ANNUAL REPORT 2024

SFI AUTOSHIP

Autonomous ships for safe and sustainable operations

Norwegian Centre for Research-based Innovation

SFI AUTOSHIP

NTNU | Norwegian University of Science and Technology

FUNDING AGENCY

The Research Council of Norway

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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.

Photo: Ingeborg Guldal/NTNU

Anastasios M. Lekkas
Centre Director SFI AutoShip

Centre Director

SFI AutoShip is now in the middle of its lifecycle and has many remarkable achievements to showcase. Five of our researchers, two PhDs and three Post-Docs, have successfully completed their work in the Centre. They all continue to contribute to the field of autonomy in Norway, alongside many of our 90 MSc graduates who are now working for either one of our partners or relevant actors. Our research has resulted in 77 journal articles, 56 conference papers, 158 dissemination activities, 4 reports, and we have organized 15 webinars involving many of our partners. In terms of innovation, the Centre has produced 18 innovation leads at various technology readiness levels, 5 disclosure of invention applications (DOFIs) and 1 patent application.

In terms of international collaboration, in 2024 we had researchers visiting the Massachusetts Institute of Technology (MIT), the University of Porto and the University of Liverpool, while we hosted researchers from the University of Genoa and the University of California, Berkeley. All these interactions have contributed considerably to knowledge transfer and broadening our international network of top experts in the field of autonomy.

Our user partners are more engaged and committed to the Centre than ever, as the high participation to all our events (SFI Days, researcher workshops, webinars) indicates. Notably, the activities of the dedicated working group on COLREG (Convention on the International Regulations for Preventing Collisions at Sea), which is led by DNV, commenced in 2024 and are attended by a significant portion of our consortium. Moreover, many numerous discussions are taking place with user partner initiatives with the aim of starting new joint activities within the Centre.

I wish to thank all our members for their dedication and commitment to SFI AutoShip's activities and objectives. With such a dedicated consortium, a research capacity that soon reaches 24 active researchers and top-tier infrastructure that allows for extensive full-scale testing from now on, we can only expect the Centre's activity and impact to reach new heights from 2025 onward!

Photo: Ingeborg Guldal/NTNU

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

Chairman of the Board

As the chairman of the board for the research center SFI AutoShip, I am very happy to present the 2024 annual report. I would also like to extend a warm welcome to the new researchers who joined us last year, and big thank you for the contributions from the PhDs and Postdocs that have now concluded their assignments in SFI AutoShip.

As we enter our fifth year of operation, I am proud to see SFI AutoShip continue to mature into a leading research center, delivering industry leading research across various scientific fields. Our researchers have published numerous high-quality scientific papers, firmly establishing the center on the international stage in autonomous ship research. One thing that sets us apart is the integration of solid scientific research with state-of-the art industry expertise, experiments, and physical trials.

In 2024, we have further strengthened our focus on connecting people and knowledge across the center. We continue to organize a series of well-attended webinars on key research topics, featuring presenters from many of our industry partners. Additionally, increased participation from industry partners in researcher workshops has enabled direct discussions between academic researchers and industry experts. The SFI days included a record number of participants, with excellent presentations from many partners and researchers. Moving forward, we will continue to focus on connecting people and knowledge between researchers and industry partners, aiming to create results that are directly relevant to the industry.

The world outside SFI AutoShip is also evolving. In recent years, we have witnessed massive attention on AI applications, such as ChatGPT, demonstrating the capabilities of modern AI technology. This has significantly influenced public attention and investment in AI and related technologies. We are already seeing increased attention and research funding being directed towards AI development, which is also benefiting the field of autonomous ships. Additionally, the regulatory framework is progressing, with the IMO MASS Code nearing its first non-mandatory version, scheduled for publication in 2026. Once in force, this will become a key milestone for the commercial utilization of autonomous ship technology, enabling many of the results from SFI AutoShip to be applied in the real world.

As chairman of the board, I would once again like to express my sincere thanks to the center director Anastasios M. Lekkas and administrative coordinator Ingeborg Guldal for their continuous dedication and commitment, which have been instrumental in the success of SFI AutoShip. I also extend my gratitude to all our partners for their efforts and enthusiasm in making SFI AutoShip a rewarding environment for state-of-the-art research and innovation in autonomous ship technology. I am grateful for the support and collaboration from all our partners and look forward to achieving many exciting joint results in the coming years as part of SFI AutoShip.

Illustration: Bjarne Stenberg/NTNU

SFI AutoShip Facts 2024

8
WORK PACKAGES

23
PARTNERS

34
CONFERENCE PAPERS

30
JOURNAL PAPERS
(6 of which co-authored with industry partners)

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 2024. 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

Odd Erik Mørkrid, 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 M. 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
Kjell Røang	Forskningsrådet	Board Member
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
Knut Hovda	Kystverket	Board Member
Hugo Rosano	MacGregor	Board Member
Vegard Evjen Hovstein	Maritime Robotics	Board Member
Kristine Prøsch	Massterly	Board Member
Kenneth Johanson	NCL	Board Member
Ingelin Steinsland	NTNU	Board Member
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Terje Meisler	Trondheim Havn	Board Member
Øyvind Tanum	Trondheim kommune	Board Member
Trond Solvang	UiO	Board Member

INNOVATION AND COMMERCIALISATION ADVISORY COMMITTEE		
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 shows 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 2024, the research in WP1 has focused on several tracks. One track has been the collection of relevant sensor data. In order to enable efficient data acquisition, a light-weight sensor rig was developed. Independently of this, a large set of radar data, which can be used for evaluation of multi-object tracking methods, was recorded in the Trondheim city canal. Another track has focused on motion control for collision avoidance and docking, using techniques such as reinforcement learning and nonlinear model-predictive control. A third track has focused on perception and interpretation of sensor data through techniques such as multi-object tracking and simultaneous localization and mapping (SLAM). Representation of the environment by in digital twins is playing a role of increasing importance in this research.

Postdoctoral researcher Trym Tengesdal completed his project "Simulation framework and software environment for evaluating automatic ship collision avoidance algorithms" in autumn 2024 and presented his results at the SFI Days.

Photo: Ingeborg Guldal/NTNU

Trym Tengesdal, postdoc

Simulation framework and software environment for evaluating automatic ship collision avoidance algorithms

Problem statement

Research on automatic ship collision avoidance and anti-grounding is nowadays abundant and features a rich set of proposed algorithms/systems. Despite many of these having been tested extensively in experiments, there is limited focus on systematic and extensive testing and validation also in a simulation environment. This is paramount for regulatory bodies and the public to gain trust in autonomous navigation systems and will make it easier to deploy such systems as decision support in existing vessels and as part of the autonomy suite on emerging autonomous ship technology. Most of the cited studies have created their own simulators, selected some situations for testing, and evaluated the performance qualitatively or on non-standard metrics. This type of simulation and evaluation suffers from several limitations: First, it makes the comparison of algorithms hard and sometimes impossible due to the discrepancy between scenarios, initial conditions, and metrics used. Second, studies reporting scarce amounts of evidence might easily miss negative evidence regarding the validity of the proposed COLAV algorithm. Third, the completeness and robustness of algorithms are not being gauged properly.

Proposed solution

A tailor-made framework for simulation and evaluation of maritime vessels with an automatic collision avoidance and anti-grounding (motion planning) system. The framework can be used for verification and assurance, and further enables automatic adjustment of collision avoidance systems online or offline. It can also be used for automatic scenario search in system stress testing. The system comes with a set of standard scenarios, i.e. a benchmark, that can be used and built upon in the testing. The user can set up scenarios with grounding hazards from Electronic Navigational Charts, realistic target tracking on either intelligent or non-intelligent nearby vessels. The performance of the system can then afterwards be automatically evaluated according to the maritime traffic rules (COLREG). Any kind of motion planning algorithm can be tested, as long as the framework interface is adhered to.

Main activities during 2024

- Trym completed his postdoc project in September 2024. He developed a simulation framework for testing collision avoidance algorithms which is considered as unique and SFI AutoShip is discussing how to further build on it, in collaboration with user partners.
- Visited MiT for a 2-week research stay at the Marine Autonomy Lab (MAL), Boston, USA.
- Co-supervised 7 MSc projects to completion.
- Conference paper: Real-time Feasible Usage of Radial Basis Functions for Representing Unstructured Environments in Optimal Ship Control, American Control Conference (ACC).
- Co-authored conference paper: Nonlinear Model Predictive Control for Enhanced Navigation of Autonomous Surface Vessels, IFAC-PapersOnLine.
- Presented the results from his research to the consortium at the SFI Days in October.

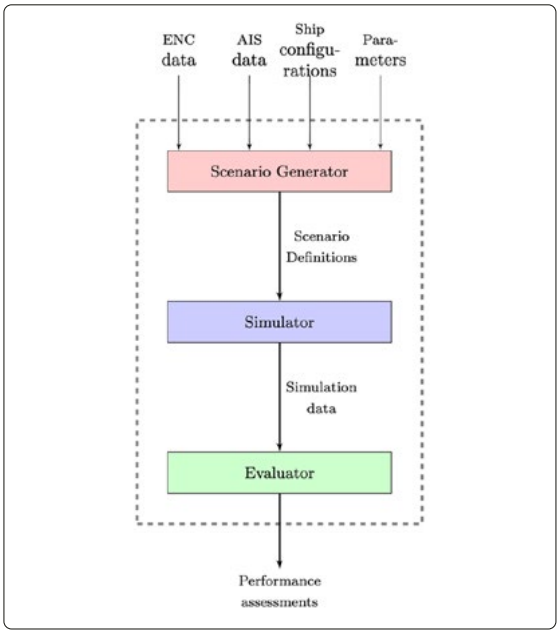


Figure 1: Framework architecture. ENC: Electronic Navigational Chart, AIS: Automatic Identification System

Emil Martens

Caspar (CUDA Accelerator for Symbolic Programming with Adaptive Reordering)

Background & Motivation
Modern autonomy systems, including autonomous surface vehicles, depend on sequential quadratic programming (SQP) to solve critical tasks like localization, tracking and control optimization. Unfortunately, computational complexity forces developers to compromise to make systems run in real time. Caspar aims at solving this by offering a more efficient way to solve optimization problems.

Objective & Innovation
Caspar extends SymForce (an open-source symbolic optimization library) to leverage NVIDIA GPUs via automatic CUDA kernel generation. It integrates optimization strategies from Google's Ceres solver with custom low-level register reordering to minimize latency and achieve high performance. This hybrid approach bridges symbolic math's flexibility with GPU-driven performance gains.

Expected Impact
Benchmarks show Caspar provides state of the art performance while retaining SymForce's ease of use. Skydio, the company behind SymForce, have shown great interest and are collaborating on integrating it into SymForce where it will be publicly available under the Apache 2.0 license.

A Sensor Rig for data acquisition in maritime environments

Problem Statement
High-quality datasets are critical for advancing ASV algorithms, but traditional data collection methods tend to be labor-intensive. Faster and better ways to acquire this data has been identified as a focus area.

Proposed Solution
A portable, standalone sensor rig was developed for easy acquisition of high quality maritime data. In 2024, development efforts focused on its quality assurance, documentation, usability and research integration. Emil is supervising a new master student who is working on demonstrating its potential and showcasing the benefits of polarization cameras in the maritime domain.

Main activities during 2024
- Published a paper at ICMASS titled "A Lightweight, Polarization-Camera Equipped Sensor Rig for the Development of Autonomous Surface Vehicles."
- Acquired funding to hire two summer interns who helped develop drivers for a new LIDAR sensor, implement a client to get coastal maps from Norwegian Mapping Authority and helped design and build two complementary tracking boxes.
- Continued supervising one of the student interns for his project thesis titled "3d modelling and rendering of coastline and ports using tide and mapping data", which lay the groundwork for automatic dataset augmentation with the sensor rig. This supervision continues on his Master's in 2025.

Visualization of polarization data, demonstrating how polarization cameras offer new insights in the maritime domain.

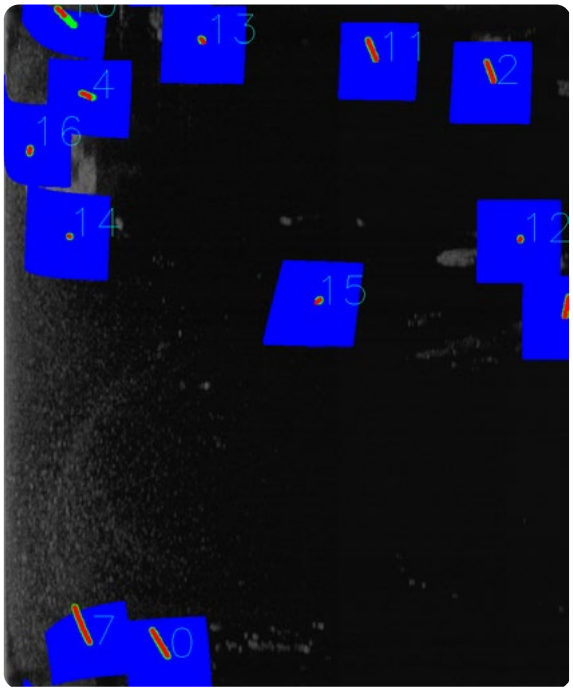
Henrik Dobbe Flemmen

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. That is great, because GNSS is highly available, very precise and has high integrity. Still, 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
There are several possible solutions, but the one I pursue is based on the radar. We can use it to keep track of land relative to the ship, and thus keep track of the motion of the ship. This will allow the ship to continue operations with increased safety margins when it loses GNSS position.

Main activities during 2024
- Work with a continuous internal representation for radar data without dividing it into scans.
- Work with alternative warps that better fit the geometry of the radar.
- SFI AutoShip webinar “Radar in maritime situational awareness - Beyond point measurement”, 30.01.2024.



This image shows the radar data as a polar image, width distance along the x-axis, and angle along the y-axis. The blue shapes are the shape of the tracked patch and start out as squares. The green path is the expected track, and the red path is the estimated track.

Daniel Menges

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

Problem statement

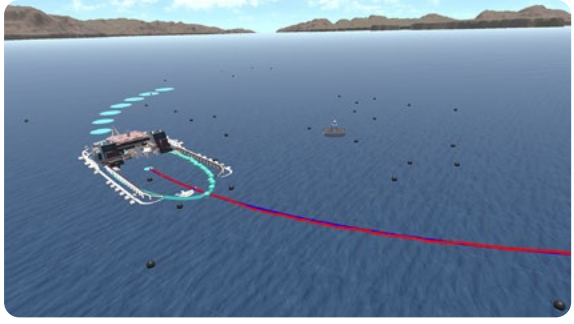
This PhD project aims to enhance situational awareness for autonomous surface vessels and utilize this knowledge for optimal control by integrating digital twins. Reliable environmental perception and awareness of a vessel's internal state, such as engine conditions, are critical for improving decision-making 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

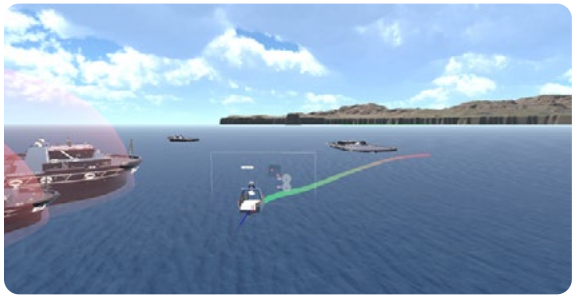
This research proposes solutions to enhance digital twin capabilities, including scalable frameworks integrating diverse data sources, predictive functionalities, and advanced control techniques. It introduces adaptive tools for estimating environmental forces, proactive control methods for collision 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 2024

- Conducted a research stay in Porto, focusing on multi-sensor fusion techniques and autonomous docking applications.
- Presented findings at 3 international conferences.
- Published journal papers: Real-Time Predictive Condition Monitoring Using Multivariate Data, IEEE Transactions on Image Processing. Co-author: Modular control architecture for safe marine navigation: Reinforcement learning with predictive safety filters, Artificial Intelligence. Multi-Target Tracking for Autonomous Surface Vessels Using LiDAR and AIS Data Integration, Applied Ocean Research. Digital Twin Syncing for Autonomous Surface Vessels Using Reinforcement Learning and Nonlinear Model Predictive Control, Nature.
- Published conference papers: Nonlinear Model Predictive Control for Enhanced Navigation of Autonomous Surface Vessels, IFAC-PapersOnLine. Digital Twin of Autonomous Surface Vessels for Safe Maritime Navigation Enabled Through Predictive Modeling and Reinforcement Learning, ASME. Computationally and Memory-Efficient Robust Predictive Analytics Using Big Data, IEEE – CAI.
- Completed the writing and submission of the PhD thesis "Digital Twin for Situational Awareness and Optimal Control of Autonomous Surface Vessels".
- SFI AutoShip webinar "Safe Optimal Control and Multi-Target Tracking Demonstrated with a Digital Twin", 03.10.2024.
- Papers currently under peer review: "Digital Twin for Autonomous Surface Vessels: Enabler for Safe Maritime Navigation" submitted to Expert Systems with Applications and "Predictive Digital Twin for Condition Monitoring Using Thermal Imaging" submitted to Engineering Applications of Artificial Intelligence.



Digital twin demonstration of the milliAmpere ferry on the Trondheim fjord executing a predictive multi-target tracking algorithm in the presence of measurement noise.



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

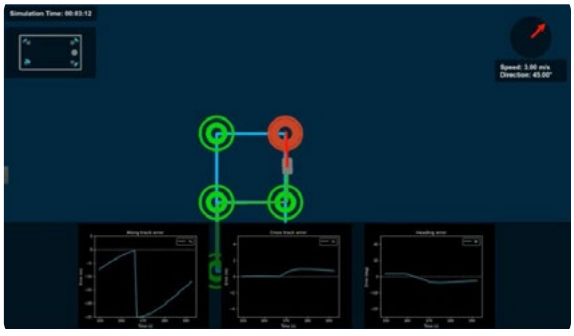
Simon J. N. Lexau

Autonomous docking of marine surface vessels

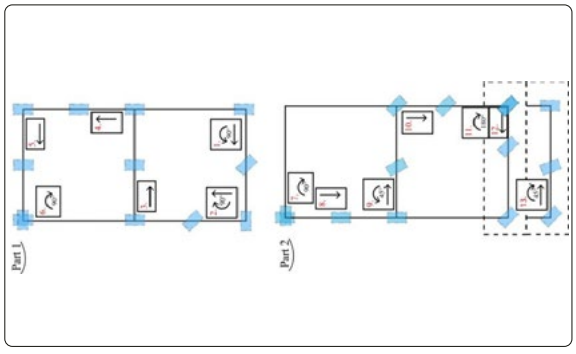
Problem statement
The development of Autonomous Surface Vessels (ASVs) aims to enhance the shipping industry by reducing operational costs, minimizing human error, and improving overall efficiency. One of the key challenges in this field is achieving safe and efficient autonomous docking in complex port environments. To maneuver accurately and predictably in these settings, precise ship models are essential. However, these models are typically obtained through the costly and time-consuming process of system identification.

Proposed solution
The primary goal of my PhD research is to develop advanced planning algorithms for maneuvering ships through challenging environments. Additionally, I aim to create sophisticated low-level control systems that ensure the vessel follows the planned trajectory safely and with optimal energy efficiency. My research also focuses on adaptive control methods capable of handling significant modeling errors and performing system identification in real-time.

Main activities during 2024
- Conference article: Nonlinear PID Control for Automatic Docking of a Large Container Ship in Confined Waters Under the Influence of Wind and Currents, IFAC CAMS in Virginia, USA. This work showcased the development of Nonlinear PID control integrated with a robust control allocation scheme for autonomous docking in adverse conditions.
- Developing a conference article on Reinforcement Learning-based Nonlinear Model Predictive Control (RL-NMPC) for low-level control and thrust allocation, in scenarios with significant modeling errors. The reinforcement learning algorithm demonstrates the ability to mitigate these errors through both offline and online learning.
- Collaboration and co-supervision of master students working on object tracking using stereoscopic sensors such as LiDAR and cameras. This collaboration aims to enhance the perception capabilities of ASVs, which is crucial for safe navigation and docking.
- Preparations for testing on the milliAmpere1 during the spring of 2025, to validate the robustness and efficiency of the developed control systems in practical scenarios. These trials will provide valuable insights into the performance of the autonomous docking system in real-world conditions. The system is designed to enable vessels to navigate safely through complex harbor settings amid wind, currents, and dynamic obstacles, while reducing energy consumption and minimizing wear on the vessel's thrusters.
- I am eager to explore opportunities for testing the control system on surface vessels that industry partners may have available. Given the high costs associated with system identification, partners may find value in a control system that demonstrates robustness against modeling errors. The upcoming tests on the milliAmpere1 will provide further insights into the practical applicability of these technologies.



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

Enabling supervisory control of autonomous vessels through transparency and explainability

Background including motivation for the research

A key challenge in the development and deployment of autonomous ships is establishing trust with human users and society. Additionally, complexities in the maritime environment prevent autonomous ships from being fully unsupervised, particularly during high-risk tasks such as collision and grounding avoidance (CAGA) where they are susceptible to incomplete situational awareness due to sensing limitations and uncertain target intent prediction. Therefore, it is essential to design transparent CAGA systems that can provide clear explanations to validate their actions, fostering trust with human users through effective, efficient and satisfactory interactions.

Objective and main tasks

The main tasks of this project are two-fold, with an objective of bridging the gap between CAGA systems and human navigators: Firstly, state-of-the-art methods from literature are utilized to develop a reliable AI-based CAGA system that incorporates interpretable design elements. In addition, methods in eXplainable AI (XAI) are employed to generate suitable explanations that illustrate prominent factors behind the system's response.

The second task addresses the human factors aspect of the objective by proposing a framework for demonstrating and evaluating supervisory control of CAGA systems by human navigators. The framework will subsequently be employed in experimental trials to investigate the interactions of a human navigator with the developed CAGA system.

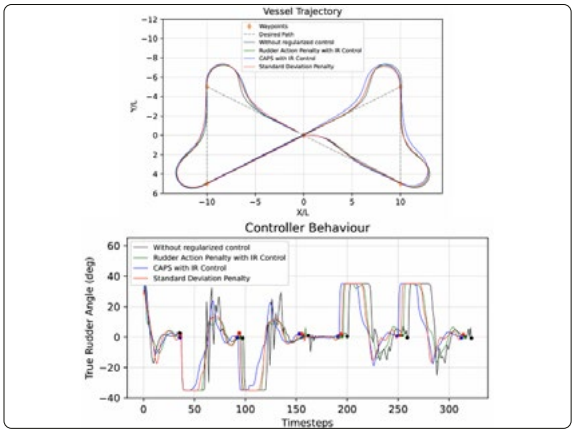
Expected results and innovations

The project is expected to yield reliable AI-based collision avoidance systems that are interpretable to a human navigator and demonstrates innovative characteristics of providing explanations of its own actions in real-time. Furthermore, the PhD work will contribute to a novel framework for evaluating supervisory control of CAGA systems by human navigators. Finally, the project will provide insights into effect of transparency and explainability in improving interactions of CAGA systems with a human navigator.

Main activities during 2024

- Presentation and publication of the paper: Reducing Controller Effort in a Deep Reinforcement Learning-based Autopilot for an Underactuated ASV at IFAC CAMS 2024 in Virginia.
- Co-supervised a master's thesis on interpretable collision avoidance using Deep Reinforcement-Learning (DRL).
- Development of interpretable DRL-based CAGA systems for autonomous vessels based on a Collision Avoidance Simulation Framework.
- Ongoing comparative study on the influence of action spaces for DRL-based CAGA systems.
- Innovation pitch at SFI Days 2024.
- Preliminary studies on performance metrics and evaluation of human – AI interactions during supervisory control.

Illustration of Human – AI interactions during Supervisory Control of Autonomous Vessels.



Results from published conference paper on improving robustness of DRL-based controllers.

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 2024, the decentralized hierarchical collision avoidance algorithm for multiple ships previously introduced was successfully validated via numerical simulations and real-world experiments performed in Børsa (Trondheim Fjord) during 11-14.03.2025. Detection and tracking algorithms were successfully tested using real-world measurement from the radar network previously established in the Trondheim fjord. A simulator to test the robustness of collision and grounding avoidance systems in presence of situational awareness system noise, degradation, and breakdown, is under development in collaboration with DNV. A working prototype for remote control of a ferry via the public 5G network has been demonstrated. A new channel model for the phase distribution and correlation of the scattered field from the sea has been developed and verified numerically. The behavior of channel data considering spatially-correlated small-scale and large-scale fading has been simulated numerically.

Melih Akdağ defended his PhD “Collaborative collision avoidance methods for autonomous ship navigation” in September 2024 and presented his results at the SFI Days.

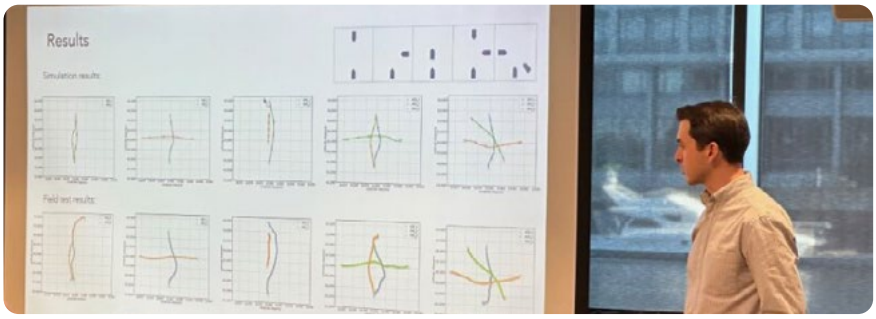


Photo: Ingeborg Guldal/NTNU

Melih Akdağ

A Decision Support System for Autonomous Ship Trajectory Planning

Problem statement

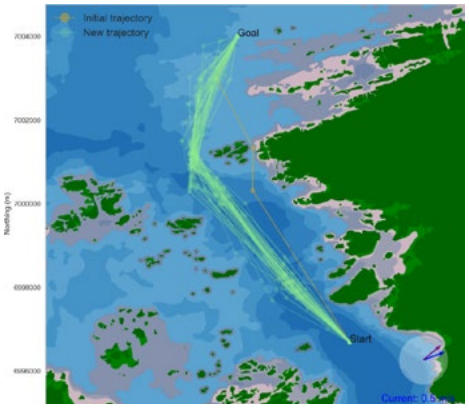
a. In what ways can autonomous ship navigation be enhanced through the integration of information about environmental forces, navigable waters, maneuvering characteristics, and potential failure modes?
b. What advantages and obstacles are associated with the utilization of a decision support system based on multi-objective optimization for autonomous ship navigation?
c. What strategies can be employed to foster collaboration between autonomous systems and operators during the decision-making process of ship navigation?

Proposed solution

a. When planning the trajectory of an autonomous ship, it is important to take into account factors beyond just chart depths. The actual depths of water can vary depending on the tide and weather conditions. High speeds in narrow channels can cause a squat effect and lead to the ship running aground in shallow areas. The ship's maneuvering abilities, such as stopping distance and turning circle, are also influenced by its speed. To ensure safety, risk assessment methods like Dynamic Consequence Analysis can be used to anticipate potential failure scenarios and incorporate maneuvering characteristics into the safety domain creation.
b. One advantage is that a decision support system based on multi-objective optimization can treat multiple conflicting objectives independently rather than merging them into a single objective. Moreover, this method creates numerous alternate solutions, giving users a range of choices. A drawback is, solving a multi-objective optimization problem take time depending on the problem definition, algorithm, hardware systems, and especially if the dynamic obstacles' future trajectories are also considered.
c. While autonomous systems excel in speed, accuracy, and multitasking, human operators possess unique qualities such as adaptability, emotional intelligence, creativity, and ethical reasoning. Evaluating the strengths and weaknesses of each information processing capability is essential for designing effective human–machine collaboration. This research aims for human–machine collaboration by utilizing multi-objective optimization algorithms to find multiple alternative solutions meeting the objective criteria, and ranking the solutions by using the human operator preferences for each objective. Additionally, the Pareto front solutions are ranked by automatic weighting with the entropy method and cluster representative solutions are retrieved to prevent subjectivity of the human preferences. Depending on the problem definition, it is experienced in this study that some solutions came up high in the ranking although they are not preferable by the authors. This serves as a valuable reminder to not solely depend on solutions suggested by autonomous systems, but to also involve human evaluation.

Main activities during 2024

- Melih defended his PhD Collaborative collision avoidance methods for autonomous ship navigation at NTNU's Department of Engineering Cybernetics in September.
- Successfully validated via numerical simulations and real-world experiments in Børsa (Trondheim Fjord) the decentralized hierarchical collision avoidance algorithm for multiple ships.
- Conference paper: Prioritizing and Ranking Ships in Multi-encounter Scenarios for Autonomous Navigation, SCIS&ISIS.
- Received the Best Student Presentation Award at the SCIS&ISIS conference in Himeji, Japan.
- Presented the results from his research to the consortium at the SFI Days in October.



Alternative trajectories calculated by the proposed decision support system.

Lukas Herrmann

Shore-based Radar Network for Autonomous Shipping

Problem statement

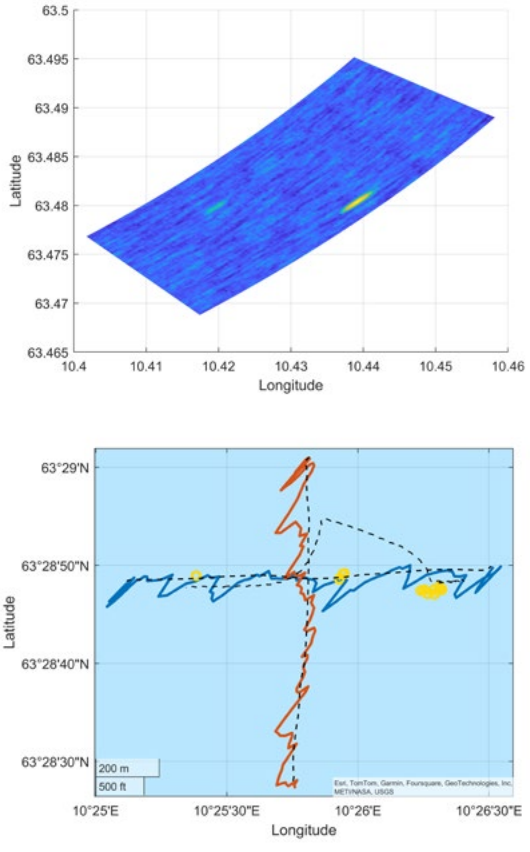
In recent years, the idea of autonomous shipping has become more concrete since autonomy has the potential to revolutionise the maritime industry by enhancing safety, reliability, sustainability, efficiency, and ultimately cost optimisation. For the whole concept to work, every vessel must know its own 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 2024

- Development and implementation of detection and tracking algorithms on both simulated and real data with a focus on low signal-to-noise ratio scenarios. Implementation of sea clutter simulations in maritime scenarios.
- Visiting researcher at the University of Liverpool, Liverpool, UK from February to June. Work on a tracking algorithm for an unknown and time-varying number of targets leading to a joint paper "Histogram-Probabilistic Multi-Hypothesis Tracking with Integrated Target Existence" submitted to IEEE Transactions on Aerospace and Electronics.
- Conference article and presentation Coherent Integration of Optical Flow for Track-Before-Detect Radar Detection at the 27th International Conference on Information Fusion (FUSION).
- SFI AutoShip webinar "Radar in maritime situational awareness - Beyond point measurement", 30.01.2024.



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

Peter Morris

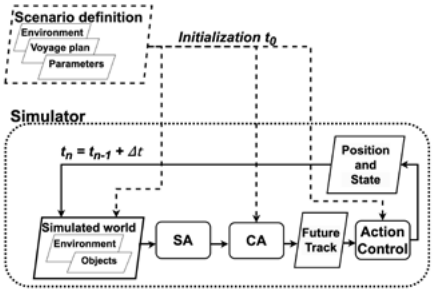
Data Fusion in Maritime IoT

Problem statement

Evaluating the effectiveness of a Collision and Grounding Avoidance (CGA) system presents significant challenges. Understanding how well it performs in non-ideal conditions, how it handles complex scenarios, and how it balances and prioritizes its various goals is critical for successful implementation. The validation of such systems is further complicated by the lack of sufficient data for robust testing. Real-world testing is not only costly but also limited in scope and often impractical for simulating rare or hazardous scenarios. Moreover, ensuring compliance with rigorous safety and industry standards adds another layer of complexity. Addressing these challenges requires a comprehensive solution that enables thorough testing, evaluation, and validation of CGA systems under realistic and diverse conditions.

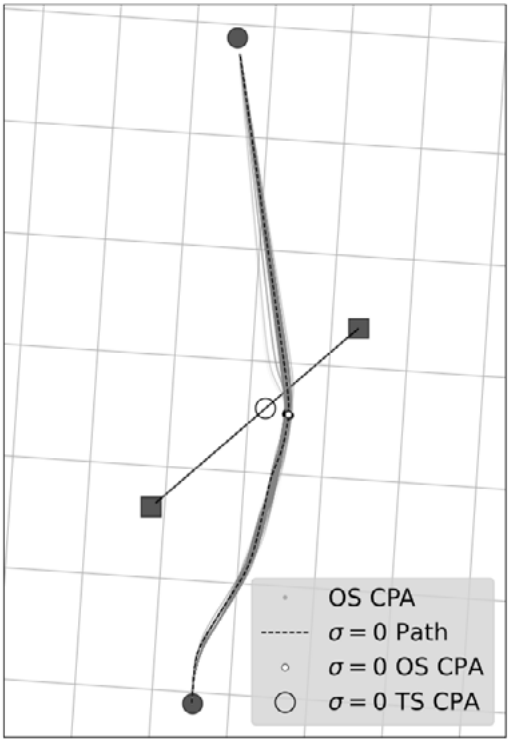
Proposed solution

The proposed solution involves a simulator designed to model the Situational Awareness (SA) system of a vessel, providing realistic input for testing a Collision and Grounding Avoidance (CGA) system. The SA model incorporates features such as sensor noise, drop-off, and realistic degradation behaviors to emulate the challenges encountered in real-world conditions. The simulator can execute a variety of predefined scenarios, requiring the tested CGA system to adapt to degraded SA data while adhering to COLREGs and pursuing its intended targets. Each scenario can then be analyzed to evaluate the CGA system's performance and compared against the "ground-truth" SA for accuracy and effectiveness. With a modular and scalable design, the simulator ensures adaptability for future advancements, offering researchers and developers a dependable platform for innovation and testing.



Main activities during 2024

During 2024, this simulator was developed in collaboration with DNV, another Autoship partner. We've submitted a paper going over the basics of the simulator to ESREL 2025, and more papers will follow as we develop a more advanced and detailed solution. In other activities unrelated to the simulator, I helped develop a system for remote control of a ferry over 5G; which has been successfully demoed and is work that will be expanded on in 2025. I am also developing a radar fusion platform, that can simultaneously collect data from multiple radar systems, and from a diverse range of data sources (weather, AIS, etc.); work that will also continue in 2025.



Giacomo Melloni

Radio channel measurements and modelling in maritime scenarios

Background and motivation for research

The demand for autonomous ships, digital twins, and maritime safety is driving the need for reliable, high-speed radio communications at sea. Within the 5G context, maritime communications are recognized as distinct vertical, requiring a thorough understanding of the radio environment. Key components of maritime channels include (i) Line-Of-Sight, (ii) specular reflection, and (iii) diffuse scattering, all of which influence channel quality. Paradoxically, specular reflection can degrade the link more when the sea is calm, causing deep notches in the received power. Limited research exists on the impact of sea surface scattering at high frequencies, critical for ship-to-shore communications.

Objective and main tasks

Research Goal:

- Develop new channel models for maritime communications to enable reliable and secure data transfer among ships, the Remote Control Centre (RCC), and other marine traffic, tailored to operational needs.

Tasks:

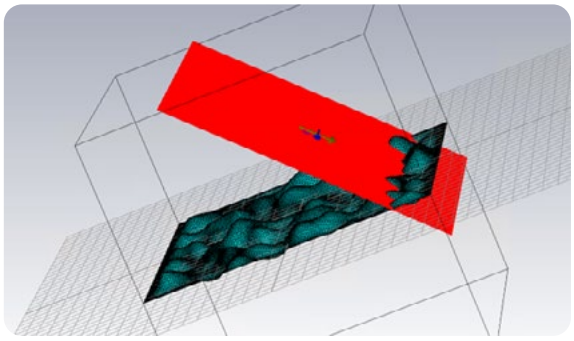
- Investigate new statistical methods to describe the channel models, based on the morphology of the sea surface.
- Research the stochastic properties of the scattered field from the sea surface, in function of the employed carrier frequency.
- Develop a new model for antenna mismatch. This issue arises when the ship's antenna orientation changes due to the morphology of the sea surface. It is particularly relevant for small unmanned vessels.
- Measurement campaigns are planned in the fjord during 2025 to validate the developed models.

Ongoing Work:

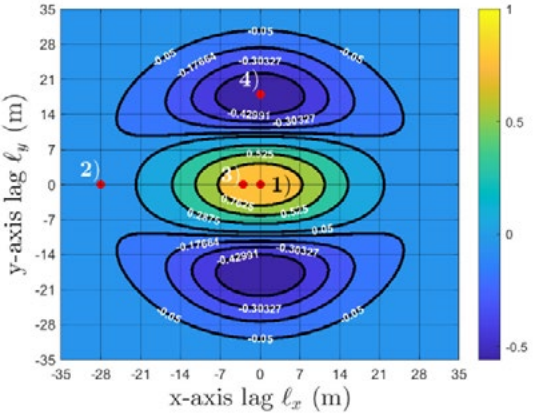
- Authored a conference paper titled "Phase Distribution of the Large-Scale Scattered Field from the Sea Surface" to be presented at EuCAP 2025.
- Investigating the distribution of the scattered field from capillary waves, aiming to derive an analytical expression for the phase and amplitude distributions.
- Analyzing how the shadowing effect—caused by waves blocking the visibility with the receiver—affects the properties of the scattered field.

Expected results and innovations

This research aims to establish new design rules to enhance maritime communication systems. By understanding key channel characteristics, such as Line-Of-Sight (LOS), specular reflections, and diffuse scattering, it will be possible to develop antennas and communication protocols tailored to the maritime environment. Both spatial and temporal properties of the channel will be addressed and used to define these aspects. The goal of having proper design rules is to reduce the outage probability—the likelihood of communication link failure— and to enhance reliability and capacity of the communications.



Study of the scattered field generated by the capillary waves (small-scale roughness) using CST Studio Suite.



New autocorrelation function of the phase of the scattered field by the large-scale roughness of the sea surface.

Manju James

Radio Twin: Digital twin for maritime communication system performance prediction

Background and motivation for research

A robust maritime communication system is essential for successful autonomous shipping. The performance of a communication system is evaluated using data rate, latency, and reliability. Variations in the radio channel affect the communication system performance. The channel noise and disturbances can increase latency and degrade data rate and reliability of the signals communicated. The maritime communication channel is highly stochastic due to fluctuating sea conditions and weather. This results in dense multipath components due to signals scattering from the ocean surface. Predicting the channel performance in advance helps to choose alternate communication techniques well in advance if the channel degrades below an acceptable level.

Objective and main tasks

The signal paths between vessels in the ocean usually involve a line-of-sight component and non-line-of-sight components (specular reflection component and diffuse scattering components from the sea). Modeling these components helps to understand multipath components (MPCs) in an ocean scenario for better channel prediction. This research proposes to model a maritime communication channel with dense multipath components from the ocean surface using machine learning algorithms. The work will use experimental and synthetic channel data to train the algorithm for channel performance prediction and validate the model with experimental data and existing research literature. This work will also investigate how the channel model can learn from available data and generate synthetic data for similar propagation scenarios.

Expected results and innovations

This research project expects a machine learning-based communication channel modelling algorithm that can generate maritime channel parameters considering multipath propagation. This algorithm will be able to learn from available channel data and generate synthetic data for similar propagation conditions. The learned channel parameters will help to predict communication system performance in a maritime scenario.

A typical maritime communication scenario (Xiao, Yang Zhuang & Min, 2023. Reinforcement Learning for Maritime Communications)

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 2024 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, and improved automation transparency.

In 2024, Work Package 3 published 17 papers, carried out more than 50 popular science dissemination activities, submitted a DOFI, filed an international patent application, and graduated one PhD. All these activities have contributed to reaching the Centre's objectives in 2024.

Andreas Madsen defended his PhD "Decision Transparency during Autonomous Collision Avoidance" in August 2024 and presented his results at the SFI Days.

Postdoctoral researcher Taufik Akbar Sitompul completed his project "OpenCrane Design System" in January 2024 and presented his results at the SFI Days.

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

Andreas Nygard Madsen

AI Decision Transparency

Problem statement

- How can we make the decisions or suggestions from an AI system transparent to a navigator?
- How can collaboration between the navigator and the system help to enhance and maintain situational awareness?
- What is required (from a human factor perspective) when operating with a periodically un-manned bridge?

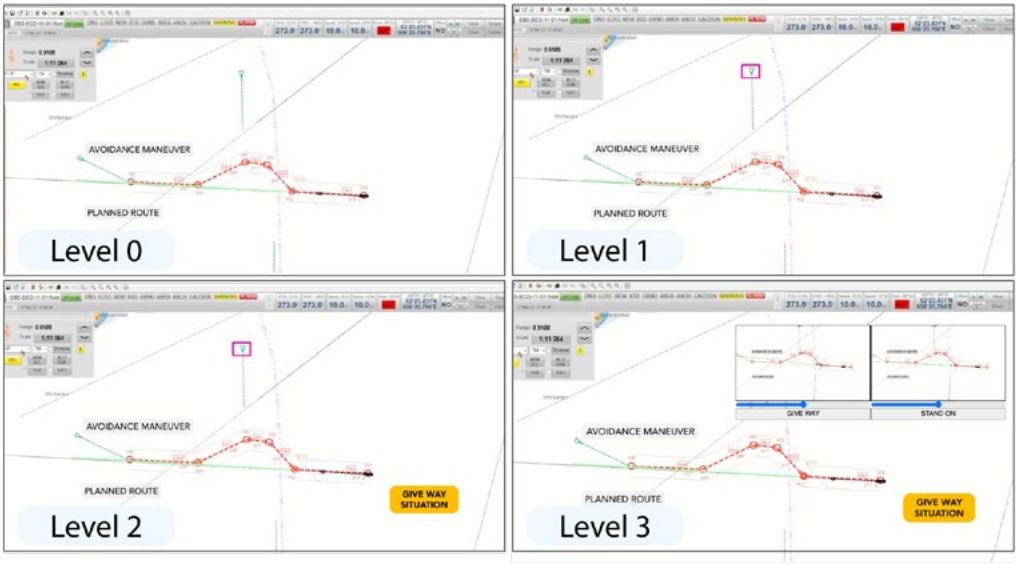
Proposed solution

Strategies for AI decision transparency and guidelines for the human-machine collaboration in collision avoidance situations:

- Assess the compatibility of human- machine interaction in full mission simulators.
- Layered approach to transparency visualization for collision avoidance.
- Take into account seamanship when creating AI for collision avoidance.
- Periodically un-manned bridge is currently on-going research.

Main activities during 2024

- Andreas defended his PhD Decision Transparency during Autonomous Collision Avoidance: On Human-AI Compatibility and Autonomous Ships at NTNU's Department of Ocean Operations and Civil Engineering in August.
- Journal paper: A state-of-the-art review of AI decision transparency for autonomous shipping, Journal of International Maritime Safety, Environmental Affairs, and Shipping.
- Co-authored journal paper: A simulator-based approach for testing and assessing human supervised autonomous ship navigation, Journal of Marine Science and Technology.
- Co-authored journal paper: Conversational user interfaces for maritime autonomous surface ships, Ocean Engineering.
- Co-authored and submitted for review the paper Sailing into the Future with Periodically Unmanned Bridges - a Viable Concept for Mitigating Seafarer Shortages?, Journal of Marine Science and Technology.
- Presented the results from his research to the consortium at the SFI Days in October.



Protoype of transparency layers on ECDIS. Conceptualization by Andreas Madsen NTNU Ålesund. Design Jooyoung Park NTNU, Shore Control Lab

Taufik Akbar Sitompul, postdoc

OpenCrane Design System

Problem statement

Currently, crane manufacturers and third-party suppliers create their own user interfaces (UIs), since there are still no standardized UIs for operating cranes. This situation leads to significantly different UIs even for the same type of cranes. The significantly diverse UIs also pose two major challenges. Firstly, the cost for developing user interfaces is high, since crane manufacturers and third-party suppliers must develop everything from scratch and perform evaluations on their UIs. Secondly, operators need to train themselves every time they utilize UIs from different crane manufactures or third-party suppliers. Using significantly different UIs may also increase the risk of human error, since different UIs may have different rules or mechanisms that operators should follow.

Proposed solution

To improve the design consistency across UIs from different crane manufacturers and third-party suppliers, there is a need for a design system that crane manufacturers and third-party suppliers can use or refer to when developing their own UIs. OpenCrane Design System offers open-source UI elements for operating cranes that everyone could use, adapt, and distribute at no cost. The UI elements will serve as building blocks that everyone could freely choose, use, and adapt depending on their needs.

Main activities during 2024

- Taufik completed his postdoc project in January 2024. He developed the "OpenCrane Design System", which was also submitted as a DOFI to NTNU Technology Transfer. SFI AutoShip is discussing how to further build on his results, in collaboration with user partners.
- Conference papers: Evaluating Graphical User Interfaces for Improving Depth Perception with Remote Crane, COMPSAC, Handling Constant and Changing Latency with Graphical User Interfaces: A Study with Remote Crane Operators, IEEE Conference on Telepresence, Analyzing Online Videos to Create a List of User Interface Elements: A Case for OpenCrane Design System, INTERACT 2023.
- Co-authored Lessons learned from the trial operation of an autonomous urban passenger ferry, Transportation Research Interdisciplinary Perspectives (TRIP),), Dataset on passenger acceptance during autonomous ferry public trials: Questionnaires and interviews, Data in Brief.
- Co-supervised 3 MSc theses to completion.
- Presented the results from his research to the consortium at the SFI Days in October.

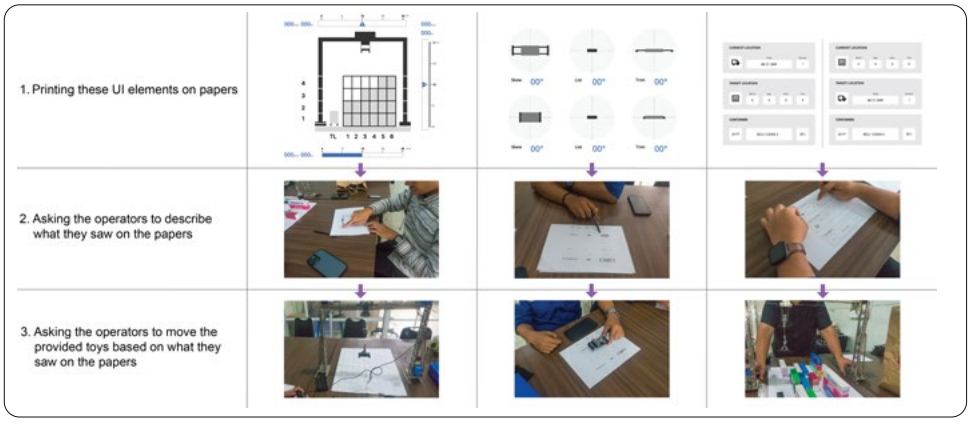


Figure 1. The images that visualize how the UI elements in OpenCrane Design System were evaluated with crane operators.

Felix-Marcel Petermann

Designing for the Transportation of the Future - Design touch points between humans and autonomous system in the ecosystem of autonomous passenger ferries

Problem statement
The transition to autonomous passenger ferries introduces new challenges in human-system interaction, particularly concerning passenger touchpoints—key moments where users engage with the ferry system before, during, and after their journey. Unlike conventional ferries with human crew providing guidance and assistance, autonomous ferries rely on digital interfaces, signage, and automated processes to facilitate passenger experience. However, gaps in communication, accessibility, and transparency can create uncertainty, reducing trust and usability. Current research lacks comprehensive frameworks for designing intuitive and inclusive touchpoints that ensure seamless interaction and maintain passenger confidence. My research investigates how to design effective passenger touchpoints that improve user understanding, trust, and overall experience in autonomous ferry operations. Through research-driven design interventions, I try to bridge the information gap between autonomous systems and passengers, ensuring a safe, efficient, and user-friendly maritime transport solution.

Proposed solution
To address these challenges, we developed and tested several solutions aimed at improving passenger experience in autonomous ferry operations. **(1) A smart passenger access gate** was designed and evaluated to provide a comprehensible boarding experience. **(2) A human-facing explanatory interface** was designed and tested to keep passengers informed about ferry operations, movements, and decisions in real-time, improving transparency and trust during a journey. **(3) Additional Touchpoint Concepts** have different states from concept draft to prototype and address different states of the users' journey and connection between the autonomous ship, passenger and remote operator. These concepts solutions have been tested through public trials, usability studies, and passenger feedback assessments, validating their effectiveness in bridging the information gap between autonomous systems and passengers.

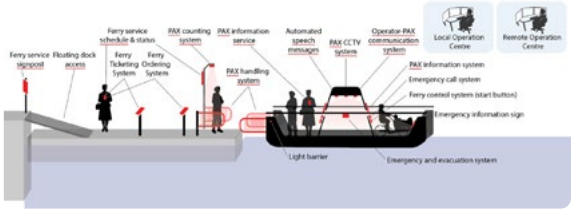
Main activities during 2024
Different dissemination activities including presenting the Shore Control Lab and presenting research on international conferences:

- Touchpoints and systems for unmanned autonomous urban ferry operation, presented at ICMASS and published in Journal of Physics: Conference Series.
- Collaborative Hazard Control: Designing a Digital Fire Control Centre for Enhanced Safety on Ships, Graphics Interfaces.
- Interaction Between Unmanned Systems and Humans: An Example of an Smart Passenger Access Gate for Autonomous Urban Passenger, COMPSAC.
- Co-authored Lessons learned from the trial operation of an autonomous urban passenger ferry, Transportation Research Interdisciplinary Perspectives, Dataset on passenger acceptance during autonomous ferry public trials: Questionnaires and interviews, Data in Brief, Understanding automation transparency and its adaptive design implications in safety–critical systems, Safety Science.

Building, deploying and testing several prototypes for both passenger and operator touchpoints.

Advising Master student projects, designing "silent alarm" interfaces and designing a modular operator chair for autonomous ships.

Research Collaboration with Gdynia Maritime University.



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

Luka Grgičević

Vessel guidance decision support systems

Problem statement

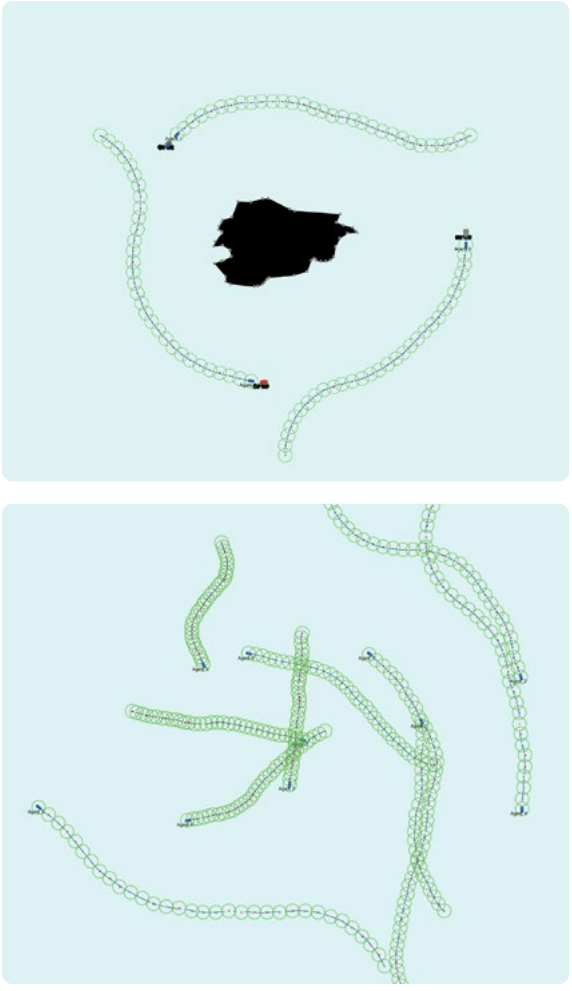
Vessels navigating in high-density traffic aim to achieve objectives such as effective collision and grounding avoidance while adhering to international, regional, and port regulations. The increasing traffic density poses a significant challenge for decision-makers, whether human navigators or autonomous 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 2024

- Research articles in peer review/underway: "Centralised Decision Support in Maritime Vessel Traffic Services: A Polymatrix Game Solution", "PULSE: An Algorithm for Multi-agent Centralised High-density Maritime Traffic Management Based on Guidance Games".
- Conference paper: Towards Decision Support in Vessel Guidance Using Multi-Agent Modelling, European Control Conference.
- Presented "Decision Support for Collision Avoidance in Maritime Multi-Vessel Encounter" at MTEC/ICMASS.
- Journal paper: Multi-Agent Maritime Traffic Simulator, MIC Journal.



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 2024

- 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 postdocs and conducted webinars together with industry related to topics on Risk of Autonomous Ships, hosted by NTNU. In 2024, we also arranged a tutorial for all partners in the SFI addressing the systems-theoretic process analysis (STPA) which enables a holistic approach to hazard identification and safety in software-intensive and complex systems.

STPA tutorial, April 2024. Photo: Ingrid B. Utne/NTNU

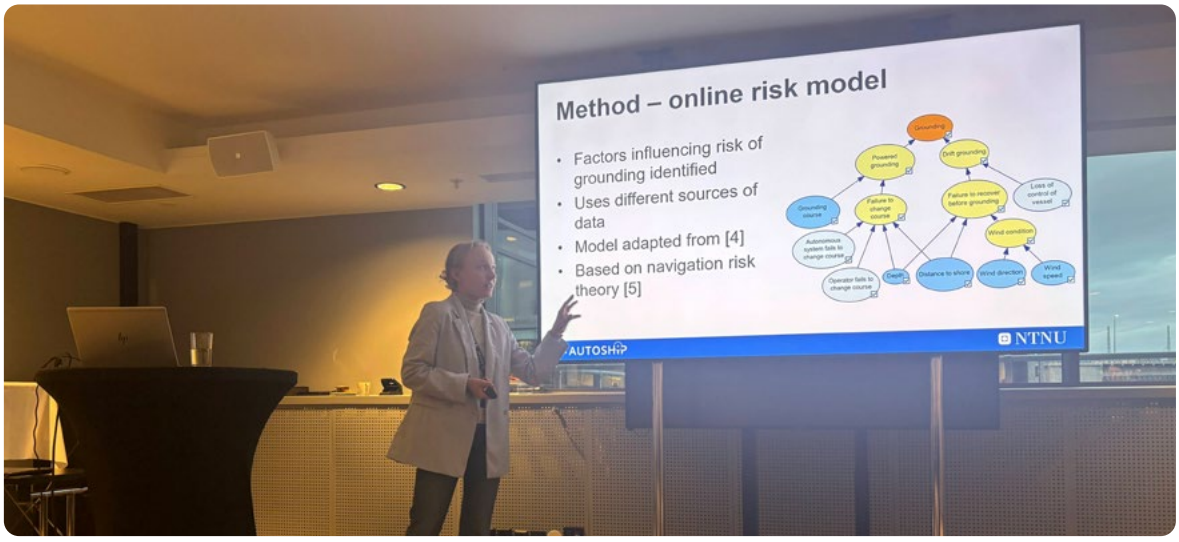
Susanna Dybwad Kristensen

Online risk modeling of autonomous ships

Problem statement
Autonomous ships may operate independently from human operators. This means that the autonomous system itself must be capable of monitoring and assessing the risk related to the operation it is performing, to make decisions for safe and efficient operations. Using risk models to provide information to the autonomous system during operation can be a solution to this. However, a condition for this is that the risk information that is provided from the risk model is suitable for supporting the decision the autonomous system is making.

Proposed solution
To investigate online risk modeling for autonomous ships, different approaches to risk assessment have been applied. Using an extended Systems-theoretic process analysis to identify hazards for a small, unmanned surface vehicle has been proposed. Further, online risk models for autonomous surface vessel (ASV) operations have been developed, with a focus on navigation risk. The online risk models have been integrated with the path planning by ASVs, and the proposed method has been tested in simulation and field trials. Tests have also been performed to investigate the influence of the choice of risk metric when online risk models are used to support ASV decisions during operation. Further tests with respect to the application of online risk models for ASV decision-making are expected. The results may contribute to the development of risk-aware ASVs.

Main activities during 2024
- Published the journal paper A systems approach to hazard identification for solar-powered and wave-propelled unmanned surface vehicle, Journal of Marine Engineering and Technology.
- Presentation and publication of conference paper Comparison of methods for including risk information in path planning for autonomous surface vessels at the MTEC/ICMASS conference and Journal of Physics: Conference Series.
- Submitted the journal paper "Evaluating the effect of risk metrics for supporting operational decision-making by autonomous surface vehicles" to Ocean Engineering.
- SFI AutoShip webinar with Fugro and Kongsberg Maritime on "Risk assessment and supervisory risk control of autonomous marine systems", 05.12.2024.
- Completed the midterm evaluation.



Picture from presentation at the MTEC/ICMASS 2024 conference.

Raffael Wallner

Safety Demonstration of Autonomously Controlled Ships using Digital Twin

Problem statement

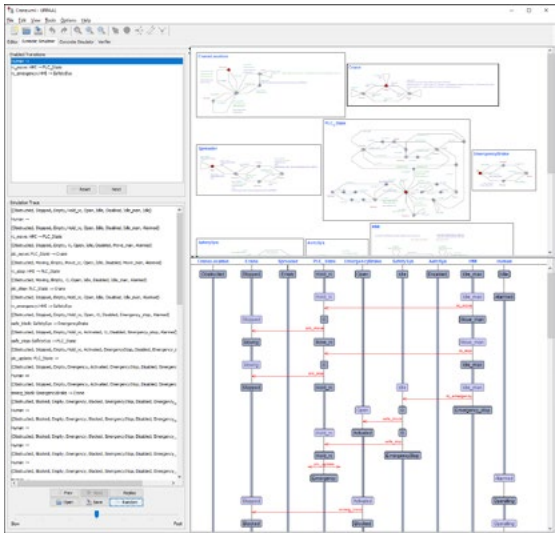
Increased levels of automation and autonomy promise to improve the efficiency, sustainability, and safety of maritime systems. However, increased automation or autonomy will also make the systems more complex and more complicated to comprehend fully. This makes it more challenging to test and verify their safety with current methods and poses a significant barrier to adopting such technologies. Hence, it is necessary to resolve that issue to boost the growth of the Norwegian maritime cluster.

Proposed solution

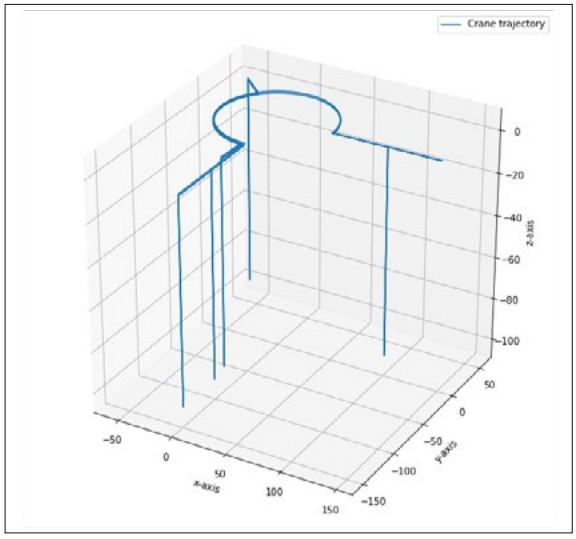
This research project focusing on safety demonstration of automated and autonomously controlled maritime systems proposes a novel solution to this problem by using scenario-based testing in simulations. In this approach, the system or system components and the operational environment are modeled in a virtual environment. Therefore, appropriate simulation models and digital twins are utilized to achieve valid representations and connections to actual control units. This allows the tested system to be exposed to any arbitrary situation it may encounter during operation, all within a risk-free simulated environment. Such a comprehensive testing approach can demonstrate that the overall system operates safely in a representative set of scenarios, covering the whole operational space from regular operations to risky situations and beyond. That way, it can be used for design verification, during certification procedures, and to support operation planning.

Main activities during 2024

- Working on methods to identify test scenario ranges based on risk assessment.
- Designing a simple system for partly automated maritime crane operations serving as a use case.
- Working on system models and representations on different platforms to test holistic conceptual simulations as well as more concrete simulations of chosen scenarios.



Holistic conceptual simulations of the system may reveal flaws in any reachable state of the system.



More concrete simulations give more specific insight into the system's actual behavior during certain scenarios and trajectories.

Spencer A. Dugan

Methods and tools for the mitigation of drifting grounding risk

Problem statement
The widespread introduction of autonomous ships is still limited by RAMS related issues. There are several differences for autonomous machinery systems when compared to conventional ships – most notably a heavier reliance on prognostics, maintenance scheduling around port visits, and lack of 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.

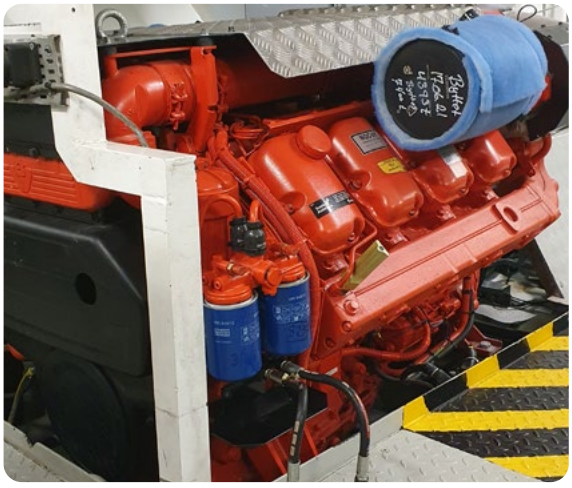
The objective is to develop knowledge and methods for reliability assessments for propulsion systems of autonomous ships. The main tasks are outlined below:
- Improve understanding of the frequency, duration, consequences, and risk influencing factors of machinery failures for conventional ships
- Develop risk-perception metrics for ship drifting grounding and implement these metrics for navigational decision-making
- 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 and identifying factors associated with their occurrence. The second phase applies this knowledge for design solutions and 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.

Expected Results and Innovation
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 better allocation of emergency response resources. Such a tool is also useful for insurance providers when setting premiums.

Assessing the reliability and safety of design topologies is necessary for both ship designers and regulators. The results should influence design criteria and guidelines and standards for autonomous ship machinery systems.

Main activities during 2024
- Published first journal article: Statistical analysis of vessel loss of command frequency, Maritime Transport Research; second submitted in peer review.
- Received the Norwegian shipowners fund scholarship to attend and present "Development of a risk indicator for ship drifting groundings" at PSAM17 in Sendai, Japan. Attended a technical tour of the Fukushima Daiichi Nuclear Power Plant. Another article titled "Analysis of the Repairability of Ship Machinery Failures" accepted for RAMS 2025.
- Organized two successful editions of the International Workshop on Autonomous Systems Safety at ESREL 2024 and RAMS 2025.



From the machine room of a ferry. Photo: Trond Johnsen/SINTEF

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 2024
- Working on the completion of the PhD thesis, 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.
- Contributed a legal perspective to a research project conducted under the umbrella of Use Case 1 – Deep-sea bulk shipping. Co-authored and submitted for review the paper "Sailing into the Future with Periodically Unmanned Bridges - a Viable Concept for Mitigating Seafarer Shortages?", Journal of Marine Science and Technology.
- Presented to the Comité Maritime International's working group on Maritime Autonomous Surface Ships (MASS) during the CMI's annual colloquium. The presentation focused on the legal challenges associated with applying the COLREGs to autonomous ships.

Illustration: Colourbox

Emir Cem Gezer

Risk-aware and safeguarding control for autonomous ships

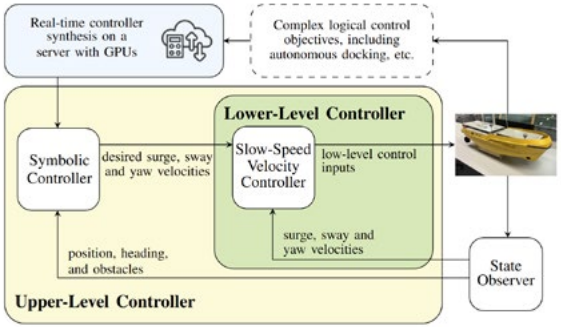
Problem Statement
The maritime industry is increasingly focusing on autonomous vessels to enhance efficiency, safety, resilience, and reliability across diverse operational scenarios. Designing vessel control systems capable of adapting to dynamic internal and external environmental factors is essential. 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.

The project focus
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 docking and the development of a modular testbed with small-scale robotic vessels for cost-effective validation. The goal is to create a mode-based control architecture that minimizes risk and enables safe, robust autonomy in complex environments.

Proposed solution
As a part of the project, we explored a hierarchical symbolic control architecture for autonomous docking of marine vessels, developed in collaboration with UCB. The approach integrates real-time symbolic controller synthesis for desired surge, sway, and yaw velocities, ensuring formal safety guarantees. These velocities are executed via a low-level feedback control loop. The methodology was evaluated through simulations and validated with scaled model experiments, addressing both static and dynamic obstacles. Testing algorithms for autonomous marine vessels is often challenging due to high operational costs and safety concerns. Additionally, designing custom model vessels and ensuring seamless integration with new algorithms can be cumbersome. To address these challenges, we developed a modular testbed environment that enables efficient and secure testing of ship autonomy.

Main activities during 2024
- Introduced a uniform software architecture for Cybership Vessels in Marine Cybernetics Laboratory.
- Collaboration with University of California, Berkeley to explore Symbolic controller applications on autonomous docking maneuver and submitted the paper titled "Symbolic Control for Autonomous Docking of Marine Surface Vessels".
- Presented the paper Maneuvering-based Dynamic Thrust Allocation for Fully-Actuated Vessels, at 15th IFAC Conference on Control Applications in Marine Systems, Robotics and Vehicles.
- Presented the software architecture of the autonomous ferry milliAmpere1 at the SFI AutoShip Days.

A talk on milliAmpere1 software at the SFI AutoShip Days. Emir Cem Gezer and Miguel Hinostroza presenting. Photo: Ingeborg Guldal/NTNU



Symbolic control scheme for Dynamic Positioning (DP) vessels with low-level velocity feedback control loop.

Sreekant Sreedharan

Safety assessment and verification of collision avoidance algorithms for autonomous ships

Problem Statement

Throughout a voyage, a ship's master constantly balances a myriad of concerns before taking an action. The vessel's location in an region, a term we hereafter refer to as spatial zone - High Seas, Territorial Waters (Coastal waters), Internal Waters (Strait), Port or Inland Waters - determines which regulatory protocols apply. Whereas in the High Seas, international regulations apply, as the vessel nears the port, territorial, regional or domestic rules often override or supplement the international ones. This is necessary because a myriad of concerns including security, safety and traffic measures often change depending on location. Although the range of territorial waters vary from one state to another, states can declare the extent of their territorial waters within the maximum of 12 NM. Thus assuring safe behavior of an autonomous vessel designed to augment or relpace a ship's master is a complex, multi-faceted and nuanced problem.

In the hypothetical scenario, a vessel approaches the Strait from the Black Sea in the north, intending to navigate southward through the narrow channel with the destination of Haydarpaşa Port, an international port situated at the southern end of the Istanbul Strait. International regulations apply to a vessel starting 6 NM outside the northern entrance of the Istanbul Strait. As the vessel approaches the port, additional safety, environmental, and customs protocols under Turkish regulations come into effect closer to the coast. These concerns may be generally grouped into the categories detailed in the information box on the side. Superior seamanship involves skillfully balancing multiple competing concerns. How these categories of cross-cutting concerns impact decision making as a vesssels enters into port can be captured into mathematical representations is the focus of the research.

Proposed solution

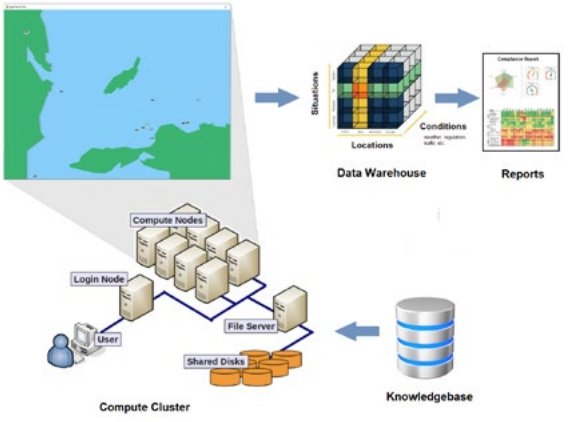
This research addresses the challenge of developing the tools, platforms, and practices required to evaluate an autonomous vessels' ability to navigate various regulatory requirements, with the skill expected of good seamanship, while efficiently transporting goods and passengers across waterways. We then introduce COS a simulation platform that leverages large-scale computing to generate a vast array of simulated virtual environments, within which Autonomous Navigation System (ANS) can be tested to observe their behavior across diverse operational contexts. Our core hypothesis is that by exploring a vast, extensive range of situational scenarios, we can uncover the nuanced behaviors of these algorithms with greater precision, allowing for a deeper understanding of their inherent characteristics.

Main activities during 2024

Publication (2)
- Published COS paper at ER2024
- Published Legata paper at ACM CS&Law2025

Research & Development
- Delivered core simulation framework (COS)
- Delivered a domain language (legata) for 'encoding law'

Courses (3)
- DT8123 Advanced Computing
- DT8124 Intelligent Agent
- DT8116 Web Mining



Jon Estil Krågebakk

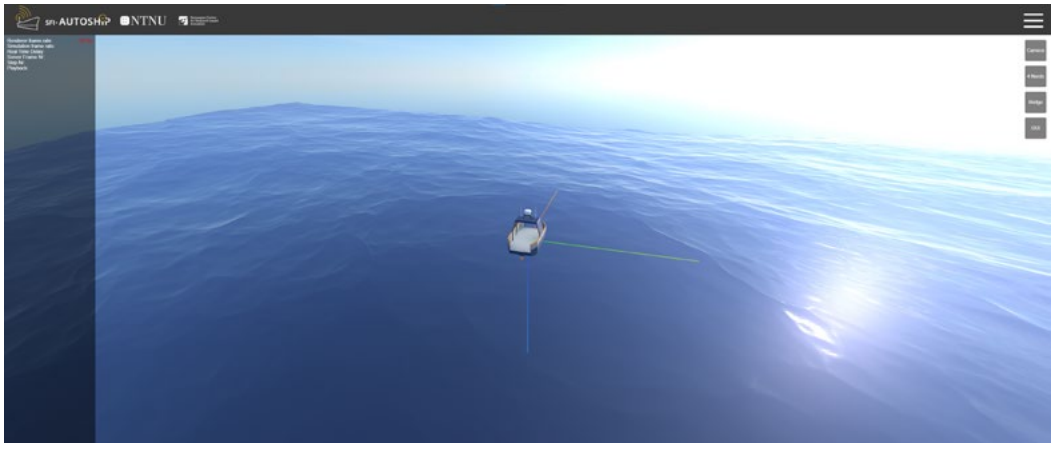
Dynamic Positioning (DPS) and Seakeeping with Dynamic Ocean Mapping and safe decision making with fully explainable AI

Background and Motivation
Seakeeping and dynamic positioning are critical for safe and efficient maritime operations, particularly in irregular wave conditions. While traditional methods based on statistical wave models have proven effective, there is an opportunity to explore new approaches that leverage modern computational capabilities. This project aims to advance the state of the art by using graphics card compute shaders for real-time dynamic ocean mapping and by training a diffusion model to visually sense the water surface. These tools aim to complement existing techniques by enabling a dynamic, data-driven approach to ocean mapping.

My background is rooted in computer vision, particularly in the development of classical methods for processing point clouds in robotic localization and manipulation. This includes experience in visual servoing techniques used to guide robotic systems in dynamic environments. Building on this expertise, this project adapts advanced vision-based methodologies for maritime applications, with the goal of creating innovative tools for real-time ocean sensing and control.

Objective and Main Tasks
The objective of this project is to develop an innovative seakeeping approach capable of handling larger and irregular waves to ensure load security. Central to this effort is the integration of a fully explainable AI that will dynamically evaluate the feasibility of various control methods and determine whether intervention from a remote operator is necessary. The AI model will incorporate a Bayesian Belief Network (BBN) designed from a dynamic risk model perspective. The signals from the model are designed so that they may be used directly to quantify some risk levels online. The project will begin by implementing the seakeeping controller in a simulation environment, followed by deploying a dynamic ocean mapping methodology using a real sensor rig.

Expected Results and Innovation
- Develop a gradient descent method on BBNs where the training parameters can be arbitrarily chosen from the whole network.
- Develop a python physics engine specialized for simulating the dynamics and kinematics between ocean and surface vehicles.
- Implement a DP & Seakeeping controller with Dynamic Ocean Mapping.
- Develop Dynamic Ocean Mapping software for the SFI AutoShip's SITAW Lightweight sensor rig.



Paul Lee

Supervisory risk analysis and control in operation

Background and motivation for research

The maritime industry is transitioning to the new era of fully autonomous maritime ecosystem, where artificial intelligence (AI)-based agents are envisioned to make safety-critical decisions independently of human intervention. However, an important precondition prior to their full-scale adoption is the assurance of their risk awareness, which refers to the degree of safety concept incorporated into the physical and/or metaphysical aspects of those agents.

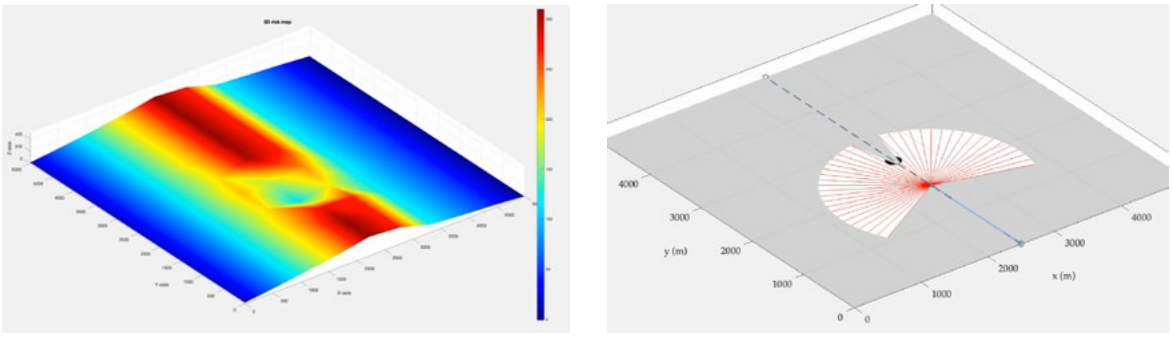
The motivation behind this project, apart from being a new research area that has not been extensively investigated, is that it focuses on a more fundamental question of not whether AI is safe or not, but whether AI knows or does not know what safety is. Despite maritime being a late adaptor of autonomy compared to other industries, a methodical approach is deemed pivotal to tackle the domain specific challenges by assuring that the risk awareness of AI is safe enough.

Objective and main tasks

The aim of this project is to develop a methodology that incorporates risk awareness, risk assessment, and risk management of AI-based agents into a holistic framework used during the safety-critical operations of autonomous ships. Main objectives include: a) review the state-of-the-art risk awareness level of AI-based agents, b) develop hybrid online risk modelling approaches based on traditional risk assessment and AI methods, c) verify and validate the effectiveness of the methodology in simulation and real-world environments.

Expected results and innovations

It is envisioned that the results of project will pave the way for the development of AI-based agents that are risk aware and whose risk awareness level can be monitored, assessed, and controlled in real time based on regulatory standards and involved stakeholders' objectives.



Risk perception of an AI-based agent during collision avoidance.

5 Sustainable Operations

WP Leader: Senior Project Manager Odd Erik Mørkrid, 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 optimisation of automatic control of mooring and cargo-handling systems to automate port operations.

The main activities in WP5 in 2024 were related to remote operation of deck cranes for container ships and logistics analysis for container ships.

The study on remote operation of deck cranes for container ships has been conducted in cooperation with NCL, SINTEF Ocean and SINTEF Digital. This study seeks to identify needed sensors and configurations for situational awareness in remote control of ship cranes using a simulator framework. A modular crane simulator framework has been developed to evaluate situational awareness for different sensor configurations. The sensor configuration has been evaluated with feedback from a crane expert at NCL. This research has identified potential sensor configurations for enhancing situational awareness in remote crane operations. The developed simulator framework has demonstrated its flexibility and efficiency as a platform for testing and optimizing cargo handling operations. The results from this study were published in a paper at MTEC/ICMASS 2024. NCL has now started testing the crane simulator to give feedback on the development.

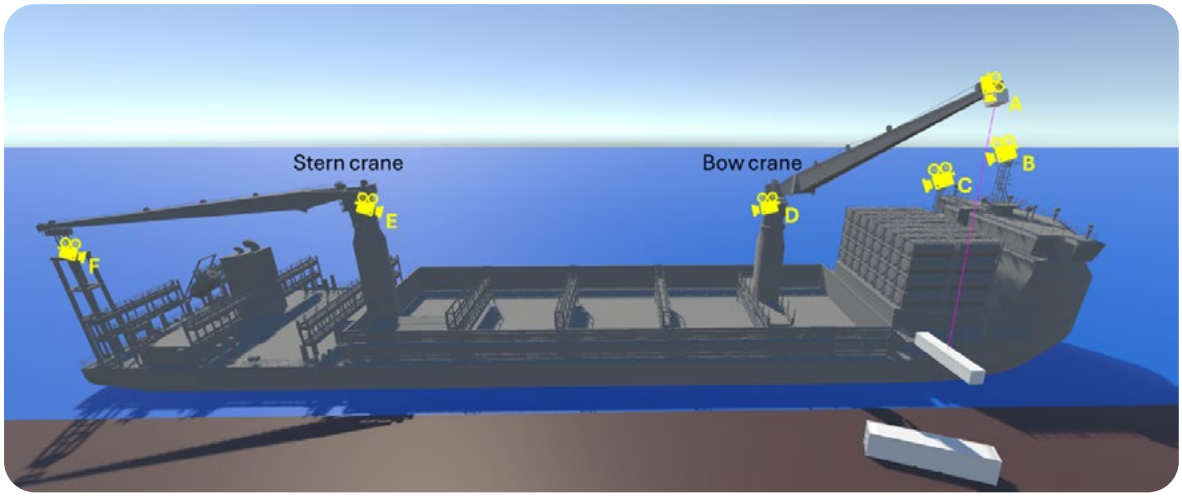


Figure 1: Illustration of crane simulator with possible camera positions on the ship.

For the logistics system cost-benefit analysis, a simple tool was created in cooperation with NCL that could analyse data from Kystdatahuset and extract relevant information on the age and type of ships that operate along the Norwegian coast. The result from these analyses can then be used as input to the logistic analysis tool in order to decide where autonomous ships with particular specifications could be deployed in the future. This, along with other work in WP5 can then be used in the future to analyse specific scenarios in the logistic analysis tool.

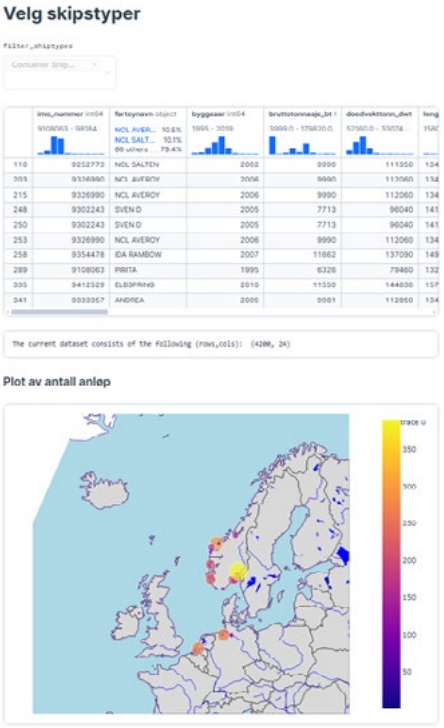


Illustration of tool for logistic and port call analysis.

6 Use Case

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

Our objective is to demonstrate the applicability and value-adding potential of research and innovation results from the Centre and disclose new problems for further research.

The objective of the use case is three-fold, where the use case will:

1. Provide direction and prioritization for relevant topics tied to the use case applications areas in focus
2. Be the common ground for dedicated use case workshops where the purpose is to mature requirements, needs and central technology gaps
3. Serve as an arena, through connected infrastructure, for testing and demonstrating research results and identify topics which require further research and innovation.

Each use case will involve at least one end user, product and service providers, research institutes, universities, and authorities, which represent the entire research- innovation chain as well as competence at all technology readiness levels (TRLs). At the start of the Centre, four use cases have been identified as most promising from the industry-partners' perspective. Regarding objective 3, PhD/PD and other research activities will plan for deployment of the results in collaboration with involved partners. When the focus areas of the use case have reached a sufficiently high TRL, these will be handed over to the industry partners for further development internally and/or through new and dedicated research and innovation projects.

From autumn 2024, Svein Peder Berge was phased in as new work package leader after Trond Johnsen. The new work package leader has used the autumn to get to know the researchers and ensured the best possible transfer of knowledge and experience from the previous work package leader. During 2024, Researcher workshops have been organized where the focus was to highlight that research topics for PhDs/PDs must be well anchored in one or more of the use cases. In December, a separate workshop was held with PhDs/PDs focusing on actions for better involvement of the industry partners in the research work and, not least, to focus on the value of the research being useful for industry. This workshop was organized together with Kjell Olav Skjølsvik, leader of WP7 Innovation and Commercialization.

There are currently 4 use cases:

Photo: Piotr Lewandowski/G2Ocean

Use Case 1: Deep-sea bulk shipping
This use case is led by Grieg Star. Grieg Star has defined a case scope including automation related to cargo handling and navigation, specially focusing periodically unmanned bridge during overseas sailing.

Photo: North Sea Container Line/NCL

Use Case 2: Short-sea container shipping
This use case is led by North Sea Container Line (NCL). Cargo handling is the most challenging part of operation today and there is a huge potential both in efficiency and safety improvement, hence also cost. This goes both for automation of the cargo handling operation itself, but also for communication between ship and terminal and other stakeholders.

Photo: Torghatten/NTNU

Use Case 3: Ferries
This use case is led by Torghatten. This use case aims to further develop the idea of flexible and environmentally friendly passenger ferries as alternatives to bridges and the traditional ferries. The focus will be on both small urban ferries for use in cities like Trondheim, but also on bigger car ferries. SFI AutoShip aims to develop and demonstrate the technology and infrastructure needed to realise new concepts for passenger ferries. Partly unmanned bridge, predictive maintenance, remote control and communication by utilizing 5G are all areas that will be investigated.

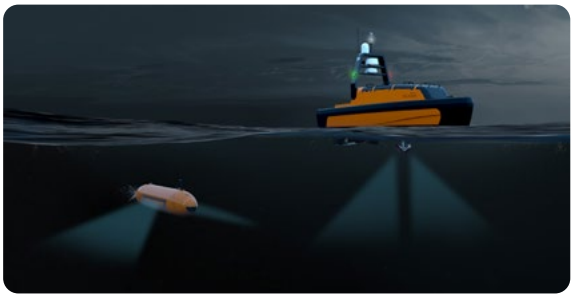


Illustration: Kongsberg Maritime

Use Case 4: Offshore support operations
This use case is led by Equinor. Research focus will be on using unmanned support vessels (USVs) in combination with autonomous underwater vehicles (AUVs) or remotely operated vehicles (ROVs) to perform inspection and maintenance operations offshore. These operations could be related to pipelines as well as floating wind installations. Relevant research areas are navigation, risk assessment and communication between the assets and an onshore control centre.

7 Innovation and Commercialisation

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

With the centre fully mobilised with high activity and research results emerging, a focus for the innovation management this year has been monitoring and reporting results to the consortium partners. In parallel, as highlighted in the annual report, a number of validation activities are taking place in collaboration with partners to assess research outcomes. The centre portfolio of potential innovations has now exceeded 18 defined innovation leads, several under validation by user partners.

The bi-annual innovation gatherings for PhD/PDs were arranged in June and December. Topics for this year's gatherings were introduction to the innovation maturity model, assessing and promoting value of own research and workshop on integration of research and user case activities.

As an element of the Centre's self-assessment, action research on innovation management in the centre was performed with contributions from Kongsberg Maritime and DNV as a research activity. Input was collected from user partners and researchers, and the results have been summarised in a research article submitted for publication in 2025.

Innovation workshop in June.

Photos: Ingeborg Guldal/NTNU

Innovation workshop in December.

Highlights from 2024

Meet our graduates

We are very proud of the four researchers who completed their projects in the SFI during 2024. Among them are the first two PhD graduates from the Centre, and our second and third completed postdoctoral researchers. 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.

ANDREAS NYGARD MADSEN

Andreas Nygard Madsen is the first PhD candidate in the SFI to submit his thesis, at the Department of Ocean Operations and Civil Engineering, NTNU in Ålesund. He defended his PhD on 19 August. He has since taken up a position as an Associate Professor at NTNU.

What was your project about?
Imagine you are driving a car. It is an advanced vehicle with a high degree of automation. Suddenly it tells you to move into the opposite lane, and you don't understand why. Would you do it? Most people would not since we humans are reticent to apply and trust in decision support that we do not fully understand. My project was on Human-AI Compatibility to enhance decision transparency in autonomous collision avoidance systems, thereby improving navigators' situational awareness. Here, I advocate for a design philosophy that places human needs and capabilities at the forefront of technological innovation.

What have you achieved during your PhD?
During my PhD, I have achieved several milestones that contribute both to the academic community and the practical field of Human-AI interaction. I have authored four articles as the first author and contributed to four additional articles.

Being a part of the SFI has been incredibly beneficial, providing me with opportunities to network and collaborate with both industry- and research partners. These interactions have enriched my research, allowing me to integrate diverse perspectives into my work. Collaborating with other PhD candidates within the SFI has also fostered a supportive and intellectually stimulating environment.

What will you do next?
I will take up a position as an associate professor at NTNU in Ålesund and will focus my energy on nautical education and research. My goal is to continue exploring and developing innovative solutions that enhance Human-AI interaction, particularly in the context of maritime navigation and safety. I am excited to be contributing to the academic community at NTNU and shaping the next generation of seafarers.

MELIH AKDAĞ

The first PhD recruited to the SFI, Melih Akdağ, submitted his thesis at the Department of Engineering Cybernetics, NTNU in Trondheim, and defended his PhD on 5 September. Melih was subsequently hired by Centre partner DNV, as an AI Researcher.

As my PhD journey reaches its conclusion, I feel mixed emotions. The past three years have been an intellectually rewarding adventure, filled with the satisfaction of exploring groundbreaking concepts in autonomous ship navigation. Yet, a sense of melancholy washes over me as I bid farewell to the supportive and vibrant environment that has nurtured my academic growth.

What was your PhD project about?
My research delved into collaborative collision avoidance strategies for autonomous ships. We identified four key maritime players - autonomous vessels, conventional ships, Vessel Traffic Service (VTS), and Remote Control Centers (RCC) - and their interactions in various scenarios. Our work focused on developing collaborative strategies that leverage active communication and information exchange among these actors to prevent collisions. This journey brought together the fields of cybernetics, computer science, and marine technology, as we implemented various control, optimization, and AI methods.

What have you achieved during your PhD?
The fruits of this labor are evident: six journal papers, two conference papers, and more than 25 presentations to industry partners, researchers, and the general public, all facilitated by SFI AutoShip. Beyond the research itself, I had the privilege of participating in workshops organized by Kjell Olav Skjølsvik, covering areas like Functional Analysis System Technique (FAST), Intellectual Property, and Research Innovation. These invaluable experiences honed my transferable skills, preparing me for the exciting career path ahead.

Looking back, I owe a debt of gratitude to NTNU and SFI AutoShip for providing an exceptional PhD experience. My academic knowledge, research skills, communication and dissemination abilities, and network have all flourished under their guidance.

Special thanks go to my supervisors, Prof. Tor Arne Johansen and Prof. Thor I. Fossen. Their invaluable guidance throughout my research journey was a perfect blend of freedom to explore my ideas with crucial support and insightful feedback. I also extend my gratitude to Tom Arne Pedersen, my co-supervisor and industry contact point from DNV. His industry perspective, gleaned from experience, insightful comments and discussions, significantly enhanced the real-world applicability and overall quality of my research.

Finally, immense appreciation goes to Anastasios M. Lekkas, Ingeborg Guldal, SFI AutoShip partners, and all PhD/PD colleagues for fostering an inclusive, supportive, and innovative research environment.

What will you do next?
As this chapter closes, a new one begins. I'm thrilled to announce my new role as AI Researcher at the DNV Group and Research Department in Trondheim. Here, I'll be joining the simulation technologies group, collaborating with a talented team of researchers and software developers. Building upon my PhD experiences, I'll be leveraging my knowledge to develop smart testing and assurance methods for cyber-physical systems, with a particular focus on autonomous ships.

Stay tuned for exciting developments in the world of safe and reliable autonomous navigation!
Fair winds and following seas!

TAUFIK AKBAR SITOMPUL

Postdoctoral researcher Taufik Akbar Sitompul completed his postdoc-project at NTNU's Department of Design in January 2024. He has since been hired as a Senior Researcher at NTNU.

What was your Postdoc project about?
My Postdoc project was about human-machine interfaces for remotely operated cranes. Cranes are traditionally operated by operators who are also present on-site, but nowadays there are also cranes that can be operated from remote control rooms. A shift from on-site to remote operation also introduces various issues that did not exist before, such as reduced sensorial information, latency, and even boredom. My Postdoc project attempted to address some of these issues through graphical user interface (GUI) designs.

What have you achieved during your Postdoc fellowship?
In the past 2 years, I attempted to address some of the issues mentioned above. I proposed 2 GUIs that could be used for helping crane operators control their cranes in the presence of latency. Unfortunately, the results from my experiment showed that both GUIs for handling latency did not help the crane operators perform better and safer, compared to when they had no support. I also proposed 3 GUIs for improving depth perception in remote crane operation. This time, the results from my experiment showed that 2 out of 3 GUIs for improving depth perception helped the operators perform better and safer, than when they had no support.

The role of having good GUIs becomes more important in remote crane operation, since crane operators could not see their cranes and the surroundings directly. This concern led me to developing OpenCrane Design System, which aims to offer user GUI components for operating cranes that anyone can reuse, modify, and distributed at no cost. I also received NOK 200K from NTNU Discovery to develop OpenCrane Design System.

All in all, my Postdoc fellowship in SFI AutoShip produced 7 published papers, 3 accepted papers, and 1 Disclosure of Invention (DOFI) to NTNU Technology Transfer.

What will you do next?
I will still be working at Department of Design. Since February 2024, I have been working as a work package leader in the EU-funded SHEREC project. The project aims to improve safety to workers and reduce toxic waste to the environment in the ship-recycling process by deploying robots. The work package that I am leading investigates how such robots should be designed and measures the societal and environmental impacts of those robots in the ship-recycling process.

TRYM TENGESDAL

Trym Tengesdal completed his postdoc project at NTNU's Department of Engineering Cybernetics in September. He was recruited by AutoStore, where he works as an R&D Developer.

What was your project about?
The maritime environment is incredibly complex, with lots of perils from winds, currents, waves, grounding hazards, and nearby vessels with uncertain intentions and inclinations toward following the rules of the sea (COLREG). This environment changes over time, and new situations are encountered frequently, making it hard to configure ship collision avoidance systems such that they work over long periods of time, in any kind of situation. Based on the above, my project was focused on developing adaptable data-driven collision avoidance algorithms and frameworks for developing, training, and testing such planning algorithms that have to consider and tackle these challenges for autonomous ships to become a reality.

What have you achieved during your postdoc?
During my postdoc from 2022 to 2024 I have authored two conference papers, two journal papers with one of them still under review, co-authored one conference paper and one journal paper, and have supervised 7 Master's students to completion. As a stepping stone towards facilitating easy development of new algorithms, I have developed a simulation framework for developing and testing new collision avoidance planning algorithms and machine learning algorithms, which I hope will be utilized by the research community and multiple parties in the future, making it easier to do advanced research on the topic of maritime collision avoidance. A last journal paper on data-driven collision avoidance is still in progress, utilizing the above-mentioned framework, which I intend to finalize next year.

I want to thank Prof. Tor Arne Johansen for allowing me the freedom to pursue my interests within the field, providing timely feedback when wanted and required. It has been a pleasure over the last 5 years, both during my PhD and my postdoctoral fellowship. I want to thank Anastasios M. Lekkas and Ingeborg Guldal for steering SFI AutoShip in an excellent manner, the many partners of the centre for good conversations and interest in my work, and lastly all my good colleagues and friends for making the past years a pleasurable ride.

What will you do next?
After my period ended as a researcher at SFI AutoShip in September, I have ventured into industry and another domain, now working as an R&D developer within logistics optimization for the Norwegian unicorn company AutoStore. Although not focused on marine autonomy anymore, I am using my competence and interest in optimization, estimation, and machine learning to improve their routing system. Exciting work and I will for sure benefit from the knowledge and experiences I have accumulated during my time at NTNU and AutoShip.

milliAmpere1 during field trials in Autumn 2024.

Conducting field trials with milliAmpere1 ferry prototype

By Miguel Hinostroza (NTNU) and Camilla Fruzzetti (University of Genoa)

Current system architecture onboard milliAmpere
The current system architecture onboard milliAmpere1 (mA1) autonomous ferry prototype is divided into several subsystems, as can be seen in Fig.1. The propulsion system, composed of four azimuthal electric thrusters connected through a CAN bus network. The navigation system consists of a GNSS station receiver with RTK correction and an IMU. The power supply system, composed of 8 marine lithium batteries that supply power to the le system, including 24 V DC and 220 V AC. The onboard control and monitoring system, which includes a fanless industrial computer running Linux and ROS-based software, allows for real-time control, monitoring, and system logging. The situational awareness system, which features a LiDAR, maritime radar, 5 EO cameras, and 5 IR cameras, provides information about the ferry's surroundings. Additionally, the mA1 is equipped with a radio joystick controller and emergency stop buttons to ensure the safe operation of the mA1.

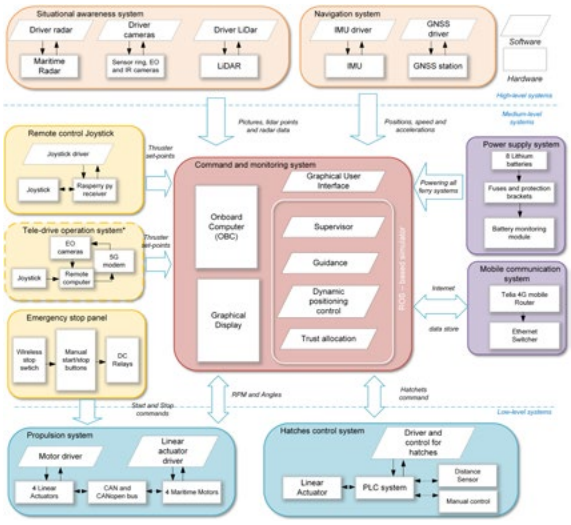


Fig.1. System architecture onboard of milliAmpere 1 autonomous ferry prototype.

How milliAmpere facilitates research in the SFI project
The milliAmpere1 can serve as a versatile platform for research within the scope of the SFI project, offering a complete framework for hardware-in-the-loop and field trials. For example, the high versatility of deployment and the challenging maneuvering characteristics of the vessel make it a challenging testing platform for automatic control strategies, dynamic positioning, precise navigation, and stability under various conditions. In guidance experiments, the ferry can simulate real-world maritime scenarios to evaluate path planning and navigation strategies. Collision avoidance systems can be tested by creating controlled environments to assess the effectiveness of sensors and algorithms in detecting and avoiding obstacles. Lastly, the prototype can gather data for perception systems, helping to improve object detection, tracking, and decision-making in maritime environments.

Field trials in autumn 2024
During weeks 42 and 43 of October 2024, a series of tests were carried out on the milliAmpere1, as shown in the photo on page 54. The trials took place in the Nyhavna harbour basins, in Trondheim, and had a twofold purpose. The first is to build datasets to identify the ship motions and dynamics of the ship actuators; since the propulsion system was upgraded, it became necessary to identify the dynamics of both the new thrusters and the total ship system in order to be able to use this data in the milliAmpere1 control systems and the simulator, which is fundamental for the early stages of development. The second is to carry out tests on a possible high-drift angle motion control system developed earlier.

The initial experiments, focused on building datasets, occupied most of the test days, as the recorded data needed to be analyzed in depth. In addition to basic tests aimed at analyzing the dynamics of the azimuth thrusters, correct setpoints were determined to perform all possible motions in the horizontal plane at various speeds. The final series of tests evaluated a dynamic positioning system that had previously been developed and tested in simulation.

Charting New Waters with Periodically Unmanned Bridges (B0) – an empirical study

Along with shipowners across the globe, project partner Grieg Star is increasingly facing the challenge of ensuring compliance with the current regime of rest time regulations. One important contributing factor is the continuous year-on-year decline in the availability of trained seafarers[1]. Another is the improved ability to make use of Artificial Intelligence for voyage optimisation, especially in terms of minimising energy consumption by accounting for e.g. sailing speed, heading, expected weather along the route, and congestion at port of arrival. Investigating the operational concept of sailing with a periodically unmanned bridge (B0) has therefore received increased interest among several actors. This interest has also been driven by the scarcity of objective research data on the subject, which has left the potential advantages of the B0 concept largely unexplored.

In essence, the B0 concept relies on the advancements in sensor technology, enabling a ship's bridge to be left unattended under specific and pre-defined operational conditions (e.g., open sea, clear weather, no engine failures). Enabled by automation, ship-systems undertake navigation and course keeping, and in case automation is not able to make a decision itself, the deck officer on watch receives an alarm and summons to the bridge. However, indeed promising in terms of alleviating the working conditions for seafarers, and in particular bridge crew, the concept also introduces significant challenges that need to be addressed, including legal and human-centred considerations.

In close cooperation with Grieg Star, research partners of WP3 and WP6 represented by IFE, SINTEF Ocean, NTNU and UiO, joined forces, and together we set out to explore how navigators would experience the B0 concept. As an important starting point, the working group had several meetings for scoping the study, including the definition of the operational concept and expectations related to assumed benefits and potential risks and drawbacks. All forming an important basis when designing the study and the research questions. The applied method was a combination of semi-structured interviews and the use of the full mission bridge simulator at NTNU Ålesund. Quantitative and qualitative data were collected, focusing on eight highly experienced navigators' perceptions of B0 operations and their ability to quickly establish situational awareness.

The results indicate that today's solutions need to be improved to enable safe B0 operations. Among other things, this includes targeted specification for human centred design requirements for the development of navigational aids and bridge decision support systems.

From a broader perspective, the primary advantage of B0 seems to be the potential for improved compliance with rest time regulations. However, this benefit needs to be balanced with the navigators concerns about trust and reliability of the required technology, including its ability to detect general system failures and identify of cyber-attacks. While the current study shows that the B0 concept can contribute to improving seafarers' resting time conditions, significant technological, regulatory, and human-centred challenges have yet to be addressed.

The work was concluded by organising a webinar for the SFI AutoShip consortium on December 10, 2024. Regarding dissemination, a journal paper detailing the study is currently undergoing peer review for publication.

Authors and contributors: Magnhild Kaarstad[1], Andreas Madsen[2], Even Ambros Holte[3], Ayoub Tailoussane[4], Prosper Ameh Kwei-Narh[1], Alf Ove Braseth[1], John Gabriel Östling[5]

[1] Institute for Energy Technology, Halden, Norway.

[2] Norwegian University of Science and Technology, Department of Ocean Operations and Civil Engineering, Ålesund, Norway

[3] SINTEF Ocean, Department of Energy and transport, Trondheim, Norway

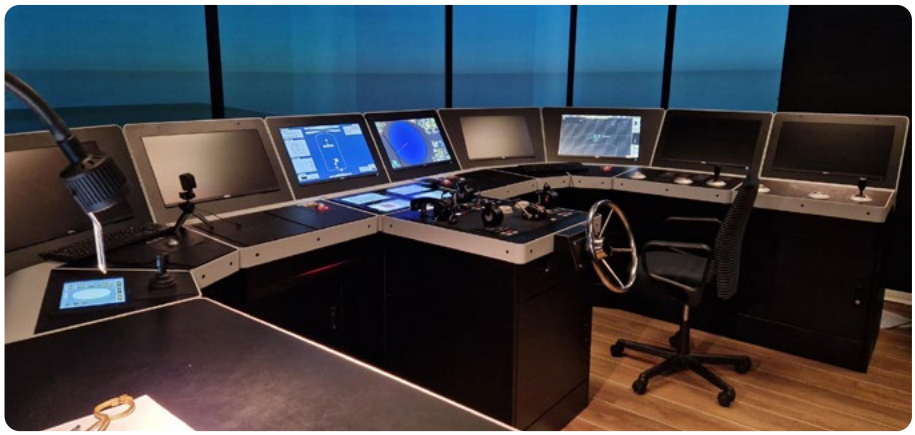
[4] University of Oslo, Scandinavian Institute of Maritime Law, Oslo, Norway

[5] Grieg Star, Bergen, Norway

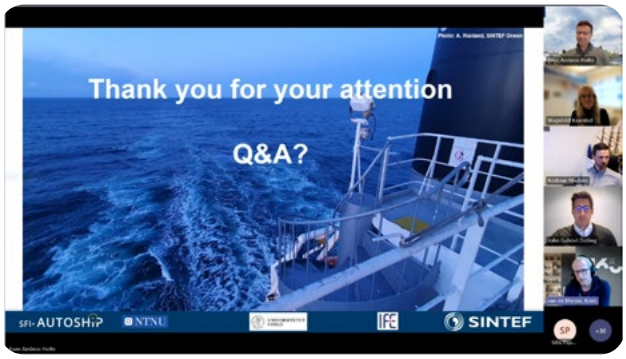
[1] Drewry (2023). Seafarer labour market tightest on record. https://www.drewry.co.uk/news/news/seafarer-labour-market-tightest-on-record

View from the bridge at night on a Grieg Star ship. Photo: Agathe Rialland/SINTEF Ocean

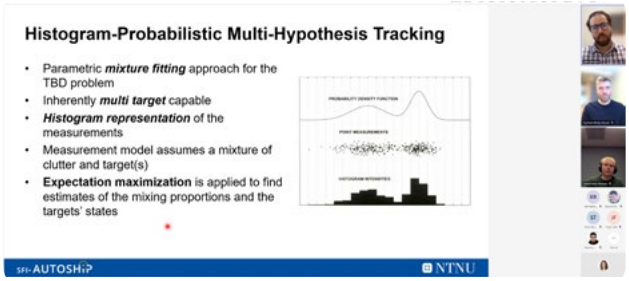
View from the bridge during the day on a Grieg Star ship. Photo: Agathe Rialland/SINTEF Ocean



Full-scale bridge simulator, NTNU Ålesund. Photo: Magnhild Kårstad/IFE



WP5 Periodically unmanned bridge webinar, December 2024.



WP1 Radar in maritime situational awareness webinar, January 2024.

WP4 Risk assessment and supervisory risk control of autonomous marine systems webinar, December 2024.

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 and seminars during 2024:

1. WP1: Radar in maritime situational awareness - Beyond point measurement (NTNU, Kongsberg Maritime)
2. WP4: Systems-Theoretic Process Analysis (STPA) tutorial (physical seminar organised by NTNU)
3. WP1: Safe Optimal Control and Multi-Target Tracking Demonstrated with a Digital Twin (NTNU)
4. WP4: Risk assessment and supervisory risk control of autonomous marine systems (NTNU, Kongsberg Maritime and Fugro)
5. WP5: Navigator experiences of periodically unmanned bridge – an empirical study (IFE and SINTEF Ocean)

Mary Ann Lundteigen presenting at the WP4 STPA tutorial, April 2024. Photo: Ingrid B. Utne/NTNU

International Collaboration

Autonomous ship development constitutes a difficult research problem that must be addressed across disciplines. While much expertise can be found in Norway, naturally, we have benefited from collaboration with relevant research groups abroad, and hired researchers internationally.

SFI personnel have also participated in international forums and projects. An example in 2024 was the Centre director presenting the SFI at the International Maritime Organisation, on the invitation of consortium partner NMA, during the 109th session of the Maritime Safety Committee (MSC 109). Many of our research and user partners are key contributors to autonomous ship technology and operations, and as such they participate in many flagship projects. Since SFI AutoShip started, our partners have been involved in at least 14 new projects in Europe and Norway.

SFI AutoShip participates 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. We have a total of 5 high-quality international candidates receiving additional funding through this scheme, 2 of which started in 2024. From a total of 25 researchers who have been hired in the Centre, 18 come from outside Norway. They have brought significant expertise within robot perception, systems theory, remote operations and other disciplines.

3 of our researchers went on research stays abroad in 2024:

- PhD candidate Lukas Herrmann (WP2) spent a semester as visiting researcher at the Signal Processing Group at the University of Liverpool, UK. The group, which is led by Simon Maskell, has expertise and research interests in areas such as Bayesian computational methods, autonomy, decision support, data fusion, tracking, image processing, radar and acoustic analysis, and machine learning.

- PhD Candidate Daniel Menges (WP1) spent a semester as a visiting researcher at the Centre of Robotics and Autonomous Systems (CRAS), University of Porto, Portugal. Menges collaborated with Prof Aníbal Matis, Prof. Andy Pinto and researchers from the CRAS group. During his stay, Menges focused on machine learning and sensor fusion, and explored how these disciplines can be integrated to improve perception and data analysis. Data was collected via field trials, and a paper is being prepared.

- Postdoctoral researcher Trym Tengesdal (WP1) went on a 2-week stay at the Marine Autonomy Lab (MAL) at the Massachusetts Institute of Technology (MIT), Boston, USA. The lab is headed by Dr. Michael R. Benjamin and has developed a unique framework for marine autonomy, MOOS-IvP. The stay was mostly focused on networking, information sharing, discussing possible future collaboration and writing a report on the topics MAL working on and the autonomy platforms they are using.

SFI AutoShip also hosted researchers from from the University of California at Berkeley and the University of Genoa during 2024, conducting testing at our Marine Cybernetics Lab (MC-Lab) and on milliAmpere 1, resulting in collaborative journal and conference papers.

- Prof. Murat Arcak, PhD Elizabeth Dietrich and PD Bingzhuo Zhong from the University of California at Berkeley collaborated with WP4 researchers in tests at our Marine Cybernetics Lab (MC-Lab).

- PhD Camilla Fruzzetti from the University of Genoa visited and participated in field trials with milliAmpere 1, along with WP1 and WP4 researchers.

From left to right; Researchers from University of California, Berkeley, Elizabeth Deitrich and Bingzhuo Zhong, and from NTNU Emir Cem Gezer. 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 4 PhDs and 1 postdoc to the Centre in 2024.

Name	PhD project	Work package	Supervisor	Host department
Joel Jose	Enabling supervisory control of autonomous vessels through transparency and explainability	1	Erlend Magnus Lervik Coates	Dept. of ICT and Natural Sciences
Giacomo Melloni	Radio channel measurements and modelling in maritime scenarios	2	Torbjörn Ekman	Dept. of Electronic Systems
Manju James	Radio Twin: Digital twin for maritime communication system performance prediction	2	Kimmo Kansanen	Dept. of Electronic Systems
Paul Lee	Supervisory risk analysis and control in operation	4	Ingrid B. Utne	Dept. of Marine Technology
Jon Estil Krågebakk	AI and data-driven safety management in operation of autonomous ships	4	Ekaterina Kim	Dept. of Marine Technology

Joel Jose, PhD Candidate,
Dept. of ICT and Natural Sciences, NTNU.

Paul Lee, postdoc,
Dept. of Marine Technology, NTNU.

Giacomo Melloni, PhD Candidate,
Dept. of Electronic Systems, NTNU

Jon Estil Krågebakk, PhD Candidate,
Dept. of Marine Technology, NTNU.

Manju James, PhD Candidate,
Dept. of Electronic Systems, NTNU.

PhDs and Postdocs

Melih Akdağ
Collaborative Collision Avoidance for Autonomous Ships
Supervisors: Tor Arne Johansen and Thor I. Fossen (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
Decision Support Systems for Autonomous Vessels
Supervisors: Erlend Magnus Lervik Coates, Ottar L. Osen and Robin T. Bye (IIR, NTNU), Thor I. Fossen (ITK, NTNU)

Lukas Herrmann
Shore-based Radar Network for Autonomous Shipping
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
Enabling supervisory control of autonomous vessels through transparency and explainability
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)
Supervisory risk analysis and control in operation
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

Andreas Nygard Madsen
AI decision transparency in autonomous shipping
Supervisors: Magne Aarset (IHB, NTNU), Ole Andreas Alsos (Design, NTNU), Tae-Eun Kim (UiT), Andreas Brandsæter (IIR, NTNU)

Felix-Marcel Petermann
Investigating New Solutions for Situational Awareness in Autonomous Passenger Ferries
Supervisors: Ole Andreas Alsos and Eleftherios Papachristos (Dept. of Design, NTNU)

Taufik Akbar Sitompul
Human-machine interface for remote crane operation
Supervisor: Ole Andreas Alsos (Dept. of Design, NTNU)

Sreekant Sreedharan
Safety assessment and verification of collision avoidance algorithms for autonomous ships
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)

Trym Tengesdal
Machine learning methods applied to parameter identification and automatic adjustment of ship motion planning algorithms
Supervisor: Tor Arne Johansen (ITK, NTNU)

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

Opinion piece in Skipsrevyen

WP5 researchers Pauline Bellingmo, Even Ambros Holte and Ulrik Jørgensen wrote the opinion piece Har du opplevd å bli utskjelt av en sint bergenser? in Skipsrevyen.

Maritim Forskning:

Har du opplevd å bli utskjelt av en sint bergenser?

Illusrtrasjonsfoto: Bratafe/Wikimedia Commons

Som fergemannskap risikerer du nettopp det. Ukentlig. Men, det er ikke bare bergensere som blir sinte. Dette er et problem fergemannskap i hele landet kjenner på. Spesielt utsatt er matrosene som dirigerer av- og påkjøringen. Ikke rart fergerederiene sliter med rekruttering. Kan løsningen være å automatisere av- og påkjøringen?

Pauline Bellingmo
SINTEF

Even Ambros Holte
MEDFORFATTER

Ulrik Jørgensen
MEDFORFATTER

Skipsrevyen, «Har du opplevd å bli utskjelt av en sint bergenser?», 30.04.2024.

Opinion piece in Nidaros

SFI researchers Morten Breivik and Ole Andreas Alsos contributed with the opinion piece Fremtiden er nå together with several colleagues, in the news site Nidaros, about Trøndelag and Nyhavna as a hub for research and development on maritime autonomy and drones.

Fremtiden er nå

– Fredag og lørdag blir det mulighet til å se, prøve og høre historiene om hvordan droner både utvikles, bygges og brukes her i byen og over hele verden, skriver Bernt Scjetne, Ragnar Eggen, Morten Breivik, Ole Andreas Alsos, Åshild Adsen og Frode Halvorsen. Foto: ScoutDI

Av Bernt Schjetne, daglig leder, Ocean Tech, Ragnar Eggen, Clean Sea Solutions, Morten Breivik, førsteamanuensis, institutt for teknisk Kybernetikk, NTNU, Ole Andreas Alsos, førsteamanuensis/prodekan for innovasjon og formidling, NTNU, Åshild Adsen, direktør Vitensenteret i Trondheim og Frode Halvorsen, leder, Ocean Autonomy Cluster

Publisert: 23.10.24 12:20 Del

Med de sterke fagmiljøene på NTNU og SINTEF og teknologitunge næringer utvikles fremtidens verktøy i Trøndelag.

Nidaros, «Fremtiden er nå», 23.10.2024.

Interview about the development of Nyhavna as a “Silicon Harbour”

WP3 researcers Ole Andreas Alsos and Felix-Marcel Petermann was interviewed by news site Nidaros, about the NTNU Shore Control Lab and Nyhavna as a “Silicon Harbour”, a cluster for ocean space technology.

NYHAVNA NTNU NÆRINGSLIV

– Vi har jobbet veldig hardt for at det ikke skal bli bare boliger og kafeer her

Stipendiat Felix-Marcel Petermann og leder Ole Andreas Alsos inne i Shore Control Lab på Nyhavna. Foto: Berit Buran Juul

Av Berit Buran Juul Publisert: 20.06.24 07:06 Del

De siste årene har det vokst fram en havromsklynge på Nyhavna. Nå er denne klyngen en sentral del av framtidsplanen til bydelen.

Nidaros, «Nyhavna, NTNU – Vi har jobbet veldig hardt for at det ikke skal bli bare boliger og kafeer her», 20.06.2024.

News coverage of mHUD

News site Shifter mentioned the recipients of NTNU Discovery funding in June 2024, one of which was developed partly through SFI AutoShip with our researchers Ole Andreas Alsos and Felix-Marcel Petermann: “mHUD 2.0”, a head-up display for improved maritime situational awareness.

Delte ut 4,6 millioner til disse NTNU-prosjektene

Kahoot fikk i sin tid støtte fra NTNU Discovery. Nå er nye gründerspirer premiert med pengepott.

Shifter, «Delte ut 4,6 millioner til disse NTNU-prosjektene», 10.06.2024.

Njord Challenge 2024

SFI AutoShip was mentioned as a sponsor of Njord Challenge in an article in Skipsrevyen about the 2024 student world championship in autonomous ships.

Navier fra Universitetet i Sørøst-Norges campus Horten vant seieren i Njord - the Autonomous Ship Challenge 2024. Foto: Live Oftedahl

Studenter skal revolusjonere skipsfarten

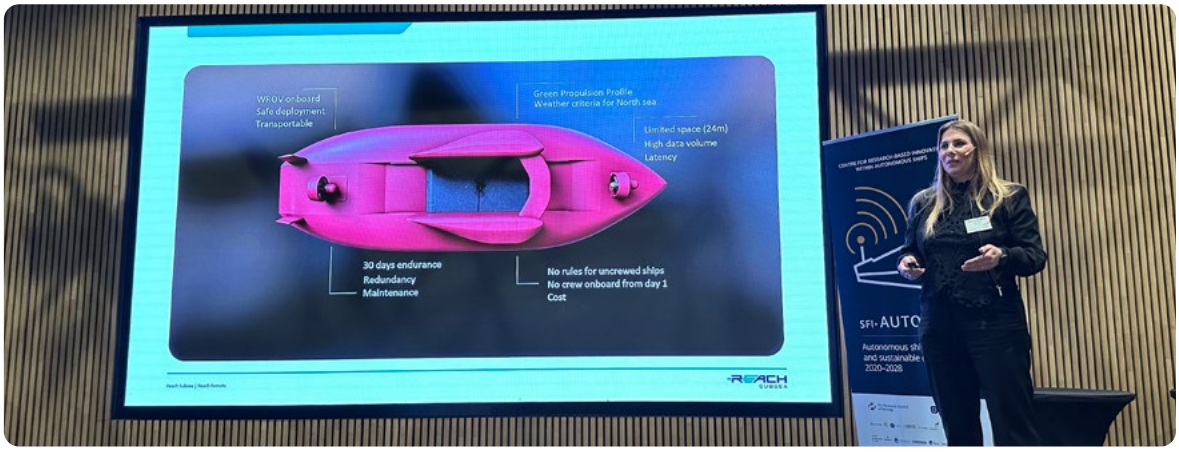
Skipsrevyen, «Studenter skal revolusjonere skipsfarten», 20.08.2024.

Events

SFI AutoShip Days

More than 100 participants from our consortium attended our main annual event, the SFI AutoShip Days on 15-16 October, at Quality Hotel Prinsen.

Presentations reflected the wide range of research and innovation activities of the Centre partners, including the Skipsrevyen-awarded "Ship of the Year 2024" Reach Remote 1 by Reach Subsea and Kongsberg Maritime; new DNV class notations for autonomous and remotely operated ships; an overview of the IMO's MASS code by NMA; presentations of results by 4 of our PhD and PD graduates; the integration of autonomy in offshore operations by Fugro; our internal group on COLREGS; the student competition Njord Challenge; a demo of remote operation and auto-crossing of NTNU's autonomous vessels, milliAmpere 1 & 2; hardware and software on milliAmpere 1; autonomous ships and logistics performance by SINTEF Ocean; a periodically unmanned bridge presentation by IFE; and self-introductions by our 6 newly employed researchers.



Bjørg Mathisen Døving from Reach Subsea presenting. Photo: Ingeborg Guldal/NTNU

The mobile remote operation centre at Ravnkloa during the SFI Days. Photo: Ingeborg Guldal/NTNU

Participants at the SFI Days aboard milliAmpere 2, with milliAmpere 1 in the background. Photo: Ingeborg Guldal/NTNU

SFI AutoShip Days 2024. Centre director Anastasios M. Lekkas on stage with Are Jørgensen from DNV. Photo: Ingeborg Guldal/NTNU

SFI AutoShip Researcher Workshops

The spring researcher workshop was held in March and included presentations on industry-related research challenges from industry partners DNV, Fugro and Kongsberg Maritime, as well as participation by many other consortium partners, with a record 60 people in attendance. Five newly employed PhDs also presented their projects. After lunch, parallel session discussions focused on the involvement of PhDs and postdocs with partner organisations, according to work packages.

We also welcomed 60 participants from both research and industry to our Autumn researcher workshop in September. Fugro provided an interesting presentation from an industry partner perspective, and we were updated on the Centre's Use Cases. Finally, a live demonstration of milliAmpere 1 being remotely controlled from the conference venue was carried out, by researchers from the adjacent Autoteaming project. The day was as usual rounded off with great discussions in parallel sessions in the work packages. These sessions focused on next year's annual work plan as well as the 3-year plan for the final phase of the Centre.

Spring and autumn researcher workshops. From top/left: Peter Morris (NTNU), Iurii Kapitaniuk (Fugro) and Alexey Gusev (NTNU) presenting. Photos: Ingeborg Guldal/NTNU

Publications and Presentations in 2024

TYPE	NAME/DESCRIPTION	NAME OF JOURNAL/ CONFERENCE/BOOK	AUTHOR(S)
Journal articles	Lessons learned from the trial operation of an autonomous urban passenger ferry	Transportation Research Interdisciplinary Perspectives	Ole Andreas Alsos, Mina Saghafian, Erik Veitch, Felix-Marcel Petermann, Taufik Sitompul, Jooyoung Park, Eleftherios Papachristou, Egil Eide, Morten Breivik and Øyvind Smogeli
	A Multiple Extended Object Tracker with the Gaussian Process Model Utilizing Negative Information	Journal of Advances in Information Fusion	Martin Baerveldt, Michael Ernesto Lopez and Edmund Brekke
	Enhancing Situational Awareness for Remote Control of Ship Cranes	Journal of Physics: Conference Series	Pauline Bellingmo, Ulrik Jørgensen, Magnus Bjerkeng and Kenneth Johanson
	Multi-Target Tracking for Autonomous Surface Vessels Using LiDAR and AIS Data Integration	Applied Ocean Research	Andreas von Brandis, Daniel Menges and Adil Rasheed
	A simulator-based approach for testing and assessing human supervised autonomous ship navigation	Journal of Marine Science and Technology	Andreas Brandsæter and Andreas Nygard Madsen
	Statistical analysis of vessel loss of command frequency	Maritime Transport Research	Spencer Dugan and Ingrid B. Utne
	Maneuvering-based Dynamic Thrust Allocation for Fully-Actuated Vessels	IFAC-PapersOnLine	Emir Cem Gezer and Roger Skjetne
	A novel STPA approach to software safety and security in autonomous maritime systems	Heliyon	Alojz Gomola and Ingrid B. Utne
	Multi-Agent Maritime Traffic Simulator	MIC Journal: Modeling, Identification and Control	Luka Grgičević
	PMBM Filtering With Fusion of Target-Provided and Exteroceptive Measurements: Applications to Maritime Point and Extended Object Tracking	IEEE Access	Audun Gullikstad Hem, Martin Baerveldt and Edmund Brekke
	Validation of Automatic Identification System Information With Exteroceptive Sensor Fusion for Unmanned Marine Operations	IEEE Intelligent Transportation Systems Magazine	Audun Gullikstad Hem and Edmund Brekke
	Autonomous Marine Collision Avoidance With Sensor Fusion of AIS and Radar	IFAC-PapersOnLine	Audun Gullikstad Hem, Edmund Brekke, Giorgio Kufoalor and Ivan Håbjørg Kingman

TYPE	NAME/DESCRIPTION	NAME OF JOURNAL/ CONFERENCE/BOOK	AUTHOR(S)
	Temporal mission planning for autonomous ships: Design and integration with guidance, navigation and control	Ocean Engineering	Miguel Hinostroza and Anastasios M. Lekkas
	Conversational user interfaces for maritime autonomous surface ships	Ocean Engineering	Philip Hodne, Oskar K. Skåden, Ole Andreas Alsos, Andreas Nygard Madsen and Thomas Porathe
	A systems approach to hazard identification for solar-powered and wave-propelled unmanned surface vehicle	Journal of Marine Engineering & Technology	Susanna Dybwad Kristensen, Alberto Dallolio and Ingrid B. Utne
	Comparison of methods for using risk information in path planning for autonomous surface vessels	Journal of Physics: Conference Series	Susanna Dybwad Kristensen, Roger Skjetne and Ingrid B. Utne
	Nonlinear PID Control for Automatic Docking of a Large Container Ship in Confined Waters Under the Influence of Wind and Currents	IFACPapersOnLine	Simon Lexau, Anastasios Lekkas and Morten Breivik
	A state-of-the-art review of AI decision transparency for autonomous shipping	Journal of International Maritime Safety, Environmental Affairs, and Shipping	Andreas Nygard Madsen and Tae Eun Kim
	Hybrid Control Barrier Functions for Continuous-Time Systems	IEEE Transactions on Automatic Control	Mathias Marley, Roger Skjetne and Andrew R. Teel
	Real-Time Predictive Condition Monitoring Using Multivariate Data	IEEE Transactions on Image Processing	Daniel Menges, Adil Rasheed; Harald Martens and Torbjørn Pedersen
	Nonlinear Model Predictive Control for Enhanced Navigation of Autonomous Surface Vessels	IFAC-PapersOnLine	Daniel Menges, Trym Tengesdal and Adil Rasheed
	Multi-Horizon Model Predictive Control for Energy Management in Zero-Emission High-Speed Passenger Vessels	Journal of Physics: Conference Series	Samieh Najjaran and Roger Skjetne
	Stereo Camera-based Free Space Estimation for Docking in Urban Waters	MIC Journal: Modeling, Identification and Control	Trym A. Nygård, Nicholas Dalhaug, Rudolf Mester, Edmund Brekke and Annette Stahl
	Touchpoints and systems for unmanned autonomous urban ferry operation	Journal of Physics: Conference Series	Felix-Marcel Petermann, Ole Andreas Alsos, Egil Eide, Morten Breivik, and Erik Veitch
	A Comparison of the State-of-the-Art Reinforcement Learning Algorithms for Health-Aware Energy and Emissions Management in Zero-Emission Ships	IEEE Journal of Emerging and Selected Topics in Industrial Electronics	Namireddy Praveen Reddy, Roger Skjetne, Oliver Os and Dimitrios Papageorgiou

TYPE	NAME/DESCRIPTION	NAME OF JOURNAL/ CONFERENCE/BOOK	AUTHOR(S)
	Understanding automation transparency and its adaptive design implications in safety–critical systems	Safety Science	Mina Saghafian, Dorthea M. K. Vatn, Stine T. Moltubakk, Lene E. Bertheussen, Felix-Marcel Petermann, Stig O. Johnsen and Ole A. Alsos
	Real-time Feasible Usage of Radial Basis Functions for Representing Unstructured Environments in Optimal Ship Control	American Control Conference (ACC)	Trym Tengesdal, Sebastien Gros and Tor Arne Johansen
	Obstacle Intention Awareness in Automatic Ship Collision Avoidance: Full-Scale Experiments in Confined Waters	Field Robotics	Trym Tengesdal, Sverre V. Rothmund, Erlend Basso, Henrik Schmidt-Didlaukies and Tor Arne Johansen
	A systems approach to hazard identification for solar-powered and wave-propelled unmanned surface vehicle	Journal of Marine Engineering & Technology	Susanna Dybwad Kristensen, Alberto Dallolio and Ingrid B. Utne
	Modular control architecture for safe marine navigation: Reinforcement learning with predictive safety filters	Artificial Intelligence	Aksel Vaaler, Svein Jostein Husa, Daniel Menges, Thomas Nakken Larsen and Adil Rasheed
	Dataset on passenger acceptance during autonomous ferry public trials: Questionnaires and interviews	Data in Brief	Erik Veitch, Ole Andreas Alsos, Mina Saghafian, Felix-Marcel Petermann, Taufik Sitompul and Jooyoung Park
Conference papers/ workshop presenta-tions	Prioritizing and Ranking Ships in Multi-encounter Scenarios for Autonomous Navigation	Joint 13th International Conference on Soft Computing and Intelligent Systems and 25th International Symposium on Advanced Intelligent Systems (SCIS & ISIS)	Melih Akdağ and Tor Arne Johansen
	Automated Aquaculture Operations With Vessel-Mounted Robotic Arm: An Experimental Feasibility Study	European Control Conference 2024	Martin A. Brandt, Sverre Herland, Martin Gutsch, Halgeir Ludvigsen and Esten Ingar Grøtli
	Autonome skip: Interaksjon og situasjonsforståelse	Maritim Uke	Edmund Brekke
	SFI AutoShip webinar: Radar in maritime situational awareness - Beyond point measurement	SFI AutoShip webinar	Edmund Brekke, Lukas Herrmann and Henrik Dobbe Flemmen
	Combining Short and Wide Baseline Stereo Cameras for Improved Maritime Target Tracking	27th International Conference on Information Fusion (FUSION)	Nicholas Dalhaug, Annette Stahl, Rudolf Mester and Edmund Brekke
	Development of a risk indicator for ship drifting groundings	17th International Conference on Probabilistic Safety Assessment and Management & Asian Symposium on Risk Assessment and Management (PSAM17&ASRAM2024)	Spencer Dugan and Ingrid B. Utne

TYPE	NAME/DESCRIPTION	NAME OF JOURNAL/ CONFERENCE/BOOK	AUTHOR(S)
	Fading Distribution Model for the Maritime Radio Channel	18th European Conference on Antennas and Propagation (EuCAP)	Torbjörn Ekman
	Automatic drone landing on a boat: Theory and preliminary experimental results	ASME 2024; 43rd International Conference on Ocean, Offshore and Arctic Engineering	Martin Falang, Miguel Hinostroza, Peter Bull Hove, Thomas Sundvoll, and Anastasios M. Lekkas
	Model-Based Motion Control Design for the Milliampere1 Prototype Ferry	European Control Conference (ECC).	Camilla Fruzzetti, Michele Martelli, Anastasios M. Lekkas, Roger Skjetne and Morten Breivik
	Maneuvering-based Dynamic Thrust Allocation for Fully-Actuated Vessels	15th IFAC Conference on Control Applications in Marine Systems, Robotics and Vehicles	Emir Cem Gezer and Roger Skjetne
	Decision Support for Collision Avoidance in Maritime Multi-Vessel Encounter	MTEC/ICMASS	Luka Grgičević
	Towards Decision Support in Vessel Guidance Using Multi-Agent Modelling	European Control Conference (ECC)	Luka Grgičević, Erlend M Coates, Robin Bye, Thor I. Fossen and Ottar Osen
	FusedWSS: Water Surface Segmentation Fusing Machine Learning and Geometric Cues	27th International Conference on Information Fusion (FUSION)	Jon T. Grini, Rudolf Mester, Trym A. Nygård, Nicholas Dalhaug, Edmund Brekke and Annette Stahl
	Towards the Use of Temporal Convolutional Networks for Guiding Dynamic Risk Assessment Methods	17th International Conference on Probabilistic Safety Assessment and Management & Asian Symposium on Risk Assessment and Management (PSAM17&ASRAM2024)	Renan Guedes Maidana and Yiliu Liu
	A Radar Dataset from the Trondheim City Canal	27th International Conference on Information Fusion - FUSION	Petter Hangerhagen, Edmund Brekke, Egil Eide and Roger Skjetne
	Coherent Integration of Optical Flow for Track-Before-Detect Radar Detection	27th International Conference on Information Fusion (FUSION)	Lukas Herrmann, Edmund Brekke and Egil Eide
	Maritime Tracking-By-Detection with Object Mask Depth Retrieval Through Stereo Vision and Lidar	7th International Conference on Information Fusion	Henrik Hilmarsen, Nicholas Dalhaug, Trym A. Nygård, Edmund Brekke, Rudolf Mester and Annette Stahl
	SFI AutoShip webinar: Navigator experiences of periodically unmanned bridge – an empirical study	SFI AutoShip webinar	Even Ambros Holte and Magnhild Kaarstad
	Reducing Controller Effort in a Deep Reinforcement Learning-based Autopilot for an Underactuated ASV	15th IFAC Conference on Control Applications in Marine Systems, Robotics and Vehicles	Joel Jose, Sanjeev K. R. Sudha and Erlend M. Coates

TYPE	NAME/DESCRIPTION	NAME OF JOURNAL/ CONFERENCE/BOOK	AUTHOR(S)
	Enhancing Situational Awareness for Remote Control of Ship Cranes	MTEC/ICMASS	Ulrik Jørgensen, Pauline Røstum Bellingmo, Magnus Christian Bjerkeng and Kenneth Johanson
	SFI AutoShip webinar: Risk assessment and supervisory risk control of autonomous marine systems	SFI AutoShip webinar	Susanna Dybwad Kristensen, Sondre Solvang and Lex Veerhuis
	Variational Autoencoders for Exteroceptive Perception in Reinforcement Learning-Based Collision Avoidance	ASME 2024 43rd International Conference on Ocean, Offshore and Arctic Engineering	Thomas N. Larsen, Eirik R. Barlaug and Adil Rasheed
	Nonlinear PID Control for Automatic Docking of a Large Container Ship in Confined Waters Under the Influence of Wind and Currents	Control Applications in Marine Systems, Robotics and Vehicles (15th CAMS 2024)	Simon Lexau, Anastasios M. Lekkas and Morten Breivik
	A General Low-Parameter 3D Ship Hull Extent Model for Object Tracking	27th International Conference on Information Fusion (FUSION)	Michael E. Lopez, Kjetil Vasstein, Edmund Brekke, Rudolf Mester and Annette Stahl
	A Lightweight, Polarization-Camera Equipped Sensor Rig for the Development of Autonomous Surface Vehicles	MTEC/ICMASS	Emil Martens, Edmund Brekke, Rudolf Mester and Annette Stahl
	SFI AutoShip webinar: Safe Optimal Control and Multi-Target Tracking Demonstrated with a Digital Twin	SFI AutoShip webinar	Daniel Menges
	Nonlinear Model Predictive Control for Enhanced Navigation of Autonomous Surface Vessels	8th IFAC Conference on Nonlinear Model Predictive Control (NMPC)	Daniel Menges and Adil Rasheed
	Digital Twin of Autonomous Surface Vessels for Safe Maritime Navigation Enabled through Predictive Modeling and Reinforcement Learning	43rd International Conference on Ocean, Offshore & Arctic Engineering	Daniel Menges, Andreas Von Brandis and Adil Rasheed
	Computationally and Memory-Efficient Robust Predictive Analytics Using Big Data	IEEE Conference on Artificial Intelligence -	Daniel Menges and Adil Rasheed
	Dynamic Scene Representation for Docking in Urban Waters Using a Stereo Camera	MTEC/ICMASS	Trym A. Nygård, Edmund Brekke, Rudolf Mester and Annette Stahl
	Collaborative Hazard Control: Designing a Digital Fire Control Center for Enhanced Safety on Ships	GRAPHICS INTERFACE 2024. Association for Computing Machinery (ACM)	Felix-Marcel Petermann
	Concept of a situation awareness enhancing tool for maritime environments	Hermann Hauser I.E.C.T. Summer School	Felix-Marcel Petermann
	Interaction Between Unmanned Systems and Humans: An Example of a Smart Passenger Access Gate for Autonomous Urban Passenger Ferries	2024 IEEE 48th Annual Computers, Software, and Applications Conference (COMPSAC)	Felix-Marcel Petermann

TYPE	NAME/DESCRIPTION	NAME OF JOURNAL/ CONFERENCE/BOOK	AUTHOR(S)
	Touchpoints and systems for unmanned autonomous urban ferry operation	MTEC/ICMASS	Felix-Marcel Petermann and Ole Andreas Alsos
	Evaluating Graphical User Interfaces for Improving Depth Perception with Remote Crane Operators	48th IEEE International Conference on Computers, Software, and Applications (COMPSAC)	Taufik Akbar Sitompul
	Handling Constant and Changing Latency with Graphical User Interfaces: A Study with Remote Crane Operators	The 2024 IEEE Conference on Telepresence	Taufik Akbar Sitompul
	Using Graphical User Interfaces to Address Challenges in Remote Crane Operation	SFI AutoShip Days 2024	Taufik Akbar Sitompul
	Analyzing Online Videos to Create a List of User Interface Elements: A Case for OpenCrane Design System	Design for Equality and Justice. INTERACT 2023. Lecture Notes in Computer Science	Taufik Sitompul, Jooyoung Park and Ole Andreas Alsos
	Safety Assurances in Autonomous Vessels	International Conference on Conceptual Modeling 2024	Sreekant Sreedharan, Muthuraja Ramachandran, Erik Røsæg and Børge Rokseth
	Systems-theoretic process analysis (STPA) tutorial	Tutorial for all partners in SFI AutoShip	Ingrid B. Utne, Børge Rokseth and Mary Ann Lundteigen
Doctoral theses	Collaborative collision avoidance methods for autonomous ship navigation	Doctoral thesis at NTNU	Melih Akdağ
	Decision Transparency during Autonomous Collision Avoidance: On Human-AI Compatibility and Autonomous Ships	Doctoral thesis at NTNU	Andreas Nygard Madsen
Other presenta-tions and events	Presentation of NTNU Nyhavna and Shore Control Lab	Visit of Haugesund municipality	Ole Andreas Alsos
	Presentation of NTNU Nyhavna and Shore Control Lab	Nyhavna utvikling	Ole Andreas Alsos
	Presentation of NTNU Nyhavna and Shore Control Lab	NTNUs Ecosystem for Commercialisation	Ole Andreas Alsos
	Presentation of NTNU Nyhavna and Shore Control Lab	Visit of SFI AutoShip partner Gard	Ole Andreas Alsos
	Presentation of Shore Control Lab.	Boreal	Ole Andreas Alsos

TYPE	NAME/DESCRIPTION	NAME OF JOURNAL/ CONFERENCE/BOOK	AUTHOR(S)
	Presentation of Shore Control Lab	Zeabus, Torghatten AB	Ole Andreas Alsos
	Presenting Work of NTNU Shore Control Lab	Skaperfest	Ole Andreas Alsos
	Presentation of the Shore Control Lab (SCL) and OpenCrane Design System	Visit of Tokyo University of Marine Science and Technology	Ole Andreas Alsos, Felix-Marcel Petermann, Taufik Sitompul and Jooyoung Park
	Presentation of the Shore Control Lab (SCL) and OpenCrane Design System	Visit of SIX Mobile Work Machines, Finland	Ole Andreas Alsos and Taufik Sitompul
	Presentation of SFI AutoShip	International Maritime Organisation (IMO), 109th session of the Maritime Safety Committee (MSC 109)	Anastasios M. Lekkas
	Presentation of SFI AutoShip	PERSEUS event, NTNU	Anastasios M. Lekkas
	Presentation of SFI AutoShip	32nd Mediterranean Conference on Control and Automation (IEEE MED 2024)	Anastasios M. Lekkas
	Presenting NTNU Shore Control Lab - Innovations in Teleoperations	Visit of Mayor of Bodø	Felix-Marcel Petermann and Ole Andreas Alsos
	Presenting Work of NTNU Shore Control Lab	Visit of Ministers of Trade and Industry and Research and Higher Education	Felix-Marcel Petermann and Ole Andreas Alsos
	Presenting Work of NTNU Shore Control Lab	Visit from Nato Innovation Fund	Felix-Marcel Petermann and Ole Andreas Alsos
	Touchpoints and systems for unmanned autonomous urban ferry operation	MTEC/ICMASS 2024	Felix-Marcel Petermann and Ole Andreas Alsos
	Presenting NTNU Shore Control Lab	Visit of Arctic Coast Guard Forum	Felix-Marcel Petermann and Ole Andreas Alsos
	Presenting Work of NTNU Shore Control Lab	CISaR in Trondheim	Felix-Marcel Petermann
	Presenting Work of NTNU Shore Control Lab	Visit of Singapore Delegation	Felix-Marcel Petermann and Ole Andreas Alsos
	Presentation of NTNU Shore Control Lab (SCL)	Ocean Engineering Summer School 2024	Taufik Akbar Sitompul

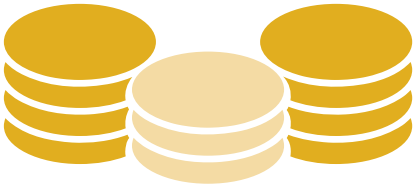
Master Students 2024

MASTER THESES WITH SFI AUTOSHIP TOPICS COMPLETED IN 2024

NAME	SEX	THESIS TITLE	SUPERVISORS
Aduragbemi Samuel Adetunji	M	State Estimation and Improved User Experience Through Automatic Control for an Underwater Drone.	Roger Skjetne
Jørgen Dyrskog	M	Implementation and Validation of a Deep Reinforcement Learning Algorithm for Maritime Collision Avoidance and Anti-Grounding	Tor Arne Johansen, Trym Tengesdal
Steffen Folåsen	M	Extended object tracking using a Gaussian Process extent model and scene flow-lidar fusion.	Edmund Brekke
Jon Torgeir Grini	M	Bayesian Adaptive Segmentation of Water Surfaces with Reflection Correction.	Annette Stahl, Edmund Brekke, Rudolf Mester, Trym A. Nygård, Nicholas Dahlhaug
Vilde Halleland	F	Implementation and Validation of an MPC-based Mid-Level Collision Avoidance Planning Algorithm	Tor Arne Johansen, Trym Tengesdal
Magnus Falck Halvorsen	M	Combining active path generation and following with VR in Unity to improve remote control of unmanned surface vessels.	Roger Skjetne, Emir Cem Gezer
Petter Hangerhagen	M	A Benchmark Radar-Based Dataset from the Canal in Trondheim.	Roger Skjetne, Edmund Brekke
Henrik Hilmarsen	M	Maritime Tracking-by-Detection Using Camera and Lidar	Annette Stahl, Edmund Brekke, Rudolf Mester, Nicholas Dalhaug, Trym A. Nygård
Erling Hjermstad	M	Target Tracking from a Moving Platform	Edmund Brekke
Amalie Rikardsen Jaatun	F	Deep Reinforcement Learning for Anti-grounding and Trajectory Tracking in the Presence of Environmental Disturbances	Tor Arne Johansen, Trym Tengesdal
Andreas Kristensen	M	Path planning for ships operating within wind farms	Tor Arne Johansen, Trym Tengesdal
Kristian Hope	M	Development of a Simultaneous Localization and Mapping System for the Otter Uncrewed Surface Vessel.	Edmund Brekke, MR co-supervisor
Marie Bringsvor	F	Temporal AI planning, Guidance and Control of Autonomous Vessels	Anastasios M. Lekkas
Håvard Olai Kopperstad	M	Planning and Motion Control of Autonomous Docking Maneuvers for a RORO Vessel in Confined Waters under the Influence of Wind and Current	Anastasios M. Lekkas
Alexander Brevad Rambech	M	Docking of an Underactuated ASV using Reinforcement Learning-based NMPC	Anastasios M. Lekkas, MR co-supervisor
Ådne Meland	M	Design Research and Concept of Silent Alarms	Erik A. Veitch, Felix-Marcel Petermann
Linn Jeanette Myhren	F	Dynamic Positioning system for ships operating within offshore wind farms	Tor Arne Johansen, Trym Tengesdal

NAME	SEX	THESIS TITLE	SUPERVISORS
Jørgen Myklebust	M	Simulation-Based Verification of an Intention-Aware Probabilistic Scenario-Based MPC with Realistic Target Tracking	Tor Arne Johansen, Trym Tengesdal
Peder Myklebust	M	Investigating the Impact of Applying Design Principles and Guidelines on Usability when Redesigning a Graphical User Interface Derived from a Design System	Yngve Dahl and Taufik Akbar Sitompul
Torvid Opsahl	M	How the Adherence of Design Principles Influences the Usability of User Interfaces Built from a Design System?	Yngve Dahl and Taufik Akbar Sitompul
Andreas von Brandis	M	Multi-Target Tracking for Autonomous Surface Vessels: Fusing LiDAR and AIS Data in a Digital Twin Framework	Adil Rasheed
Xiangming Shen	M	Deep Reinforcement Learning for Interpretable Autonomous Navigation of Surface Vessels	Erlend M. Coates, Joel Jose
Emma Siberg Nakken	F	Control of Autonomous Ships - Designing a System and Modular Operator Station for the Monitoring and Control of Autonomous Ships	Ole Andreas Alsos, Felix-Marcel Petermann, Einar Johan Hareide
Thomas Nils Tellier	M	Automatic Sun Compass	Edmund Brekke
Edvard Indrebø Vedeler	M	Uncertainty-aware DRL-based Ship Collision Avoidance and Trajectory Tracking	Tor Arne Johansen, Trym Tengesdal
Mathias Vehus	M	Design System in Practice: Exploring Implications of Using a Design System to Implement User Interface Components for Remotely Operated Cranes	Taufik Akbar Sitompul

Annual Accounts for 2024



All figures in 1000 NOK.

FUNDING	AMOUNT
The Research Council	15 854
The Host Institution (NTNU)	11 790
Research Partners*	1 119
Enterprise partners**	13 655
Public partners***	7 252
Total	**49 670**

COSTS	AMOUNT
The Host Institution (NTNU)	25 553
Research Partners*	7 223
Enterprise partners**	9 642
Public partners***	7 252
Total	**49 670**

*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
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
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
Espen Tangstad	SINTEF Ocean	Autonomous control system
Even Ambros Holte	SINTEF Ocean	Maritime logistics and autonomous shipping
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
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	Supervisory risk analysis and control in operation
Taufik Akbar Sitompul	Indonesia	01.02.2022-01.02.2024	M	Remote Control for Crane/ Design of human-machine interface
Trym Tengesdal	Norway	13.09.2022-12.09.2024	M	Risk-based COLAV/anti-grounding

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
Audun Hem	Autosit/MAROFF 2/ NFR	Norway	01.10.2020-05.06.2024	M	PhD in the Autosit project: Autonomous ships, intentions and situational awareness
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
Lars-Christian Tokle	NTNU	Norway	01.01.2019-01.03.2024	M	Sensor Fusion and Situational Awareness for autonomous urban ferries in the Autoferry project. Research topics include sensor fusion for SLAM and target tracking.

PHD STUDENTS WITH FINANCIAL SUPPORT FROM THE CENTRE BUDGET

NAME	NATIONALITY	PERIOD	SEX M/F	TOPIC
Andreas Nygard Madsen	Norway	01.09.2021-31.07.2024	M	AI decision transparency in autonomous maritime operations
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	01.08.2021-31.07.2025	M	Investigating New Solutions for Situational Awareness 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	01.10.2021-30.09.2024	M	Radar-based SLAM for autonomous ships
Joel Jose	India	01.01.2024-01.10.2027	M	Enabling supervisory control of autonomous vessels through transparency and explainability
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	Decision Support Systems for Autonomous Vessels
Lukas Herrmann	Germany	01.06.2022-31.05.2025	M	Shore-based Radar Network for Autonomous Shipping
Manju James	India	29.02.2024-28.02.2027	F	Digital twin for maritime communication system performance prediction
Melih Akdağ	Turkey	20.05.2021-19.05.2024	M	Collaborative collision avoidance for autonomous ships
Peter Morris	Canada	16.10.2023-16.10.2027	M	Data Fusion in Maritime IoT
Raffael Wallner	Austria	29.11.2021-14.02.2025	M	Safety Demonstration of Autonomous Control Systems using Digital Twin
Simon Lexau	Norway	23.08.2022-22.08.2025	M	Autonomous docking of marine surface vessels
Spencer Dugan	USA	01.09.2021-30.04.2025	M	Reliable design and operation of propulsion systems for autonomous ships
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

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