous marine vessels. Testing and validation are difficult due to high operational costs and safety constraints, while designing custom model vessels and integrating new algorithms is often time-consuming. To overcome these limitations, we developed a modular testbed environment that enables efficient and safe evaluation of ship autonomy.

Main activities during 2025
- Collaboration with University of California, Berkeley with the paper titled "pacSTL: PAC-Bounded Signal Temporal Logic from Data-Driven Reachability Analysis".
- Presented the paper titled "Digital-physical testbed for ship autonomy studies in the Marine Cybernetics Laboratory basin", ICSOS 2025.
- Submitted a conference article titled "Risk-Aware Obstacle Avoidance Algorithm for Real-Time Applications", ESREL2026.



Sreekant Sreedharan

Platforms, Languages & Tools for Safety Assurances in Autonomous Vessels

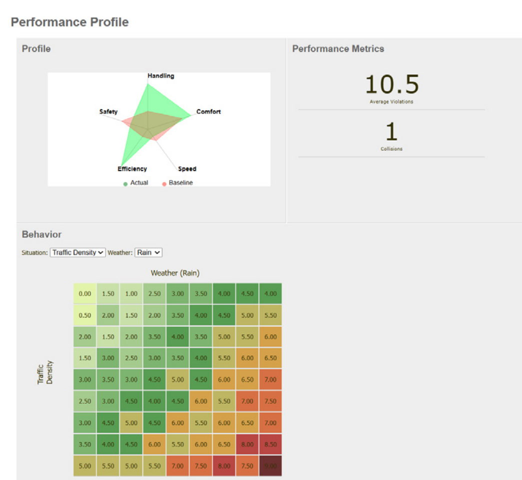
Problem Statement
Autonomous and maritime autonomous surface ships (MASS) must operate safely and legally, yet current regulations such as COLREG and local traffic rules are written for humans. These rules rely on judgment, context, and seamanship, making them difficult to convert into precise, machine-interpretable requirements. As a result, existing assurance methods struggle to evaluate complex, adaptive behaviour. Traditional verification techniques cannot fully capture the real-time decision-making required in dynamic maritime settings. Most research focuses on simplified open-sea collision-avoidance or path-planning scenarios, even though real incidents and regulatory ambiguity occur in congested waters such as ports, straits, and traffic separation schemes. Challenges intensify because applicable rules change with geographic zones, while human masters routinely balance traffic, safety, security, environmental factors, and local practices—pressures that are amplified in narrow or high-risk areas.

Proposed solution
The proposed solution integrates two main components:
1. **A machine-readable regulatory language (Legata)** that encodes maritime regulations into computable logic.
2. **Large-scale simulation-based testing** that assesses autonomous navigation behaviour and produces quantitative evidence of regulatory compliance.

How can the results be utilised?
The platform supports several stakeholder groups in the maritime autonomy ecosystem:

- **Technology developers (ANS/MASS vendors, operators)**: Use Legata and simulation tools to build repeatable compliance test suites across diverse operating contexts, including complex port and strait environments. Large-scale testing enables identification of behavioural patterns and rule-violation trends to inform iterative design.
- **Classification, assurance, and risk organisations:** Employ Legata scripts, scenario sets, and scorecards as auditable artifacts linking written rules to machine-executable logic and observed evidence. This supports more transparent, quantitative assurance discussions, including future risk-weighting extensions.
- **Regulators, VTS authorities, and policy stakeholders:** Test new operational concepts virtually and identify regulatory gaps that hinder machine execution.
- **Research and standards bodies:** Develop reusable rule templates and scenario libraries—such as for the Istanbul Strait—to support shared benchmarking of MASS compliance.

Main activities during 2025
- Conference papers prepared/submitted: “Convolutional A*: An Approach to Progressive Path Planning’, ICRA conference. ‘Living Knowledge, Foundations for General Intelligence”, ICML.
- Journal Paper “Interpreting the Law”, under revision.
- TK8111 - final course work completed.
- Research on Actor based modelling, led to the collaborative development of Rebeca compiler for python with MDU (Vasteras). Collaboration is ongoing.
- Developed a proposal for Microsoft Research Fellowship. Submitted, under review.



A sample performance report of a simulation job for a vessel algorithm.

Jon Estil Krågebakk

AI and data-driven safety management in operation of autonomous ships

Problem statement

A crucial part of situational awareness for autonomous surface vessels, enabling safe decision-making during operation, is accurate sea state estimation. Traditionally, wave estimation has primarily been performed using single-point observers, which represent the sea state as a set of parameters and/or wave spectra. Certain wave phenomena cannot be captured by point-wise wave measurements, and therefore spatiotemporal techniques are required. Wave models capable of accurate 3D surface reconstruction, along with velocity and pressure fields over large spatiotemporal domains, would enable more accurate calculation of wave loads and wave-induced motions where previous methods are insufficient. However, methods capable of capturing spatiotemporal wave fields are largely absent from existing marine vessel systems.

Proposed solution

We propose the use of a polarimetric stereo camera sensor rig with dual GNSS antennas and motion tracking via an IMU (SFI lightweight sensor rig, see Figure 1), paired with a machine learning architecture (see Figure 2), to predict surface elevation, velocity fields, and pressure fields directly from the sensor input space. Future pressure fields and surface elevations are then simulated using the open-source REEF3D::NHFLOW solver. However, as neither the pressure-field output space nor the polarimetric input space are available in existing datasets, these data had to be simulated and custom datasets created for neural network training. This effort culminated in the open-source REEF3D-Python-Blender project named Ægir-Frames, which renders the emulated input space of the SFI lightweight sensor rig from simulated ground-truth wave field data.

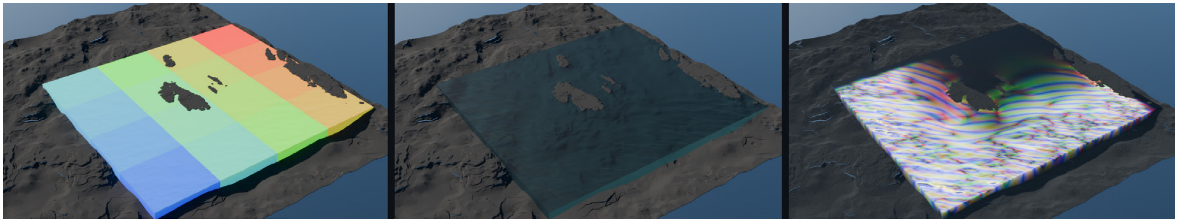
How can the results be utilised?

Ægir-Frames is an open-source software package that renders REEF3D simulation data using a ray-traced, physics-based renderer. The package includes custom shaders and geometry nodes capable of emulating the SFI lightweight sensor rig. In addition, the software contains shaders for visualizing other parameters and properties of wave simulations (see Figure 3).

The package can parse any REEF3D::NHFLOW simulation files, allowing users to generate datasets for wave fields under arbitrary conditions, including bathymetry-dependent effects in confined or coastal areas.

Main activities during 2025

- Creation of Ægir-Frames.
- Conference paper prepared: "Image-Driven Regression AI for Sea State Prediction in a Confined Volume with Discrete Decomposition", OMEA 2026.



A short sample of available shaders in the open source Ægir-Frame software package. Left: MPI Core Simulation Shader, Middle: Transparent Glass Shader, Right: Component Emissive Velocity Shader.

Paul Lee

Risk-aware AI agents for the safety-critical operations of autonomous ships

Problem statement

Recent advances in artificial intelligence (AI) have accelerated the shift toward autonomous, engineering-driven applications motivated by sustainability and financial incentives. This trend is often justified by the strong cognitive performance of AI agents, which now surpass many traditional algorithms—and in some cases human benchmarks. As AI becomes more deeply embedded in decision-making for safety-critical autonomous systems, an important challenge emerges: safety assessment is typically performed late in development, meaning safety issues often become apparent only after real-world incidents occur.

This highlights the growing importance of safe and risk-aware AI, particularly systems capable of understanding and accounting for risk in their decision processes. The research addresses two main challenges: (1) investigating what risk awareness means for AI agents, and (2) identifying how such agents can be developed and controlled during safety-critical operations of autonomous ships.

Proposed solution

The first part of the research problem is addressed through a systematic literature review aimed at bridging the gap between the safety and AI domains. This includes synthesizing a generic risk awareness definition from the safety domain, identifying risk awareness gaps within the AI community, and outlining a conceptual pathway toward genuinely risk-aware AI agents.

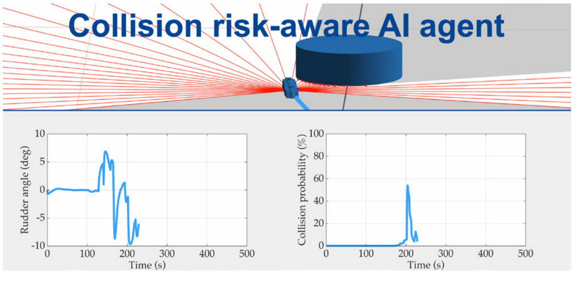
The second part is addressed through a novel deep reinforcement learning (DRL) framework designed to embed risk awareness during training. A case study involving an autonomous ship facing collision hazards demonstrates the framework's capabilities. Simulation results show that: (a) the AI agent learns to estimate collision probability as a fundamental element of the risk triplet, (b) its risk awareness is explainable through measurable outputs, and (c) this awareness directly influences its decision-making, suggesting an intrinsic, policy-integrated understanding of risk.

How can the results be utilised?

SFI partners developing AI agents for autonomous ship operations can use the DRL framework to integrate risk awareness directly from the training phase. The explainability and policy-linked collision probability estimates can support real-time monitoring in human-machine interfaces. Partners working on guidelines and standards can incorporate the risk awareness concepts into broader regulatory frameworks and define thresholds for real-time risk control. Additionally, partners involved in assurance can leverage the agent's explainable risk indicators as part of safety arguments supporting certification processes.

Main activities during 2025

- Conference paper: "Towards robust deep reinforcement learning agent for the path following of autonomous ships amid perception sensor noise", ESREL 2025.
- Partner collaboration with DNV: risk awareness & verification of AI agents.
- Presented "Towards risk-aware AI agents for safety-critical operations of MASS" at the SFI AutoShip Days. Research presentations in SFI Researcher workshops.



The collision risk-aware AI agent is capable of controlling the rudder angle, but also make its own estimation about the collision probability during a collision risk scenario.

5 Sustainable Operations

WP Leader: Research Scientist Pauline Bellingmo, SINTEF Ocean

Our objective is to develop the next generation cost-effective and environmentally friendly waterborne transport system.

The future auto-remote solutions must be aligned with the human capabilities of any remote operators and other mariners; automated berthing and mooring, cargo handling and power supplies in port must be efficiently integrated with shipboard automation; and the combination of operational strategies, automation and transport work undertaken must be optimized to be cost-effective and environmentally sound. Therefore, this work package works primarily within three axes: Logistics system cost-benefit assessments, assessment of technology and solutions for environmentally friendly operation of (periodically) unmanned ships, and optimization of automatic control of mooring and cargo-handling systems to automate port operations.

In 2025, WP5 activities covered three main tasks: 1) Logistics analysis for short-sea transport system, 2) Energy-efficient automated ferry operation, and 3) Automation of two ship cranes.

1) Logistics analysis of short-sea transport system
The logistics analysis studied the effect on remote crane operations on the scheduling of a fleet of short sea container ships. The work has been done in close cooperation between NCL and SINTEF Ocean and has been ongoing since 2024. The results from the study have been documented in a journal paper in the Journal of Physics and presented to many relevant stakeholders at the ICMASS 2025 conference. This paper investigates the scheduling of a fleet of a short sea container ship operated by North Sea Container Line (NCL), including an extension of the fleet that is currently under consideration. The paper evaluates two main questions; a) How will remote crane operations impact scheduling across the fleet? And b) Given a schedule optimised with respect to minimizing concurrent crane operations, how many crane operators would NCL need for their future fleet? Simulation results are discussed to provide insight into how remote operation of cranes can alleviate the current challenges in recruiting ship crew with crane operating skills.

2) Energy-efficient automated ferry operation
Last year, SINTEF Ocean and Torghatten started investigating how their operation of ferries could be optimized with regards to reducing energy consumption. Through discussions with Torghatten and Kongsberg, we have found potential to reduce the energy consumption during docking of Torghatten's ferries, particularly when docking automatically. Kongsberg has a long experience developing and testing autodocking systems for ferries and contributes essential insights for this study. SINTEF has been analyzing operational data from Torghatten's Flakk-Rørvik ferries to try to identify in what part of the operation energy can be saved and how it can be done. Furthermore, SINTEF Ocean has had discussions with PhD student Simon Lexau in WP1. He is also working on automatic docking, but with more focus on the city ferry Milliampere.

3) Automation of operation of two ship cranes
The work on remote and automated control of deck cranes on a container ship with NCL has continued building on work from previous years (e.g., the crane simulator developed by SINTEF Ocean and SINTEF Digital based on OSP [1] and Unity [2]). This year's focus has been to investigate how to do semi-autonomous crane operations, enabling one operator to control two cranes in parallel, thereby increasing efficiency and reducing the need for skilled crane operators. The two SINTEF institutes are cooperating to build an automation system for operation of two ship cranes, developed in ROS with an integration to the crane simulator in Unity using the MQTT communication protocol. It has been conceptualized as a framework for automation of multiple cranes, mixing task and motion planning, and a planning domain for coordinating the actions of two ship cranes has been created. Additionally, there has been work on developing a path planning algorithm for defining container trajectories, and therefore the cranes' movement, in ROS. The work on automation will continue in 2026.

The work on logistic analysis of remote crane operations and the work on the crane simulator was presented at the SFI days this year. NCL also contributed to the presentation by describing the industry need and benefits of this research. The crane simulator has been updated with new functionality, e.g. for picking and placing containers with spreaders.

The crane simulator developed by SINTEF Ocean and SINTEF Digital.

From left: Håvard Nordahl (SINTEF Ocean), Kenneth Johanson (NCL), and Magnus Bjerkeng (SINTEF Digital) presenting at the SFI Days 2025. Photo: Ingeborg Guldal/NTNU

Perspectives from SFI partner NCL

Remote crane operations on board vessels can be a change for operational efficiency across our fleet, but it needs to be validated and tested.

By joining SFI Autoship, we help shape solutions around onboard realities, while gaining early insight into what actually delivers value. That reduces adoption risk, supports more predictable cargo operations, and strengthens our competitiveness.

- Kenneth Johanson, CTO
North Sea Container Line

6 Use Case

WP Leader: Senior Business Developer Svein Peder Berge, SINTEF Ocean

The objective of WP6 is to demonstrate the applicability and value-adding potential of research and innovation results developed within SFI AutoShip, while also identifying new challenges and opportunities for further research.

KEY ACTIVITIES IN 2025

Strengthening Industry–Research Alignment
During spring 2025, all use-case leaders were contacted to provide updates on key focus areas and challenges relevant to SFI AutoShip. Based on feedback, WP6 worked throughout autumn 2025 to strengthen collaboration between researchers and industry partners. This included the development of new project ideas addressing concrete industrial challenges that can be integrated into the Centre during its final phase. Several research results show potential for further development as spin-off projects in collaboration with industry partners. This process is ongoing and continues to be a priority area for WP6.

Researcher Engagement and Innovation Focus
In October 2025, a meeting was held at to introduce the four SFI AutoShip use cases to both new and ongoing PhD candidates, postdoctoral researchers, and other researchers. A key ambition was to better align ongoing research activities with clearly articulated industry needs, as expressed by the use-case leaders, and to raise awareness of industry requirements related to data availability and information quality. Innovation Manager Kjell Olav Skjølsvik presented a framework for innovation-driven research. Each researcher presented their research plan, shared current challenges, and discussed ideas for further development.

Joint WP6 and WP7 meeting with new PhDs and PDs in October. Photo: Ingeborg Guldal/NTNU

Facilitating Industry Access During SFI Days
During the SFI Days, WP6 facilitated direct dialogue between researchers and relevant industry partners. This included discussions related to access to vessels and equipment for testing (e.g. sensors), as well as access to operational data. These interactions were important for ensuring that ongoing and future research activities are grounded in realistic operational contexts.

Innovation Workshop for Early-Stage Researchers
In December, WP6 and WP7 organized an innovation workshop at NTNU for both new and ongoing PhD candidates and postdoctoral researchers. The workshop focused on introducing the innovation-driven research framework developed by Kjell Olav Skjølsvik through dedicated training sessions.

In addition, SINTEF Ocean introduced the Osterwalder Business Model Canvas as a tool to understand how companies create, deliver, and capture value. Researchers were encouraged to apply the canvas to their own research.

USE CASE–SPECIFIC ACTIVITIES

UC1 – Deep Sea Bulk Shipping
In October, SINTEF Ocean visited Grieg Star in Bergen to discuss research outcomes and potential new initiatives related to UC1. In particular, the concept of B0 – periodically unmanned bridge was discussed as a topic for continued research within the SFI.

The visit also provided valuable insight into Grieg Star's challenges related to quality assurance of operational sensor data. These challenges highlight the need for improved data reliability and processing, which can support more robust decision-making tools for shipping operations.

UC2 – Short-Sea Container Shipping
For UC2, research activities in 2025 focused on a targeted study for North Sea Container Line (NCL). The study addressed challenges related to the shortage of crane operators and investigated how crane operators located in a Remote Operations Centre (ROC) could operate cranes on multiple vessels.
The objective was to reduce the need for crane operators onboard vessels while maintaining operational efficiency and safety.

UC3 – Ferries
For UC3 (Ferries), the main research activities focused on energy-efficient transit and docking operations for Torghatten's ferries operating between Flakk and Rørvik in the Trondheimsfjord. The ferry operator plans to introduce an automatic docking system with energy consumption equal to or lower than today's manual operations.

To document the costs and benefits of such an upgrade, an extensive analysis of operational data from the two ferries was conducted. This analysis establishes the current energy consumption profile and provides essential input for the design of an energy-efficient and safe automatic docking system.

UC4 – Offshore Support Operations
Within offshore support operations, the Reach Remote I vessel from Reach Subsea has been presented several times, both by Kongsberg Maritime as the equipment provider and by Reach Subsea as the service provider. The Reach Remote I and II vessels represent the result of a long-term collaboration between academia, research institutes, and industry, and serve as strong examples of successful research-driven innovation.

Development has progressed from initial concepts and student projects, through numerical analyses and model testing, to fully operational industrial products. Reach Remote I was awarded Skipsrevyen's Ship of the Year in 2024 and the Kongsberg Technology Award in 2025.

The concept, combining an unmanned surface vessel (USV) with a remotely operated underwater vehicle (ROV), demonstrates that complex offshore operations can be conducted from multiple Remote Operations Centres simultaneously. Remaining challenges include achieving full autonomy (no human in the loop) and scaling up operations to allow multiple USVs to be operated from the same ROC.

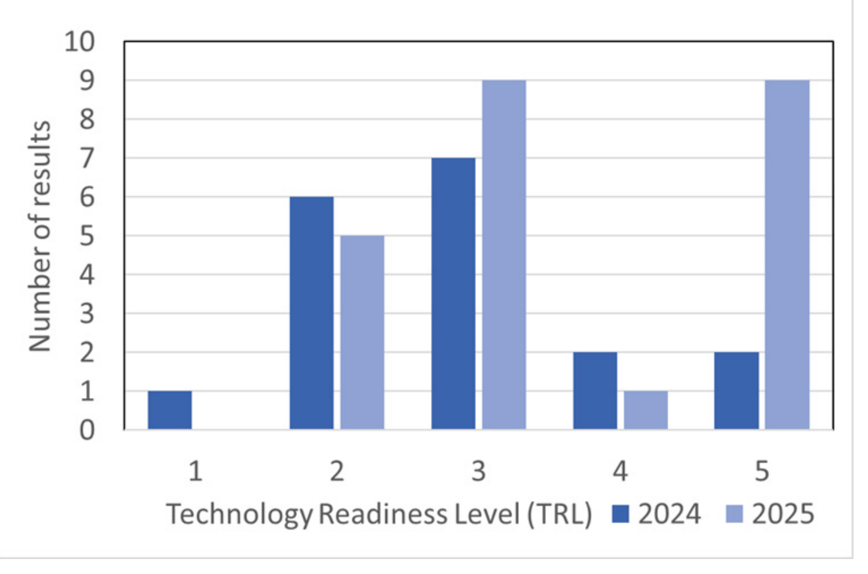
In the final phase of SFI AutoShip, both Kongsberg Maritime and Reach Subsea have highlighted technical and regulatory challenges as key research priorities for further development.

7 Innovation and Commercialisation

WP Leader: Innovation Manager Kjell Olav Skjølsvik, Dept. Of Marine Technology, NTNU

With the activity level in SFI AutoShip at a peak, as illustrated by the presentation of the activities in the various work packages, a portfolio overview is maintained to provide easily accessible information to the consortium partners on the potential for commercial opportunities represented by the research outcomes. A consolidated status updates partners on ongoing research activities, applying Technology Readiness Levels (TRL 1–9) and additional dimensions from a simplified KTH Innovation Readiness Level model to assess maturity and innovation potential.

The distribution of TRL values demonstrates notable progression, particularly among solutions related to autonomous navigation, decision support, and digital twins. Many results have advanced from conceptual stages to functional prototypes, reflecting a maturing research environment and improved integration between the partners. The results now also exhibit broader applicability across maritime use cases.



Portfolio of research results with potential commercial potential

WP1 focuses on situational awareness, sensing, and control. Key developments include radar based SLAM for GNSS fallback (TRL 3), a portable maritime sensor rig now tested in real environments (TRL 5), digital twin methods for adaptive control (TRL 3), and a simulation framework for collision avoidance validation that already is released as open source (TRL 5). Autonomous docking algorithms (TRL 5) also show strong progress.

WP2 emphasizes navigation decision support and communication systems. Major outputs include a multi objective trajectory planning tool (TRL 5), a conceptual ship shore radar network for enhanced situational awareness (TRL 3), and several communication focused innovations such as maritime radio channel modelling (TRL 2) and ML based communication performance prediction (TRL 2).

WP3 addresses human–machine interaction and design. Results include functional prototypes for AI decision transparency (TRL 5), multi vessel traffic decision support (TRL 3), the Oceanscape graph based data model (TRL 4), and enhanced operator situational awareness concepts (TRL 3). User face solutions such as passenger touchpoints for autonomous ferries (TRL 5) and the OpenCrane UI design system (TRL 5) demonstrate strong practical relevance.

WP4 concentrates on safety, risk, and regulatory frameworks. Online risk modelling for collision and grounding has reached TRL 5 with trial demonstrations. Other leads include drift grounding mitigation methods (TRL 3), digital twin based safety validation (TRL 2), a modular autonomy safety testbed (TRL 3), and COLREGs related solutions both technical and legal.

WP5 covers autonomous cargo handling, providing a modular crane simulator (TRL 5) enabling safer remote crane operations.

The portfolio of research results shows strong momentum and increasing maturity, offering significant potential contributions to safe, reliable, and efficient autonomous maritime operations.

Joint WP6 and WP7 innovation workshop for PhDs and PDs in December. Photo: Ingeborg Guldal/NTNU

Highlights from 2025

Utilising the Simulation Framework for COLAV algorithm testing and evaluation

By Bjørnar Vik, Kongsberg Maritime

As part of SFI AutoShip, a pre-existing Simulation Framework for testing and evaluation of COLAV algorithms has been furthered developed and expanded. Within Kongsberg Maritime this framework has been explored and used for testing the Collision and Grounding Avoidance (CGA) system. The framework consists of three main components: a Scenario Generator, a Simulator and an Evaluator.

Scenario generation and simulator usage

The Scenario Generator enables setting up realistic maritime scenarios. Electronic Navigational Chart (ENC) data is used to create a geographic area with grounding hazards, and one or more target vessels can be configured to represent surrounding traffic. Once the scenarios have been defined, they can be executed in the Simulator. At run-time, the Simulator allows direct interfacing with an external (thirdparty) COLAV planning algorithm, which then acts as the system under test and controls ownship behaviour. In Kongsberg Maritime, such setup has been used for testing purposes, where ownship behaviour is controlled by interfacing the Kongsberg Maritime CGA system to the Simulator.

A common limitation of many traffic simulators is that target vessels are often modelled using only an initial position, speed and a predefined track. Consequently, they do not adhere to COLREGs, leading to unrealistic behaviour that forces the ownship algorithm to compensate for situations unlikely to occur in real operations. This may cause exaggerated manoeuvres in head-on encounters and trigger undesired avoidance actions in stand-on situations where ownship should ideally maintain its course and speed. In this Simulation Framework, however, target vessels can be assigned their own COLAV planning algorithms, enabling them to behave in a COLREGs compliant manner rather than simply following a preplanned track. By introducing more realistic behaviour to the target vessels, such undesired ownship actions can be mitigated or avoided altogether.

Evaluator usage

The Evaluator tool can be used to score the performance of COLAV algorithms for both ownship and target vessels. Within Kongsberg Maritime, the Evaluator has primarily been applied to assess ownship behaviour in static scenarios, where each scenario has a predefined COLREGs classification and an expected outcome. The intention is to extend the usage to also cover dynamic scenarios where traffic evolve over time, to support more robust verification and validation of algorithm performance.

Head-on scenario with Kongsberg Maritime CGA system classifying and controlling ownship behaviour (yellow) and Simulation Framework controlling target vessel behaviour (red).

Meet our graduates

SFI AutoShip congratulates the researchers who completed their projects in the SFI during 2025. Four PhDs defended or submitted their thesis for doctoral defence. They will all continue in either academia or industry going forward, building on their experiences in the SFI. We are grateful for their many excellent contributions.

DANIEL MENGES

Daniel Menges submitted his thesis at the Department of Engineering Cybernetics, NTNU in Trondheim. He defended his PhD on May 7. He has subsequently taken up a postdoctoral position at NTNU's Department of Clinical and Molecular Medicine.

What was your project about?

Autonomous ships must navigate complex environments while maintaining awareness of their surroundings and internal systems. This PhD project focused on improving situational awareness and using that knowledge for optimal control through digital twins. Reliable perception is essential for safe and efficient operation.

By creating detailed virtual models of the vessel, this research enhances decision-making through smarter data integration, predictive capabilities, and advanced control techniques. It introduces adaptive methods to estimate environmental forces, proactive strategies for collision avoidance, and efficient algorithms for anomaly detection and big data processing. We developed learning-based approaches to enhance control adaptability, safety-focused strategies for robust operation, and multi-target tracking methods that fuse LiDAR and AIS data to improve situational awareness.

These advancements enable autonomous vessels to operate with greater efficiency, safety, and intelligence.

What have you achieved during your PhD?

Beyond the extensive knowledge I have gained over the past three years, my PhD has resulted in seven journal papers and four conference papers, with me serving as the main author on eight of them. I have consistently targeted high-quality journals and conferences to ensure the broadest impact of my work. I have presented my research at several international conferences across different continents, as well as in multiple SFI webinars, project meetings, and discussions with industry partners.

These experiences have allowed me to engage with the global research community and establish valuable academic connections. In addition, I broadened my perspective by experiencing a different research environment during my research stay at INESC TEC in Porto, where I collaborated with the Centre of Robotics and Autonomous Systems (CRAS).

What will you do next?

I am seeking a new researcher position. Driven by my passion for research and curiosity, I aim to find a role where I can apply my expertise in control, machine learning, and optimization while also expanding my knowledge into new domains.

LUKA GRGIČEVIĆ

Luka Grgičević completed his PhD project at the Department of ICT and Natural Sciences (IIR), NTNU in Ålesund, and defended his thesis on September 10. Luka has since worked as an AI and signal processing researcher and consultant.

What was your PhD project about?

Future maritime traffic is expected to increase in density. Centralised systems for guidance decision support are envisioned to be integrated in centres for vessel traffic services. For large number of traffic participants driven by metrics for operational efficiency and safety, multiplayer game-theoretical tools could be deployed.
We investigated non-cooperative games and stable Nash equilibria solutions.

What have you achieved during your PhD?
The three-year project was filled with good ideas that are summarised in four research papers, all openly available online. A notable result is PULSE, a novel algorithm for centralised maritime traffic management utilising polymatrix games and evolutionary dynamics on graphs that outputs a series of waypoints for each vessel to follow.

Main take-aways from SFI AutoShip

Being part of this centre for research-based innovation has been rewarding in many aspects for which I will be forever grateful. It elevated my knowledge in many disciplines and further developed the soft skills. I was privileged to collaborate with experienced and brilliant researchers and industry partners that helped in shaping my PhD project research objectives.

What will you do next?
I plan to continue my career in the private sector. Since the results are applicable to many real-world problems it will be interesting to continue the research on this methodology.

LUKAS HERRMANN
Lukas Herrmann completed his PhD project at NTNU's Department of Electronic Systems and defended his thesis on December 19. He has since been hired as an R&D Engineer at Kongsberg Discovery, Seatex.

What was your Postdoc project about?
Autonomous vessel operations heavily depend on environment perception and situational awareness. One of the enabling factors and main drivers is the use of radar sensors due to their long-range capability and proven robustness in the maritime domain.

However, in autonomous scenarios, challenges arise from detecting low-observable targets, such as small vessels like kayaks or ASVs, targets at long ranges, or targets made of less-reflective materials, combined with unwanted reflections from the sea surface that collectively complicate the tracking process. In my research, I addressed these challenges by developing algorithms based on the track-before-detect (TkBD) paradigm, which integrates target detection and tracking into a unified process. In contrast to the traditional detect-then-track principle, where a detection is first declared and then tracked, TkBD processes raw, unthresholded sensor data across multiple frames to detect weak targets while simultaneously estimating their kinematic state, thereby contributing to situational awareness in autonomous maritime environments.

What have you achieved during your PhD?
As part of my PhD project, we established a radar network consisting of four radar systems at two different sites to observe the Trondheim Fjord. This not only formed the foundation of my research but has also expanded the available radar infrastructure for future studies. The main findings of the research have been published in three conference proceedings and three journal articles, and were presented at the conferences as well as numerous workshops, seminars, and webinars.

Generally, throughout my PhD, I continuously grew both personally and as a researcher, and the collaboration during my stay at the University of Liverpool further supported this development and expanded my national and international network. Since TkBD had largely been restricted to simple, theoretical examples, one personal highlight was the final paper, in which we combined, analysed and verified our previously developed methods in a full-scale implementation using experimental radar data from the Trondheim Fjord, and demonstrated the applicability and performance.

Main take-aways from SFI AutoShip

For me, being part of SFI AutoShip was a valuable experience. It gave my research a clearer purpose by connecting it directly to real challenges in autonomous maritime operations. The centre provided a stimulating environment that combined academic rigor with practical industrial challenges, real-world implementation aspects, and meaningful applications.

In addition to the technical knowledge I gained during my PhD, I benefited from participating in interdisciplinary meetings that strengthened my communication skills, broadened my perspective, and encouraged networking.

What will you do next?
I'm happy to announce that I have started a position in R&D at Kongsberg Discovery, Seatex, where I will continue to work on the development of radar-based target detection and tracking methods.

SPENCER DUGAN
Spencer Dugan submitted his thesis at NTNU's Department of Marine Technology in 2025 and defended his thesis in February 2026. He was recruited by DNV, where he works as a researcher in ship autonomy.

What was your project about?
Machinery failures onboard can quickly jeopardize ship safety. Two relevant high-profile examples are the near-miss of the Viking Sky and the allision of the Dali. These failures are highly relevant when we talk about reliability and repairability for autonomous ships.

One challenge is that these failures are rarely reported or contained within accident databases. This makes it difficult to accurately determine how often they occur or identify any underlying risk factors.

The overall goal was threefold. First, investigate how often failures occur, their outcomes, and recovery characteristics for conventional ships. Second, examine the gaps and biases in maritime accident databases. Lastly, assess how this knowledge informs traffic monitoring and autonomous navigation strategies.

What have you achieved during your PhD?
I collaborated with the National Coastal Administration to analyze a dataset of observed drifting ships in Norwegian waters. We used the data to classify how often machinery failures occur. We then developed a statistical method based on epidemiology to identify "sick ships" and their underlying risk factors in the same way that medicine tries to identify risk factors for various diseases.

We applied the results to a supervisory risk controller. The controller used knowledge of the ship's machinery system reliability and recovery dynamics to mitigate drift grounding risk.

I was very fortunate to have shared my research at conferences in Poland, England, Japan and the US. Beyond the SFI, I collaborated with partners at two Polish universities on the ENDURE project to develop decision support systems for training ships.

I also helped organize three successful editions of the International Workshop on Autonomous System Safety (IWASS) in 2023, 2024, and 2025.

Main take-aways from SFI AutoShip

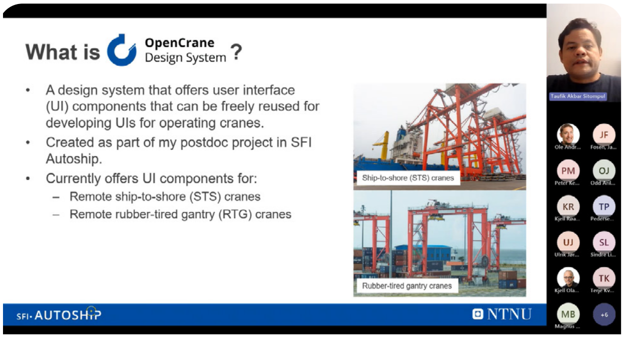
The researcher seminars and SFI days have been fantastic opportunities to see how quickly autonomy is shaping the maritime industry, and proof that the SFI is leading the way research-wise. It's also been very helpful to get feedback directly from partners. I greatly enjoyed the discussions in Work Package 4, as well as my collaboration with the National Coastal Administration and discussions with Gard.

What will you do next?
My defense is scheduled for February 18, but before that I will start at DNV as a researcher in ship autonomy. I'm very excited to work for a partner of the SFI and hope to stay involved in the project!

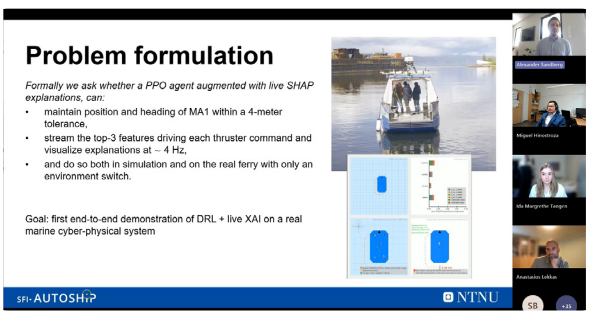
Daniel Menges' PhD defence in May. Photo: Markus Lindner/NTNU

Luka Grgičević's PhD defence in September. Photo: Eli Anne Tvergrov/NTNU

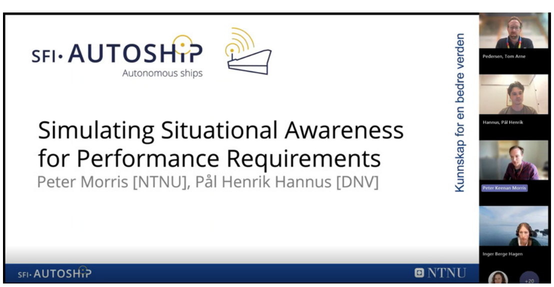
Lukas Hermann's PhD defence in December. Photo: Henrik Dobbe Flemmen/NTNU



WP3 Open crane webinar, March 2025.



WP1 Sea trials webinar, June 2025.



WP2 Simulating situational awareness webinar, June 2025.

Webinars

SFI AutoShip webinars have been consistently well attended and have been a great way for researchers and industry/public sector partners to collaborate. Recordings of the webinars are available to the consortium in Teams.

Overview of webinars during 2025:

1. WP3: Designing user interfaces for remote cranes by reusing OpenCrane Design System: Insights from software developers and crane operators (NTNU)

2. WP1: Results from sea trials with milliAmpere1 (NTNU)

3. WP2: Simulating Situational Awareness for Performance Requirements and testing Collision Avoidance Systems using Signal Temporal Logic (NTNU and DNV)

COLREG working group

The COLREG working group has continued its weekly meetings throughout 2025, coordinated by DNV and the University of Oslo. Discussions have focused on legal and computer engineering aspects of 'COLREG compliance', that is the requirements the ship's state of registration should set for certifying that the ship is safe in respect of collisions. Focus recently has been on situational awareness and the limits of the autonomous systems, including advance warnings of the need for human intervention. The idea is to develop a short paper on this theme.

International Collaboration

SFI AutoShip is part of an active international network that contributes to knowledge exchange, capacity building, and strengthening of the research for autonomous maritime operations.

We participate in the PERSEUS project, which is a collaboration between NTNU, 11 top-level academic partners in 8 European countries, and 8 industrial partners within sectors of high societal relevance. The SFI has engaged a total of 5 high-quality international candidates receiving additional funding through this scheme. From a total of 29 researchers who have been hired in the Centre, 19 come from outside Norway. They have brought significant expertise within robot perception, systems theory, remote operations and other disciplines.

The centre has a close and established partnership with the University of Genoa, particularly within the modelling and control of autonomous vessels. This collaboration has resulted in reciprocal research visits, including an extended stay by a PhD candidate at NTNU and several joint publications. In 2026, a new PhD candidate from the University of Genoa will carry out a research stay at NTNU, funded through the Erasmus Mundus programme.

Furthermore, the centre collaborates with the University of Gdańsk in Poland on the development and maintenance of a simulation framework aimed at collision avoidance and navigational safety.

SFI AutoShip is also strongly involved in and contributes to knowledge transfer from European research projects in which several of our user partners participate. During 2025, the centre maintained close contact with the EU projects Autobarge, Breach, and Seamless, all of which address key research challenges related to autonomous maritime operations, safety, and the integration of new technologies.

SFI AutoShip has a very strong and academically robust collaboration with the University of California, Berkeley, one of the leading US research environments in autonomy and control engineering. The partnership includes two-way research exchanges, joint academic activities, and ongoing dialogue about new opportunities for collaboration. For example, in autumn 2025, the centre hosted a Fulbright scholar who worked with WP4 researchers on testing safe autonomy at NTNU's Marine Cybernetics Lab. WP2 PhD candidate Giacomo Melloni is currently undertaking a research stay at the National Institute of Standards and Technology (NIST) in the United States.

The centre also participates actively in Nordic research collaboration. We have a well-established partnership with the Technical University of Denmark (DTU) within autonomy, control, and maritime systems. In addition, one of the centre's researchers completed a research stay at Mälardalen University in Sweden in 2025, further strengthening the connection to the Swedish research community within autonomous and intelligent systems.

From left to right; Researchers from University of California, Berkeley, Elizabeth Deitrich and Bingzhuo Zhong, and from NTNU Emir Cem Gezer. Dietrich has been visiting NTNU as a Fulbright scholar in 2025. Photo: Asgeir Johan Sørensen/NTNU

OUR TOP INTERNATIONAL RESEARCH PARTNERS

Prof. Ali Mosleh
UCLA

Prof. Andreas Molisch
University of Southern California

Prof. Peter Willett
University of Conneticut

Prof. Athina Petropulu
Rutgers University

Dr. Michael Benjamin
MIT

Prof. Andrew R. Teel
UC Santa Barbara

Prof. Murat Arcak
UC Berkeley

Prof. Rudy Negenborn
TU Delft

Prof. Jose Neira
University of Zaragoza

Assoc. Prof. Michele Martelli
University of Genoa

Prof Aníbal Matis, Prof. Andy Pinto
University of Porto

Prof. Simon Maskell
University of Liverpool

Recruitment

We recruited 2 PhDs and 1 postdoc to the Centre in 2025.

Name	PhD project	Work package	Supervisor	Host department
Martin Baerveldt	Combining Extended Object Tracking and Localization to Enhance Situational Awareness	1	Edmund Brekke	Dept. of Engineering Cybernetics
Johannes Robert Skarø	Safe-Space Estimation for Autonomous Surface Vessels	1	Edmund Brekke	Dept. of Engineering Cybernetics
Mikkel Bergstrand	Mission Planning for MASS systems	1	Anastasios M. Lekkas	Dept. of Engineering Cybernetics

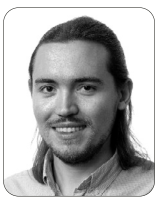
Martin Baerveldt, postdoc, Dept. of Engineering Cybernetics, NTNU.

Johannes Robert Skarø, PhD Candidate, Dept. of Engineering Cybernetics, NTNU.

Mikkel Bergstrand, PhD Candidate, Dept. of Engineering Cybernetics, NTNU.

PhDs and Postdocs

Martin Lukas Baerveldt
Combining Extended Object Tracking and Localization to Enhance Situational Awareness
Supervisor: Edmund Brekke (ITK, NTNU)



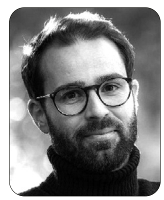
Spencer A. Dugan
Methods and tools for the mitigation of drifting grounding risk
Supervisors: Ingrid B. Utne and Mehdi Zadeh (IMT, NTNU)

Eirik Fagerhaug
Explainable AI for Autonomous Ships
Supervisors: Lars Ivar Hatledal, Ottar L. Osen and Robin T. Bye (IIR, NTNU), Anastasios M. Lekkas (ITK, NTNU)

Henrik Dobbe Flemmen
Simultaneous localization and mapping (SLAM) for autonomous ships
Supervisors: Edmund Brekke, Kostas Alexis, Anette Stahl and Torleiv Bryne (ITK, NTNU), Rudolf Mester (IDI, NTNU)

Emir Cem Gezer
Risk-aware and safeguarding control for autonomous ships
Supervisors: Roger Skjetne and Ingrid B. Utne (IMT, NTNU), Morten Breivik (ITK, NTNU)

Luka Grgičević
Game-Theoretical Maritime Guidance Algorithms
Supervisors: Erlend Magnus Lervik Coates, Ottar L. Osen and Robin T. Bye (IIR, NTNU), Thor I. Fossen (ITK, NTNU)



Lukas Herrmann
Maritime Radar Detection and Tracking of Low-Observable Targets
Supervisors: Egil Eide (IES, NTNU), Edmund Brekke (ITK, NTNU), Andreas Brandsæter (IIR, NTNU)

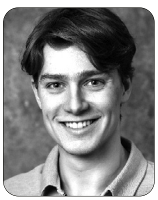
Miguel Hinostroza (researcher)
Motion control and collision avoidance for autonomous surface vessels, validated via full-scale implementations
Supervisor: Edmund Brekke (ITK, NTNU)

Manju James
Radio Twin: Digital twin for maritime communication system performance prediction
Supervisor: Kimmo Kansanen (IES, NTNU)

Joel Jose
Automation transparency during supervisory control of maritime collision avoidance systems
Supervisor: Erlend Magnus Lervik Coates (IIR, NTNU)

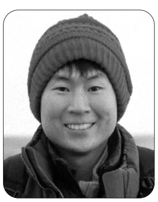
Susanna Dybwad Kristensen
Online risk modelling of autonomous ships
Supervisors: Ingrid B. Utne and Roger Skjetne

Emil Martens
Multi Sensor Detection for Autonomous Surface Vessels
Supervisors: Annette Stahl and Edmund Førland Brekke (ITK, NTNU), Rudolf Mester (IDI, NTNU)



Jon Estil Krågebakk
AI and data-driven safety management in operation of autonomous ships
Supervisor: Ekaterina Kim (IMT, NTNU)

Giacomo Melloni
Radio channel measurements and modelling in maritime scenarios
Supervisor: Torbjörn Ekman (IES, NTNU)



Paul Lee (postdoc)
Risk-aware AI agents for the safety-critical operations of autonomous ships
Supervisor: Ingrid B. Utne (IMT, NTNU)

Daniel Menges
Situational Awareness and Control of Autonomous Surface Vessels Using Digital Twins
Supervisors: Adil Rasheed, Edmund Brekke and Anastasios M. Lekkas (ITK, NTNU)

Simon Lexau
Autonomous Docking for Marine Surface Vessels
Supervisors: Anastasios M. Lekkas and Morten Breivik (ITK, NTNU)

Peter Morris
Data Fusion in Maritime IoT
Supervisor: Pierluigi Salvo Ross (IES, NTNU) i

Mikkel Bergstrand
Mission Planning for MASS systems
Supervisors: Anastasios M. Lekkas, Miguel Hinostroza (ITK, NTNU)

Felix-Marcel Petermann
Designing Interaction for Safe and Comprehensible Human-Autonomy Collaboration in Autonomous Passenger Ferries
Supervisors: Ole Andreas Alsos and Eleftherios Papachristos (Dept. of Design, NTNU)

Sreekant Sreedharan
Platforms, Languages & Tools for Safety Assurances in Autonomous Vessels
Supervisor: Børge Rokseth (ITK, NTNU)

Ayoub Tailoussane
COLREGS-compliance in the era of Autonomous Vessels – Legal challenges and future perspectives
Supervisors: Trond Solvang (NIFS, UiO), Dag Wiese Schartum (IFP, UiO)

Johannes Robert Skarø
Safe-Space Estimation for Autonomous Surface Vessels
Supervisor: Edmund Brekke

Raffael Wallner
Safety Demonstration of Autonomously Controlled Ships using Digital Twin
Supervisors: Mary Ann Lundteigen and Tor Arne Johansen (ITK, NTNU), Bjørn Axel Gran (IFE), Tom Arne Pedersen (DNV)

SFI AutoShip in the media

Interview in Adresseavisen

WP3 PhD Felix-Marcel Petermann and WP leader Ole Andreas Alsos was interviewed and featured on the front page of Adresseavisen in June, in the article «Nytt verktøy fra NTNU: - Det er nesten som et spill». They explained the development of the new tool Maritime Head-up Display (M-HUD), which streamlines minimal essential information directly into the navigator's line of sight, improving situational awareness.


Adresseavisen

Mandag
23. juni - uke 26 - 2025
Norges eldste avis - grunnlagt 1767
nr. 140 - 259. årgang - løssalg 45

Iranske Sabir Kadri:
– Det er ingen som vinner på en krig
Utland side 14, 16 og 17

Tore O. Sandvik i Kyiv – møtte Zelenskyj
Nyheter side 6–7

Solveig Løvseth måtte skaffe seg stjernemanager
Sport side 18–19

Stipendiat Felix Petermann hos NTNU har jobbet med å utvikle det splitter nye verktøyet. FOTO: NINA BERGKVAM

Nytt verktøy fra NTNU

NTNU-forskerne har funnet opp et splitter nytt verktøy. Målet er at det skal bli standard på alle skip. Nyheter side 10–11

Adresseavisen, «Nytt verktøy fra NTNU: - Det er nesten som et spill», 23.07.2025.

Interview in Universitetsavisa

WP3 PhD Felix-Marcel Petermann has been collaborating with researchers from the adjacent project Autoteaming, and was interviewed along with WP leader Ole Andreas Alsos in Universitetsavisa in September, in the article «NTNU-forskerne er først i verden med et slikt system». They described how multiple ships can be controlled from NTNU's Shore Control Lab.

NTNU-forskerne er først i verden med et slikt system

Forskere ved NTNU har lagd et unikt kontrollrom som kan styre flere skip om gangen. En hybridløsning mellom full autonomi og full kontroll gjør prosjektet unikt i verden.

Felix-Marcel Petermann, Andreas Gudahl Tufte, og Alexey Gusev fra prosjektet Autoteaming foran fergen Milliampere 2 Foto: Kristoffer Ramsøy Fredriksen

Universitetsavisa, «NTNU-forskerne er først i verden med et slikt system», 01.09.2025.

Events

SFI AutoShip Days

90 participants from our consortium attended our main annual event, the SFI AutoShip Days on October 14-15, at Scandic Nidelven in Trondheim.

Highlights include Kongsberg Maritime's updates on the Reach Remote project, NMA's insights from the ongoing MASS code process, DNV's Simulation Trust Center, Maritime Robotics' results on situational awareness and safety equivalence assessment, and developments on remote crane operations by NCL, SINTEF Digital and SINTEF Ocean. We were also fortunate to be joined by guest presenters from the Norwegian Mapping Authority as well as the international student competition Njord. Finally, results were presented by graduated and soon-to-be graduated PhDs and current researchers from NTNU, many co-presenting with industry partners. Our 3 newly hired researchers also presented their projects.

Left-right: Kenneth Johanson (NCL), Susanna Dybwad Kristensen (NTNU) and Sifis Papageorgiou (NMA) presenting. Photos: Ingeborg Guldal/NTNU

Paul Lee (NTNU) presenting. Photo: Kai Dragland/NTNU

Jorge Luis Mendez (DNV) presenting. Photo: Kai Dragland/NTNU

Marthe Kristine Sand (Kongsberg Maritime) presenting. Photo: Ingeborg Guldal/NTNU

SFI AutoShip Researcher Workshops

On March 17, 60 participants including researchers as well as industry partners from DNV, Gard, Kongsberg Maritime, Maritime Robotics, Massterly and Torghatten attended the Spring researcher workshop. Our 3 newly hired researchers presented their projects in the plenary session, before the parallel sessions were dedicated to developing the innovation leads and potential utilisation of each of the SFI PhD and PD projects, with feedback from the consortium partners. The discussions provided valuable input for the portfolio of innovation leads which was presented to the Board in June.

The Autumn researcher workshop was arranged on September 15, with 50 participants from research and industry partners including Equinor, Kongsberg Maritime, Maritime Robotics, DNV, Gard and Torghatten. WP sessions focused on the annual work plan for 2026, and the status of research activities and collaborations. Kongsberg Maritime and DNV contributed with engaging presentations during the plenary session. We also planned demonstrations and presentations in collaboration with partners for the upcoming SFI AutoShip Days.

Tom Arne Pedersen, Melih Akdağ and Chanjei Vasanthan (DNV) presenting at the Autumn researcher workshop. Photo: Ingeborg Guldal/NTNU

The WP3 parallel session at the Spring researcher workshop. Photo: Ingeborg Guldal/NTNU

A coffee break during the Autumn researcher workshop. Photo: Ingeborg Guldal/NTNU

Publications and Presentations in 2025

TYPE	NAME/DESCRIPTION	NAME OF JOURNAL/ CONFERENCE/BOOK	AUTHOR(S)
Journal articles	A Decentralized Negotiation Protocol for Collaborative Collision Avoidance of Autonomous Surface Vehicles	IEEE Transactions on Control Systems Technology	Melih Akdağ, Hoang Anh Tran, Nikolai Lauvås, Tom Arne Pedersen, Thor I. Fossen, Tor Arne Johansen
	Digital twin syncing for autonomous surface vessels using reinforcement learning and nonlinear model predictive control	Nature, Scientific Reports	Henrik S. Berg, Daniel Menges, Trym Tengesdal, Adil Rasheed
	Motion Constrained Point Cloud Matching for Maritime Tracking	IEEE Access	Nicholas Dalhaug, Martin Baerveldt, Angelica I. Aviles-Rivero, Carola-Bibiane Schönlieb, Annette Stahl, Rudolf Mester, Edmund F. Brekke
	Improved identification of maritime risk-influencing factors using AIS data in regression analysis	Reliability Engineering & System Safety	Spencer A. Dugan, Ingrid B. Utne
	The Autonomous Urban Passenger Ferry milliAmpere2: Design and Testing	Journal of Offshore Mechanics and Arctic Engineering	Egil Eide, Morten Breivik, Edmund F. Brekke, Bjørn-Olav H. Eriksen, Erik F. Wilthil, Øystein K. Helgesen, Emil H. Thyri, Erik Aleksander Veitch, Ole Andreas Alsos, Tor Arne Johansen
	Oceanscape: A graph-based framework for autonomous coastal navigation	Ocean Engineering	Eirik S. Fagerhaug, Lars Ivar Hatledal, Robin T. Bye, Ottar L. Osen
	Extended Object Tracking Using a Gaussian Process Extent Model and Scene Flow-LiDAR Fusion	IEEE Aerospace Conference. Proceedings	Steffen Folåsen, Martin L. Baerveldt, Michael Ernesto Lopez, Nicholas Dalhaug, Annette Stahl, Edmund F. Brekke
	Multi-level risk classification of distributed embedded software failures for autonomous systems	Proceedings of the Institution of Mechanical Engineers. Part O, Journal of risk and reliability	Alojz Gomola, Susanna D. Kristensen, Ingrid B. Utne
	Centralised Decision Support in Maritime Vessel Traffic Services: A Polymatrix Game Solution	IEEE Access	Luka Grgičević, Erlend M. Coates, Thor I. Fossen, Robin T. Bye, Ottar L. Osen
	Histogram-Probabilistic Multi-Hypothesis Tracking with Integrated Target Existence	IEEE Transactions on Aerospace and Electronic Systems	Lukas Herrmann, Ángel F. García-Fernández, Edmund F. Brekke
	Target Detection in Maritime Radar Tracking Based on Spatial Image Gradients	IEEE Sensors Journal	Lukas Herrmann, Gianluca Tabella, Edmund F. Brekke, Egil S. Eide

TYPE	NAME/DESCRIPTION	NAME OF JOURNAL/ CONFERENCE/BOOK	AUTHOR(S)
	Model Identification, Dynamic Positioning, and Thrust Allocation System for the milliAmpere1 Autonomous Ferry Prototype: Field Trial Results	IEEE Access	Miguel A. Hinostroza, Camilla Fruzetti, Andreas G. Tufte, Simon J.N. Lexau, Alexey Gusev, Egil S. Eide, Edmund F. Brekke, Anastasios M. Lekkas, Roger Skjetne, Michele Martelli, Morten Breivik
	milliAmpere1 Autonomous Ferry Prototype: Hardware and Software	Proceedings of ASME 2025 and OMAE2025	Miguel A. Hinostroza, Egil S. Eide, Edmund F. Brekke, Morten Breivik, Anastasios M. Lekkas, Roger Skjetne, Torleiv H. Bryne, Alexey Gusev, Andreas G. Tufte
	Evaluating the effect of risk metrics for supporting operational decision-making by autonomous surface vehicles	Ocean Engineering	Susanna D. Kristensen, Renan G. Maidana, Ingrid B. Utne, Jens E. Bremnes
	Towards robust deep reinforcement learning agent for the path following of autonomous ships amid perception sensor noise	Proceedings of ESREL 2025	Paul Lee, Ekaterina Kim
	Improving decision transparency in autonomous maritime collision avoidance	Journal of Marine Science and Technology	Andreas N. Madsen, Andreas Brandsæter, Koen van de Merwe, Jooyoung Park
	From COLREG compliance to performance requirements for situational awareness systems in autonomous navigation systems	Journal of Physics: Conference Series (JPCS)	Peter Keenan Morris, Pål Henrik Hannus, Tom Arne Pedersen, Henrik Stokland Berg, Grunde Løvoll, Kristian B. Karolius
	Nested optimal energy scheduling and power allocation for zero-emission high-speed passenger vessels	Ocean Engineering	Samieh Najjaran, Roger Skjetne
	Can remotely operated cranes solve recruitment challenges due to crane operator shortage?	Journal of Physics: Conference Series (JPCS)	Håvard Nordahl, Ulrik Jørgensen, Renan G. Maidana, Patrick Specht, Kenneth Johanson
	Maritime Head-up Display (mHUD): a safety-enhancing navigational tool for ship bridges and remote operation centres	Journal of Navigation	Felix-Marcel Petermann, Ole Andreas Alsos, Eleftherios Papachristos, Clas Olaf S. Andersen, Andreas N. Madsen
	A Comparative Study of Rapidly-exploring Random Tree Algorithms Applied to Ship Trajectory Planning and Behavior Generation	Journal of Intelligent & Robotic Systems	Trym Tengesdal, Tom Arne Pedersen, Tor Arne Johansen
	Maritime object tracking from a commercial vessel using radars, electro-optical cameras and navigational instruments	Ocean Engineering	Lars-Christian N. Tokle, Erlend S. Harbitz, Johannes Tjønnås, Torbjørn Barheim, Esten Ingar Grøtli

TYPE	NAME/DESCRIPTION	NAME OF JOURNAL/ CONFERENCE/BOOK	AUTHOR(S)
	Dataset on passenger experience after riding an autonomous ferry	Data in Brief	Erik Aleksander Veitch, Taufik A. Sitompul, Ole Andreas Alsos
Conference papers/ workshop presentations	Human in the maritime operations of the future	IMO MASS Symposium	Ole Andreas Alsos, Felix-Marcel Petermann
	Mind the Kayak! Informing UX Design of Autonomous Vehicles through Edge Case Testing in the Field	Proceedings of the 2025 CHI Conference on Human Factors in Computing Systems	Ole Andreas Alsos, Mina Saghafian, Erik A. Veitch, Taufik A. Sitompul, Felix-Marcel Petermann, Eleftherios Papachristou
	Methods to Handle Interior and Boundary Measurements for the Gaussian Process Model	International conference on Information Fusion 2025	Martin L. Baerveldt, Edmund F. Brekke
	Applying Extended Object Tracking in Confined Waterways	SFI AutoShip Days 2025	Martin Baerveldt and Andrea Wesenberg
	Maritime AI for Trustworthy Decision-Making through Fundamental Research and Industry-Driven Applications	23rd International Conference on Computer and IT Applications in the Maritime Industries	Svein Peder Berge, Pauline R. Bellingmo
	Analysis of the Repairability of Ship Machinery Failures	Annual Symposium on Reliability and Maintainability (RAMS)	Spencer A. Dugan, Ingrid B. Utne
	Digital-physical testbed for ship autonomy studies in the Marine Cybernetics Laboratory basin	ICSOS 2025	Emir Cem Gezer, Mael Korentin Ivan Moreau, Anders S. Høgden, Dong Trong Nguyen, Roger Skjetne, Asgeir Johan Sørensen
	Algorithms in Vessel Traffic Services (VTS) for Centralised Traffic Management	SFI AutoShip Days 2025	Luka Grgičević
	Track Initiation and Adaptive Target Birth in Existence-Based Poisson Histogram-PMHT	2025 IEEE Radar Conference	Lukas Herrmann, Ángel F. García-Fernández, Edmund F. Brekke, Egil S. Eide
	New solutions for harsh environments through research-industry collaboration	Arctic Shipping Summit 2025	Ekaterina Kim, Asgeir J. Sørensen, Bjørn Egil Asbjørnslett, Ingrid B. Utne, Knut V. Høyland, Mojtaba Mokhtari, Raed Khalil Lubbad, Roger Skjetne, Sønke Maus, Tor Arne Johansen, Wenjun Lu
	Safety equivalence assessment for a small passenger ferry with a periodically uncrewed bridge	SFI AutoShip Days 2025	Børge Kjeldstad
	Risk-aware autonomous surface vessels for safe and intelligent path planning	SFI AutoShip Days 2025	Susanna Dybwad Kristensen

TYPE	NAME/DESCRIPTION	NAME OF JOURNAL/ CONFERENCE/BOOK	AUTHOR(S)
	Towards risk-aware AI agents for safety-critical operations of MASS/ DNV co-simulation platform: Simulation Trust Center	SFI AutoShip Days 2025	Paul Lee and Jorge Luis Mendez
	Results from sea trials with milliAmpere 1	SFI AutoShip webinar	Anastasios M. Lekkas, Miguel A. Hinostroza, Ida Margrethe Tangen, Alexander Sandberg
	Online Model Adaptation for Autonomous Vessel Navigation: Experimental Results from Maritime Field Tests	SFI AutoShip Days 2025	Simon J.N. Lexau
	Leveraging Collision Avoidance Robustness to Establish Situational Awareness Requirements: A Closed Loop Simulator Approach	ESREL 2025	Grunde Løvoll, Kristian B. Karolius, Henrik Stokland Berg, Peter Keenan Morris
	Caspar (CUDA Accelerator for Symbolic Programming with Adaptive Reordering)	SFI AutoShip Days 2025	Emil Martens
	Phase Distribution of the Large-Scale Scattered Field from the Sea Surface	2025 19th European Conference on Antennas and Propagation (EuCAP)	Giacomo Melloni, Torbjörn Ekman
	Digital Twin for Situational Awareness and Optimal Control of Autonomous Surface Vessels	SFI AutoShip Days 2025	Daniel Menges
	Simulating the Effects of Sensor Noise on Situational Awareness and Collision Avoidance Systems	SFI AutoShip Days 2025	Peter Morris and Pål Henrik Hannus
	Simulating Situational Awareness for Performance Requirements and testing Collision Avoidance Systems using Signal Temporal Logic	SFI AutoShip webinar	Peter K. Morris, Tom Arne Pedersen, Henrik S. Berg
	Can remotely operated cranes solve recruitment challenges due to crane operator shortage? & Crane simulator for enhanced situational awareness	SFI AutoShip Days 2025	Håvard Nordahl, Kenneth Johanson, Magns Bjerkeng
	Can remotely operated cranes solve recruitment challenges due to crane operator shortage?	8th International Conference on Maritime Autonomous Surface Ships (ICMASS 2025) & Intelligent and Smart Shipping Symposium (ISSS)	Håvard Nordahl, Ulrik Jørgensen, Renan Guedes Maidana, Patrick Specht, Kenneth Johanson
	Replication vs. Modification: Comparing the Usability of Crane GUIs Designed by Reusing a Design System	Proceedings of the 11th International HCI and UX Conference in Indonesia (CHIuXiD 2025)	Torvid Opsahl, Taufik A. Sitompul
	The first MASS Code is almost done, what now?	SFI AutoShip Days 2025	Sifis Papageorgiou

TYPE	NAME/DESCRIPTION	NAME OF JOURNAL/ CONFERENCE/BOOK	AUTHOR(S)
	Humans and autonomous ships: Their information demand and how we can solve it with design-driven research	SFI AutoShip Days 2025	Felix-Marcel Petermann
	The unseen helm: Potential human-factors issues in monitoring and operating MASS	Autonomous Sea Navigation, Batumi State Maritime Academy & Universita Degli Studi Del Sannio	Felix-Marcel Petermann
	A Field Study: Evaluating the Maritime Head-Up Display (mHUD)	Interact Workshops 2025	Felix-Marcel Petermann
	From Helm to Screen: Navigator and Gamer Insights for Designing Multi-Vessel Control Interfaces	Interact Workshops 2025	Felix-Marcel Petermann
	Guided by the Light: The Design of a Navigation Support Tool for Ships	Human-Computer Interaction--INTERACT 2025: Proceedings, Part I	Felix-Marcel Petermann, Ole Andreas Alsos
	Shaping the Future of Autonomous Ships: Kongsberg Maritime's Delivery of Unmanned Surface Vessels	SFI AutoShip Days 2025	Marthe Kristine Sand
	Designing user interfaces for remote cranes by reusing OpenCraneDesign System: Insights from software developers and crane operators	SFI AutoShip webinar	Taufik Akbar Sitompul
	Shore Control Lab: A research infrastructure for investigating future challenges in monitoring and operating MASS	NATO Advanced Training Course on Autonomous Sea Navigation	Taufik Akbar Sitompul
	Free Space Estimation with Stereo Camera and LiDAR	SFI AutoShip Days 2025	Johannes Robert Skarø
	Stixel-Based Free Space Estimation for USVs Using Stereo Camera and LiDAR	International conference on Information Fusion 2025	Johannes Robert Skarø, Trym A. Nygård, Rudolf Mester, Annette Stahl, Edmund F. Brekke
	Teknologien er her – men stoler vi på den? Autonome løsninger og AI i kritisk infrastruktur	Paneldebatt, Lenovo Norge og TEK Norge	Lars A. L. Wennersberg, Alf Tore Sørheim, Bjørn Jalving, Verner Hølleland, Espen Hjertø
Doctoral theses	Game-Theoretical Maritime Guidance Algorithms	Doctoral thesis at NTNU	Luka Grgičević
	Maritime Radar Detection and Tracking of Low-Observable Targets	Doctoral thesis at NTNU	Lukas Herrmann
	Digital Twin for Situational Awareness and Optimal Control of Autonomous Surface Vessels	Doctoral thesis at NTNU	Daniel Menges

TYPE	NAME/DESCRIPTION	NAME OF JOURNAL/ CONFERENCE/BOOK	AUTHOR(S)
Other presentations and events	Presentation of NTNU Shore Control Lab (SCL)	Visit of Equinor	Ole Andreas Alsos, Andreas G. Tufte, Felix-Marcel Petermann, Alexey Gusev
	Presentation of NTNU Shore Control Lab (SCL)	Visit of Singapore Institute of Technology	Ole Andreas Alsos, Felix-Marcel Petermann, Alexey Gusev, Andreas G. Tufte
	Presentation NTNU Shore Control Lab (SCL)	Visit of Minister of climate and environment Andreas Bjelland Eriksen	Ole Andreas Alsos, Felix-Marcel Petermann, Alexey Gusev, Vikram Singh Parmar, Andreas G. Tufte
	Presentation of NTNU Shore Control Lab (SCL)	Visit of SIVA	Ole Andreas Alsos, Felix-Marcel Petermann, Andreas G. Tufte, Alexey Gusev
	Presentation of NTNU Shore Control Lab (SCL)	Visit of Massimo Banzi (Arduino)	Ole Andreas Alsos, Felix-Marcel Petermann, Erik A. Veitch, Alexey Gusev, Andreas G. Tufte
	Research on Smart Shipping in SINTEF Ocean	Smart Shipping Plenary Meeting, International Standardization Organization/Technical Committee 8 Ships and Marine Technology	Marianne Hagaseth, Lars A. L. Wennersberg
	Presentation of SFI AutoShip	Ecole Centrale and INSA in Lyon	Anastasios M. Lekkas
	Presentation of SFI AutoShip	Nordic 5 Tech visit	Anastasios M. Lekkas
	Presentation of SFI AutoShip	University of Singapore visit	Anastasios M. Lekkas
	Highlights from major Horizon Europe autonomy projects	Norway Singapore Science Week 2025	Odd Erik Mørkrid
	Presentation of NTNU Shore Control Lab	Besøk Tysk–norsk Handelskammer	Felix-Marcel Petermann
	Presentation NTNU Shore Control Lab (SCL)	Visit UiB Rector	Felix-Marcel Petermann
	Demonstration of maritime Headup-display (mHUD) on High-speed ferry	NTNU Shore Control Lab & NTNU Technology Transfer event at Brattøykaia	Felix-Marcel Petermann, Ole Andreas Alsos, Clas Olaf S. Andersen, Jens Nygaard
	Presentation of NTNU Shore Control Lab (SCL)	Visit National Sustainability Committee	Erik A. Veitch, Ole Andreas Alsos, Alexey Gusev, Felix-Marcel Petermann
	Autonomi på kurs: Hvor langt er IMO - og hvor leder Norge?	Digital samhandling til sjøs	Lars Andreas Lien Wennersberg

Master Students 2025

MASTER THESES WITH SFI AUTOSHIP TOPICS COMPLETED IN 2025

NAME	SEX	THESIS TITLE	SUPERVISORS
Maxime Audrain	M	Enhanced docking of autonomous ships through VR-assisted remote control	Roger Skjetne
Elias Johansson Bakke	M	Nonlinear Model Predictive Control as a Guidance Controller for Ship Autopilot Applications	Roger Skjetne, Christoffer Fredrik Lid Thorvaldsen
Håkon Bakke	M	Responsive Wave Load Compensation in Dynamic Positioning for Ships	Roger Skjetne
Henrik Rülcker Brekken	M	Control of Towline Force, Direction, and Vessel Heading for AHTS Vessels in Maritime Towing Operations with Winch-Based Mitigation of Wave Disturbances	Tor Arne Johansen, Eivind Duus Molven
Vegard Bårsaune	M	Real-time estimation and phase-resolved prediction of waves at ship location	Roger Skjetne
Astrid Fiskum	F	Design av brukergrensesnitt for fjernstyring av Clean Sea Solution's Aquadrone for effektiv avfallshåndtering i havner	Ole Andreas Alsos
August Johansen Fors	M	A LiDAR-Based Situational Awareness System for Autonomous Surface Vessels in Near-Shore Environments	Edmund Brekke, Simon Lexau
Jonas Tandberg Gundersen	M	Design, Development, and Evaluation of COLREGs-Compliant COLAV Methods for ASVs: A Comparative Study with Field Trials	Anastasios M. Lekkas
Anders Sandneseng Høgden	M	Dynamic power-optimal thrust allocation of over-actuated low-speed vessels: Implementation and benchmark testing on milliAmpere 1	Roger Skjetne, Emir Cem Gezer
Maren Javenes	F	From Bridge to Screen: Interface Design for Remote Operation of Ships	Ole Andreas Alsos, Alexey Gusev
Sigurd Bonden Kjørsvik	M	Guidance and control for automatic docking of an unmanned surface vessel	Tor Arne Johansen, Emil Hjelseth Thyri
Oda Hovin Lilleøkdal	F	Prediction of Ship Maneuvering Parameters Using Machine Learning on Historical AIS Data for Collision Avoidance at Sea	Tor Arne Johansen, Børge Rokseth, Dhanika Chamath Gunarathna Mahipala
Aleksander Klund	M	Bayesian and Optimization-Based Extended Object Tracking Using Fourier and PCA-Based Extent Mode	Edmund Brekke, Michael Ernesto López
Stefan Alexandru Lapadatu	M	Reinforcement Learning in Parameter Tuning for Maritime Collision Avoidance Algorithms	Tor Arne Johansen, Børge Rokseth
Jørgen Andreas Mo	M	Force- and Heading Control for Vessels Attached to Winch- or Anchor Lines	Tor Arne Johansen, Eivind Duus Molven

NAME	SEX	THESIS TITLE	SUPERVISORS
Kristian Magnus Roen	M	Meta Learning for Nonlinear Adaptive Motion Control of Marine Vessels	Roger Skjetne, Emir Cem Gezer
Erlend Sortland Rolfsnes	M	Deep Reinforcement Learning for Improving Ship Collision Avoidance using Scenario-Based MPC	Tor Arne Johansen, Børge Rokseth
Simen Rørvik	M	Extended Object Tracking of Highly Maneuverable Vessels in the Presence of Wakes	Edmund Brekke, Martin Baerveldt
Alexander Sandberg	M	Deploying Trustworthy Deep Reinforcement Learning for Dynamic Positioning: A Live Explainable AI Approach on Real Maritime Cyber-Physical Systems	Anastasios M. Lekkas
Sander August Heggland Schrader	M	Do Design Principles Matter When Redesigning User Interface for Cranes? Results From a Usability Study in a Simulated Working Environment	Yngve Dahl, Taufik Akbar Sitompul
Johannes Robert Skarø	M	Multimodel Stixel-Based Free Space Estimation in Near-Shore Waterways	Edmund Brekke, Annette Stahl, Rudolf Mester
Ida Margrethe Tangen	F	Design, Simulation, and Physical Testing of an Online Path Planner for Collision Avoidance in a Docking Environment	Anastasios M. Lekkas, Tom Arne Pedersen, Simon Lexau
Andrea Wesenberg	F	Enabling Real-Time Gaussian Process Extended Object Tracking with through Camera and LiDAR Fusion	Edmund Brekke, Audun Gullikstad Hem, Martin Baerveldt
Clemens Sundby Øxnevad	M	Automatic Scene Reference Generation and Water Surface Referending using Public Geospatial Data	Emil Martens, Annette Stahl, Edmund Brekke

Annual Accounts for 2025

All figures in 1000 NOK.

FUNDING	AMOUNT
The Research Council	9 831
The Host Institution (NTNU)	11 835
Research Partners*	6 712
Enterprise partners**	8 870
Public partners***	140
Total	**37 388**

COSTS	AMOUNT
The Host Institution (NTNU)	24 107
Research Partners*	8 209
Enterprise partners**	4 932
Public partners***	140
Total	**37 388**

*Research Partners**

Universitet i Oslo
SINTEF Digital
SINTEF Ocean
Institutt for energiteknikk

*Enterprise Partners***

DNV
Equinor Energy
Fugro Norway
Gard
Grieg Star
Idletechs
Kongsberg Maritime
MacGregor Norway
Maritime Robotics
Massterly
North Sea Container Line
Reach Subsea
Telia Norge
Torghatten

*Public Partners****

Sjøfartsdirektoratet
Kystverket
Trondheim kommune
Trondheim Havn IKS

Key Personnel

CENTRE MANAGEMENT AND ADMINISTRATION

Anastasios M. Lekkas	Centre director
Roger Skjetne	Centre co-director
Svein Peder Berge	Centre co-director and WP 6 leader
Kjell Olav Skjølsvik	Innovation manager
Ingeborg Guldal	Administrative coordinator
Frank-Robert Horgmo	Economist

KEY RESEARCHERS	NTNU	MAIN RESEARCH AREA
Adil Rasheed	Dept. of Engineering Cybernetics	Big data cybernetics, hybrid analysis and modelling
Anastasios M. Lekkas	Dept. of Engineering Cybernetics	Autonomous systems
Annette Stahl	Dept. of Engineering Cybernetics	Robotic vision
Børge Rokseth	Dept. of Engineering Cybernetics	Safety assurance of autonomous systems
Edmund Brekke	Dept. of Engineering Cybernetics	Sensor fusion
Egil Eide	Dept. of Electronic Systems	Sensors and autonomous systems
Erik Veitch	Dept. of Design	Industrial design
Erlend Magnus Lervik Coates	Dept. of ICT and Natural Sciences	GNC, propulsion and autonomous systems
Ingrid Bouwer Utne	Dept. of Marine Technology	Operational risk in marine and maritime systems
Kimmo Kansanen	Dept. of Electronic Systems	Signal processing
Kjell Olav Skjølsvik	Dept. of Marine Technology	Innovation Manager
Lars Ivar Hatledal	Dept. of ICT and Natural Sciences	
Magne Aarset	Dept. of Ocean Operations and Civil Engineering	Risk Mnagement/Artificial Intelligent
Mary Ann Lundteigen	Dept. of Engineering Cybernetics	Safety, reliability and automation systems
Morten Breivik	Dept. of Engineering Cybernetics	Autonomous systems
Ole Andreas Alsos	Dept. of Design	Interaction design
Ottar L. Osen	Dept. of ICT and Natural Sciences	Cybernetics and artificial intelligens
Pierluigi Salvo Rossi	Dept. of Electronic Systems	Signal processing, communication theory, data fusion and machine learning
Robin Bye	Dept. of ICT and Natural Sciences	Explainable AI, automation transparency
Roger Skjetne	Dept. of Marine Technology	Marine cybernetics
Runar Ostnes	Dept. of Ocean Operations and Civil Engineering	Nautical science, navigation systems and nautical operations
Taufik Akbar Sitompul	Dept. of Design	Design research, human factors, human-computer interaction, human-machine interference
Thomas Porathe	Dept. of Design	Human factors and remote control centres
Thor I. Fossen	Dept. of Engineering Cybernetics	Cyber security, navigation and control of marine craft
Tor Arne Johansen	Dept. of Engineering Cybernetics	Automatic control
Torbjørn Ekman	Dept. of Electronic Systems	Radio communications, communication theory and signal processing

KEY RESEARCHERS	UNIVERSITY OF OSLO (UIO)	MAIN RESEARCH AREA
Erik Røsæg	UiO, Department of Private Law	Maritime law, law of the sea
Trond Solvang	UiO, Scandinavian Institute of Maritime Law	Maritime law, torts law, contract law

KEY RESEARCHERS	SINTEF	MAIN RESEARCH AREA
Eirik Flemsæter Falck	SINTEF Digital	Detection, tracking, crane control
Esten Ingar Grøtli	SINTEF Digital	Sensor fusion, estimation, path planning
Johannes Tjønnås	SINTEF Digital	Sensor fusion, estimation
Magnus Bjerkeng	SINTEF Digital	Cargo handling, control systems
Marialena Vagia	SINTEF Digital	Cargo handling, control systems
Mariann Merz	SINTEF Digital	Autonomy, risk assessment, path planning, control algorithms
Martin Brandt	SINTEF Digital	Sensor fusion and motion
Ella-Lovise Hammervold Rørvik	SINTEF Ocean	Autonomous maritime systems and simulations
Espen Tangstad	SINTEF Ocean	Autonomous control system
Even Ambros Holte	SINTEF Ocean	Maritime logistics and autonomous shipping
Håvard Nordahl	SINTEF Ocean	Autonomous maritime systems and simulations
Odd Erik Mørkrid	SINTEF Ocean	Maritime logistics and autonomous shipping
Pauline Røstum Bellingmo	SINTEF Ocean	Maritime digitalization, autonomous shipping
Svein Peder Berge	SINTEF Ocean	Software development, mathematical modelling, simulation technology, control systems
Trond Johnsen	SINTEF Ocean	Maritime transport and logistics
Ulrik Jørgensen	SINTEF Ocean	Autonomous maritime systems and simulations

KEY RESEARCHERS	IFE	MAIN RESEARCH AREA
Alf Ove Braseth	Principal Scientist	Control room and interaction design
Bjørn Axel Gran	Research director	Risk, safety and security
Linda Sofie Lunde-Hanssen	Senior Scientist	Control room and interaction design
Prosper A. Kwei-Narh	Senior Research Scientist	Human-Centred Digitalization
Stine Aurora Mikkelsplass	Junior Scientist	Safety, risk and security
Stine Strand	Research director	Control room and interaction design

Temporary and Affiliated Personnel

POSTDOCTORAL RESEARCHERS WITH FINANCIAL SUPPORT FROM THE CENTRE BUDGET				
NAME	**NATIONALITY**	**PERIOD**	**SEX M/F**	**TOPIC**
Martin Lukas Baerveldt	Sweden	01.02.2025-01.02.2027	M	Combining Extended Object Tracking and Localization to Enhance Situational Awareness
Miguel Hinostroza	Peru	01.09.2023-01.09.2028	M	Motion control and collision avoidance for autonomous surface vessels, validated via full-scale implementations
Paul Lee	Greece	18.08.2024-30.06.2027	M	Risk-aware AI agents for the safety-critical operations of autonomous ships

PHD STUDENTS WORKING ON PROJECTS IN THE CENTRE WITH FINANCIAL SUPPORT FROM OTHER SOURCES					
NAME	**FUNDING**	**NATIONALITY**	**PERIOD**	**SEX M/F**	**TOPIC**
Andreas Gudahl Tufte	Autoteaming	Norway	01.03.2024-01.03.2027	M	Automation transparency for human-machine teaming
Alexey Gusev	Autoteaming	Norway	01.03.2024-01.03.2027	M	Design of human-machine teaming interface for remote operation of autonomous passenger ferries
Awa Tendeng	NTNU VISTA CAROS	Senegal	01.03.2024-31.12.2027	F	Supervisory risk and organization control of marine robotics supporting subsea operation
Børge Kjeldstad	Kunnskaps-departementet	Norway	01.01.2023-31.12.2026	M	Risk-based design criteria for uncrewed and autonomous vessels
Johan Bakken Sørensen	NTNU	Norway	1.8.2022-31.7.2025	M	Safety and assurance of autonomous ships

PHD STUDENTS WITH FINANCIAL SUPPORT FROM THE CENTRE BUDGET				
NAME	**NATIONALITY**	**PERIOD**	**SEX M/F**	**TOPIC**
Ayoub Tailoussane	Morocco	02.11.2021-31.12.2024	M	Application of the COLREGs to Autonomous Vessels: A potential solution to the legal challenges
Daniel Menges	Germany	17.01.2022-30.01.2025	M	Digital Twin for Situational Awareness and Optimal Control of Autonomous Surface Vessels
Eirik Fagerhaug	Norway	03.08.2021-04.08.2025	M	Explainable AI for autonomous ships
Emil Martens	Norway	11.08.2021-11.08.2026	M	Multi Sensor Detection for Autonomous Surface Vessels
Emir Cem Gezer	Turkey	02.01.2023-02.03.2027	M	Risk-aware and safeguarding control for autonomous ships
Felix-Marcel Petermann	Germany	01.08.2021-30.11.2025	M	Designing Interaction for Safe and Comprehensible Human-Autonomy Collaboration in Autonomous Passenger Ferries
Giacomo Melloni	Italy	07.01.2024-07.01.2027	M	Radio Channel Measurements and Modelling in Maritime Scenarios
Henrik Dobbe Flemmen	Norway	01.10.2021-14.12.2025	M	Radar-based SLAM for autonomous ships
Joel Jose	India	01.01.2024-01.10.2027	M	Automation transparency during supervisory control of maritime collision avoidance systems
Johannes Robert Skarø	Norway	14.08.2025 -14.08.2028	M	Safe-Space Estimation for Autonomous Surface Vessels
Jon Estil Krågebakk	Norway	01.09.2024-01.09.2027	M	AI and data-driven safety management in operation of autonomous ships
Luka Grgičević	Croatia	31.01.2022-30.01.2025	M	Game-Theoretical Maritime Guidance Algorithms
Lukas Herrmann	Germany	01.06.2022-15.07.2025	M	Maritime Radar Detection and Tracking of Low-Observable Targets
Manju James	India	29.02.2024-28.02.2027	F	Digital twin for maritime communication system performance prediction
Mikkel Arvid Bergstrand	Norway	14.08.2025 -14.08.2029	M	Mission Planning for MASS systems
Peter Morris	Canada	16.10.2023-16.10.2027	M	Data Fusion in Maritime IoT
Raffael Wallner	Austria	29.11.2021-13.05.2025	M	Safety Demonstration of Autonomous Control Systems using Digital Twin
Simon Lexau	Norway	23.08.2022-22.10.2025	M	Autonomous docking of marine surface vessels
Spencer Dugan	USA	01.09.2021-30.04.2025	M	Methods and tools for the analysis and mitigation of drift grounding risk
Sreekant Sreedharan	India	15.12.2023-14.12.2026	M	Platforms, Languages & Tools for Safety Assurances in Autonomous Vessels
Susanna Dybwad Kristensen	Norway	16.08.2021-23.11.2025	F	Online risk modeling of autonomous ships

SFI · AUTOSHIP

Autonomous ships