Annual Report 2022

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SFI MOVE

Marine Operations in Virtual Environments

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sfi Centre for Research-based Innovation

MOVE SFI Marine Operations

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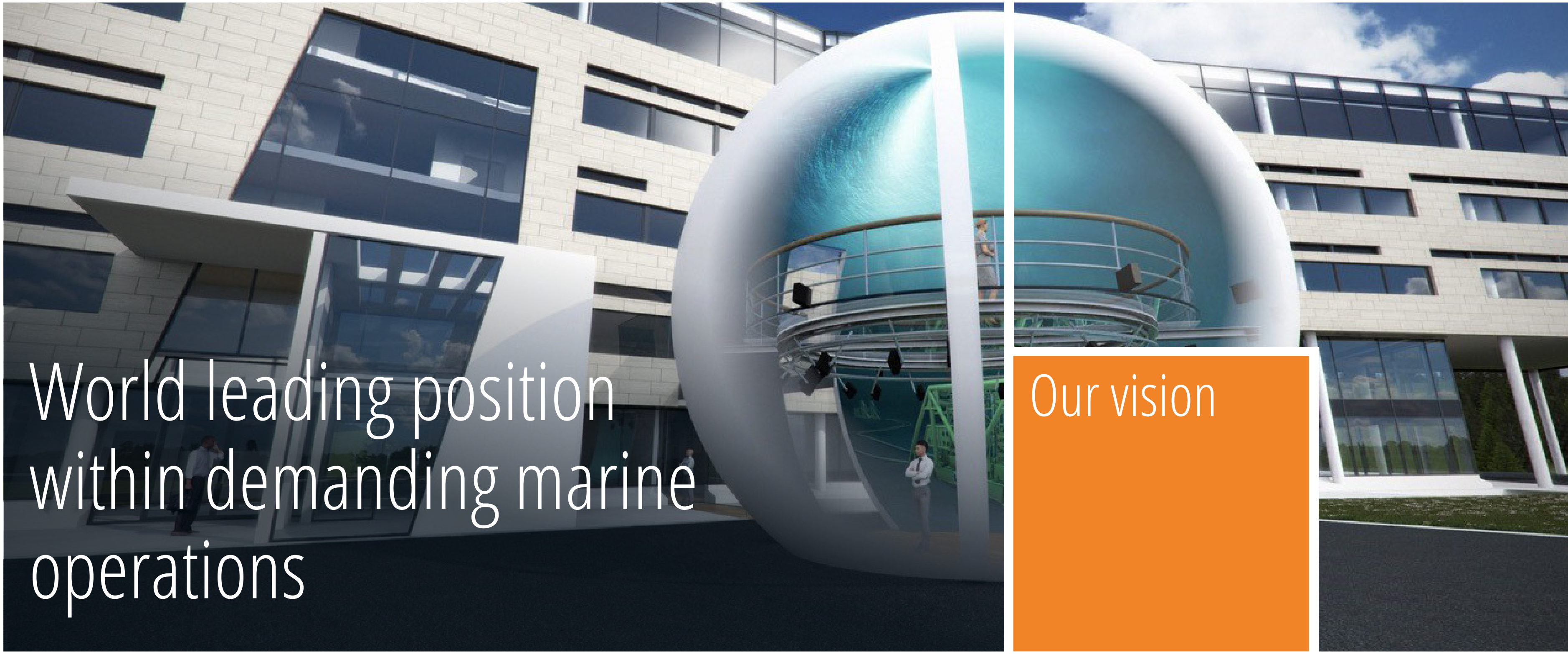


World leading position within demanding marine operations

Our vision

Our vision

To establish a world-leading research and innovation centre for demanding marine operations.

Simulation has been used for decades to plan and verify marine operations and to train crew to perm the operations.

Next-generation technology has the potential to provide virtual prototyping to pre-test marine operations including human components. On-board and remote supports simulation systems are considering the real met-ocean situation and the ship's real behaviour will reduce the waiting on weather and thereby reduce costs. Remote support has the potential to move experts from the ship to the land based organisation.

Cutting edge interdisciplinary research will provide a bridge between industrial needs, innovation and research.

Research
Our goal is to take a world leading position within demanding marine operations.

Innovation
Our goal is to put the industrial partners in front of defining needs and potential for innovation and business.

Education
The research shall lead to theory and new methods for education as well as training of professionals.

Arena
The goal is to establish an arena for research and industrial cooperation within demanding marine operations.

Objectives

The SFI centre shall support the entire marine operations value chain by developing knowledge, methods and computer tools for safe and efficient analysis of both the equipment and the operation. The developed methods shall be implemented in simulator environments to pre-test marine operations including the human component.

The SFI centre shall support the innovation process of the marine operation value chain through active involvement by industry, thus improving the competitiveness for Norwegian marine industry.

The centre shall:

- Achieve all-year subsea operations installation and service
- Perform safer and more cost-efficient operations
- Support innovation in existing and emerging ocean industries

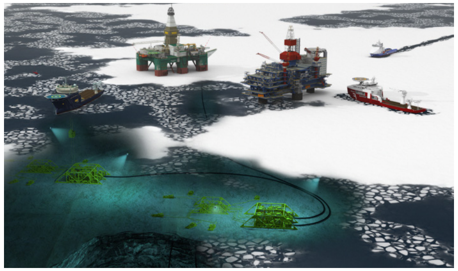
The idea is to optimize operations, from planning to execution, by a better understanding of the responses. This is a simulation-oriented approach where models are re-used throughout the value chain. To fulfil this goal the following is of vital importance:

- Improved understanding of complex physical phenomena
- Modelling and Virtual Prototyping (simulation)
- Simulation as an industrial standard
- Onboard decision support systems
- Online environment monitoring
- Improved crew performance (training & assessment)

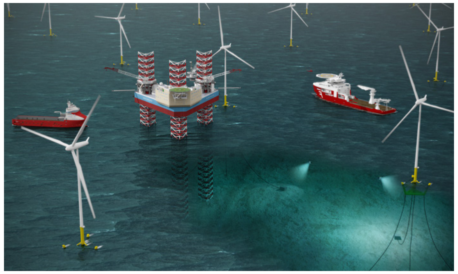
Business areas

The business areas focused on in 2022 are:

- Demanding marine offshore operations at deep water, all-year availability, or arctic areas



- Installation and maintenance of offshore wind



- Management of marine operations and shipping

Director's report

Professor Hans Petter Hildre is the leader for SFI MOVE

Figure 1.

The overall objective for SFI MOVE is to facilitate marine operations in a commercial and cost-efficient manner, thereby contributing to positioning the Norwegian maritime industry towards the market of such operations worldwide. As operations are getting more extensive, there is a need for more all-year marine operations. The need for all-year operations will significantly impact technology, operational procedures, and costs, and will require very different solutions depending on the environment in which you are operative.

Marine operations are designed, simulated, and planned for a long time before the operation is carried out. Which vessel, load condition, wind, waves, lifted objects' behaviour in air and sea, etc., are assumed. The simulation results show that the operation can be carried out if a given sea state is not exceeded. Therefore, simulations are based on a series of assumptions and uncertainties. Significant safety margins are needed to compensate for these uncertainties. How can we reduce this uncertainty and then reduce Waiting on Weather (WoW)?

In SFI MOVE we have been working on reducing Waiting on Weather by bringing the analyses close to the operations and defining operations by measured and predicted responses. Using a digital twin technology facilitates go criteria for the operations in terms of vessel or crane response rather than met-ocean parameters, which leads to more precise operational criteria.

In this year's report, I will emphasize three fundamental areas in SFI MOVE:

- Improved simulation methods and tools
- Improved handover from engineering to operations
- Real-time onboard and remote decision support
- Remote Operation Centres and dispersed teams

Improved simulation methods and tools

In many cases, the limiting sea state depends on the hydrodynamic coefficients used in the analyses. More accurate methods to estimate the coefficients and the use of time domain simulations are useful to reduce waiting for acceptable weather conditions for the operation.

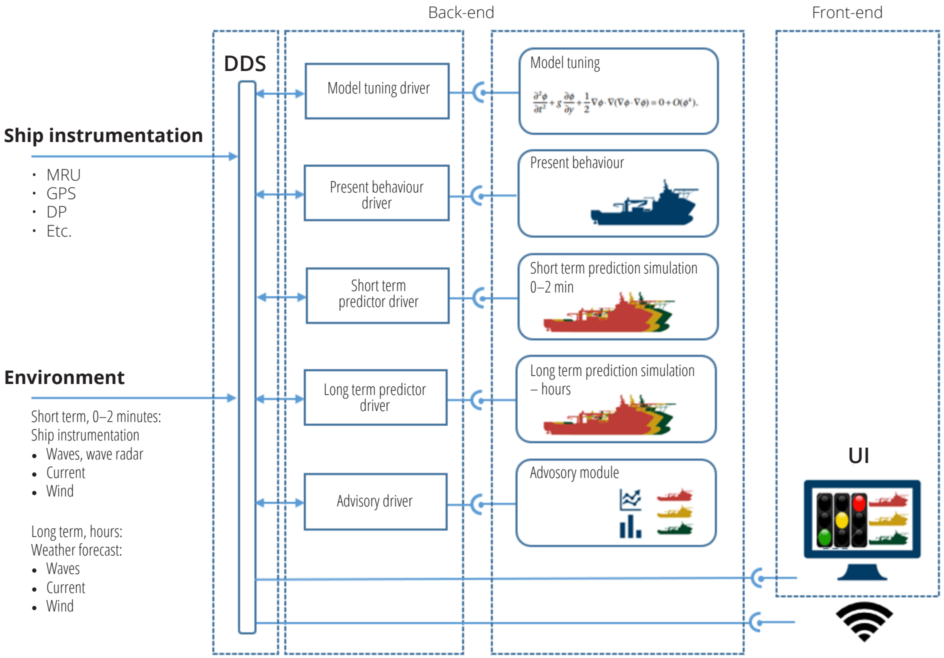
A comprehensive laboratory testing programme for hydrodynamic coefficients has been completed. Test results are combined with simulations and findings in the literature. To assist the project engineers in the estimation of the hydrodynamic coefficients, data from earlier model tests of structures, complete modules and structures close to the surface or seabed are collected. Coefficients are structured in a library made available to the MOVE partners.

It is seen from model test data that coefficients generally are dependent on the amplitude of motion and will change with proximity to the surface and bottom. In many cases, the amplitude and period dependency is more evident when the structure is close to the surface.

A new model for splash zone hydrodynamics has been established. Experimental and numerical investigations on subsea modules made of simple geometries showed that the estimation of hydrodynamic coefficients during water entry needs model test data for both individual elements in a subsea module and the full module to make an accurate numerical model.

Since this information is not easily available to an engineer for every new complex subsea module, more investigation on various types of simple geometries individually and in the proximity of other elements near the free surface is performed using commercial numerical tools, two-dimensional available model tests and new three-dimensional model tests.

Both experiences from offshore operations and from initial simulations show that the shielding effect from the ship hull is significant when a structure is deployed on the leeward side. The shielding effect increases towards short waves. If the shielding effect is included in the simulation of splash zone crossing in a consistent way, it is possible to document lower forces, higher limiting sea state, and thus increased regularity than with a simulation based on the kinematics of incoming waves. New models that consider shielding have been developed and implemented in SIMO.



Co-simulation in the field of maritime operations simulations is explored. Co-simulation is modular by nature and highly flexible, whereby a full system simulation is built from several stand-alone sub-simulators. Models can be developed efficiently in parallel, and they can easily be reused. It also leverages specialized toolchains and domain-specific knowledge already in use by participants and partners. Tools and domain knowledge within hydrodynamics can be combined with tools and methods within hydraulics, control systems and so on. Sub-simulators can run in parallel, with the potential to speed up full system simulation unless coordination between the sub-systems is too demanding.

Improved handover from engineering to operations

Marine operations are designed, simulated, and planned for a long time before the operation is carried out. Trained engineers are using specialized simulation software. Analyses are performed in steps such as process engineering studies (PRE-FEED / FEED), detailed design, Hazard and Operability Studies (HAZOP) to identify abnormalities in the work environment and pinpoint their root causes and finally Hazard Identification (HAZID) analyses to alert management of any threats and hazards on the job site.

Figure 2.

Implementation of onboard and remote support opens new opportunities. All simulations performed in advance are then available to the team performing the operations. The simulations may be updated by considering the real weather condition, the ship's loading conditions, and so on. The simulations in the engineering phase may be transferred to the remote operations centre and new simulations may be executed based on real-time sensor input from the ship. The present simulation software is not designed to communicate and advise the operative staff during an operation. We have sketched some prototypes of such communication which will hopefully be further developed in subsequent projects.

Real-time onboard and remote decision support

We are now seeing a furious pace of development of digital twins in several business fields, and it is exciting to introduce this technology within maritime operations. In general, we can say that digital twins give us the following possibilities:

- Building experience: Real data from previous operations can be used to improve understanding and reduce uncertainty. This is useful for correlating variables or running machine learning algorithms.
- Follow present situations: It is regularly updated with sensor data, often through IIoT connectivity to detect anomalies and improve model accuracy.
- Predict future responses: It synthesizes and contextualizes historical and real-time data to give insights into potential future states.

A digital twin framework for marine operations has been developed. Operational data from ship sensors combined with physics-based models are used to monitor and predict responses of the vessels and equipment used in the operation. Simulations will be performed in almost real-time and give advice to the crew performing a marine operation on how to operate safely and efficiently. The idea is to bring the analyses close to the operations and decisions based on actual responses. The simulations can be performed onboard the ship or in remote operation centres. The sensor data from the ship then needs to be transferred to the remote operation centre. The technology developed will make an important contribution to response-based operations.

Present simulation software must be re-designed to include real-time information from sensors. A key feature will be to transfer the models in engineering to the onboard system.

Co-simulation is added to the digital twin framework. Such an approach enables the re-use of simulation models and models across organizations without exposing sensitive IP by protecting models and control system software inside black-box executables. Models from a variety of specialized software tools can be combined in one single system simulation. For example, in a ship model, a thruster model, a DP model, a crane model, and a hydraulic power model, the control system can be put together in one system simulation. This framework is compatible with the Open Simulation Platform initiative.

To make good decisions, the vessel response model must have adequate quality. Being made from state-of-the-art theory and high-quality empirical data, the model may still need tuning for needed performance. Theoretical models are not accurate and the vessel's loading conditions are not well-known months before the operation takes place.

Model tuning involves modification of the theoretical hydrodynamic vessel models used in the engineering phase using real-time measurements of vessel motion responses and wave disturbances. Wave radar is used to identify wave disturbance. Model tuning methods and software are tested with data from model tests and simulations. Both direct methods modifying the theoretical vessel model parameters and machine learning algorithms are investigated.

The aim of this activity is to improve today's methods for the prediction of vessel response for the execution of marine operations. Prediction can broadly be divided into two categories: short-term prediction and long-term prediction. Short-term prediction means predicting the vessel's response a few minutes ahead. This is useful when a critical action of short duration is to be carried out. Long-term prediction (hours and days) is relevant for long-lasting operations where the motion of the vessel must be kept within given limits. In both cases, good response prediction depends on good prediction of waves and other met-ocean disturbances and good response models.

In this activity, we will address numerical response models, which are common and needed for both types of prediction. Deterministic methods are used for the short-term responses. The idea behind long-term predictions is to incorporate the latest weather forecast in the prediction of responses.

Remote Operation Centres (ROC) and dispersed teams

Marine operations are getting more technology based. New technological solutions such as digital twins, cloud computing and machine learning enable faster change and create more complex and dynamic work environments, which is followed by organizational changes, and implementations of new and more flexible structures and ways of working.

The driver for such development is reduced costs by having remote support replacing human support onboard. But also increased quality by access to a broader variety of competence and reduced risk by capacities to perform advanced analytics and trade-off scenarios.

A remote operations framework can be established by adding a copy of the onboard digital twin to a remote centre. The sensors' signals will be transferred to the remote centre and all responses will be calculated by the digital twin. Having a twin and simulation capacity at the remote centre gives several advantages.

- Low demand for transmission bandwidth.
- Alternative scenarios can be executed while the ship is waiting.
- The users in the operation centre can choose their view of interest.

A research lab for remote operations (NTNU marine operation centre, MOC) has been built at NTNU in Ålesund, see figure 1.

Case: Subsea lifting operations

Subsea lifting operations are used as cases to explore, test, and verify the research. The driver is reduced waiting on weather (WoW) and transitioning to response-based operations.

Normand Vision's installation of the Johan Sverdrup Integrated Template has been used for developing a guide for modelling and simulation of offshore lifting operations within the new framework. The case will include rigging, lifting in the air, through the splash zone and in the water column. This case was also used to explore and verify new methods for shielding effects.

Installation of suction anchors with Olympic Challenger is used to verify new methods for splash zone dynamics. Normand Vision and Gunnerus are used to verify model-tuning methods.

Case: Offshore Wind Technology (OWT)

With fewer restrictions on size and height than their onshore counterparts, offshore wind turbines are becoming giants. Siemens Gamesa's massive 14 MW turbines produced its first electricity in 2021. The Siemens turbine has a rotor diameter of 222 metres and is 260 metres high to the rotor centre. Even bigger units are in development. Westas has announced the launch of its new offshore wind turbine at 15 MW and The China State Shipbuilding Corporation (CSSC) is upping the ante on offshore wind, announcing that it is building the largest and most powerful wind turbine ever, making a peak 18 megawatts with an enormous 260-metre diameter on its three-bladed rotor sweeping an area of 10 football fields.

Installations are moving further from shore, tapping better quality wind resources, and pushing up capacity factors. Next-generation giant turbines demand new methods for installation, service, and repair. Installation of giant offshore structures is presently done by huge crane vessels with the lifting capacities and heights needed. Such assembly is done in sheltered areas and then towed to the wind farm for mooring. This is a complex and costly operation. Assembly and installation are limiting the development and it is probably not realistic to use ships with cranes lifting thousands of tonnes higher than 300 metres.

Remote operation centre, NTNU/NMK.

SFI MOVE has been working with an innovative solution for lifting the tower including the nacelle and blades by wires at a lower point – see the comparison in figure 2.

This case has also been used to test co-simulation technologies. Hydrodynamic models of the ship and spar have been combined with hydraulic and control systems.

Case: Dispersed teams and use of Remote Operation Centres

The NTNU research vessel Gunnerus is instrumented, and signals are transferred to the marine operation centre (MOC) at NTNNU. A digital twin of the Gunnerus vessel was made in 2020 and included real-time data, for example ECDIS for vessel position, heading and speed, MRU data as pitch, roll and heave, crane data as joint angles, engine data, etc.

Proof of concept tests have been performed, and studies of dispersed ship crew were performed in 2021 and 2022.

The aim of this case study is to investigate new ways of doing maritime operations, how the use of digital twin technology can enable collaboration between shore and vessel, and how dispersed teams can optimize workflow and organization change.

Marine operation centres have gained popularity in the last few years and have been an important enabler in introducing increased automation and autonomy.

Norway – a maritime superpower

Text/photo: Børge Sandnes

Eight years of collaboration and research are coming to an end, and now the Centre Director of SFI MOVE, Hans Petter Hildre at NTNU in Ålesund, aims to launch the results into real-life settings.

Main profiles:

Hans Petter Hildre
Centre Director SFI MOVE

Professor,
Head of Department of Ocean Operations and Civil Engineering, NTNU in Ålesund

Complex marine operations, and a Centre for Research-based Innovation (SFI) – Marine Operations in Virtual Environments. An eight-year project where the Department of Ocean Operations and Civil Engineering at NTNU in Ålesund has researched and developed tools to simulate, calculate and streamline maritime operations – this is the backdrop for our visit to the office of Centre Director Hans Petter Hildre in Ålesund.

– "Today, demanding marine operations are mostly calculated and simulated a long time in advance, where simulations, calculations and assumptions are developed to carry out operations involving, for example, a given wave height . I believe that in the future you will be able to perform calculations and analyses during or immediately before the operation while you are out in the field," says Hildre.

Here in Sunnmøre, there are few people in the maritime community who have not heard of this energetic academic, who is happiest on the fjords with fishing gear at hand. We have invited ourselves over to hear more about what the SFI MOVE project is all about, and what eight years of teamwork have resulted in.

SFI MOVE involves 20 companies along the Norwegian coast, from Møre og Romsdal all the way to Stavanger, including Equinor, Subsea 7, Olympic, Ulstein, Kongsberg, Vard and Havila, to name a few of those involved.

Building blocks

– "These are marine operations – for example, how to install the offshore wind turbines of the future, how to moor them, how to install them, how to service them in the most cost-effective way possible. We build digital twins of operations. These include ships, waves, currents, cranes, loads to be lifted or modules on the seabed," explains Hildre.

– "When you then add sensor signals from various systems on the vessel, wave radar, currents, wind, and how the vessel is moving, you can predict what is going to happen in the operation. We are not quite there yet, but we have put very many building blocks in place towards that reality," he adds.

He believes that this will bring us many benefits. Traditionally, the models are developed perhaps one year in advance, and often they are not entirely correct when they are calculated at such an early stage.

– "For example, you do not necessarily know how the vessel is loaded or where the centre of gravity is – factors that will influence the way it will move in the sea. The ability to run the simulations in real time during the operation will greatly improve accuracy and the potential for predicting what will happen."

Cost-effective

Since the launch of the centre nearly eight years ago, many building blocks have been developed, and the project has worked with a variety of operations. Lifting operations, subsea operations, seabed mining, offshore wind.

– "Many of the building blocks for achieving this have now been developed. We have also looked at remote control operations. Large and complicated operations will require many crew members on board who each have a small role during a month's work. They might as well work ashore and support those who are on board. So when we talk about calculation in real time, this can take place both onboard and on land. We have also looked at ways of creating new teams where some members are on shore and some on board, all functioning as one team. So, I believe that a higher level of remote-controlled support is absolutely vital for achieving this. This means that you reduce costs, you can have fewer people on board, you can connect with experts when you need them – so they don't need to be on board all the time. This will have a significantly reduced cost element," explains Hildre.

Another advantage of being able to do the calculations while you are there in real time is that you can expand the weather window and achieve more accurate calculations, knowing what the situation is right now, which will increase the potential for year-round operations, he notes.

61 cod so far

Hans Petter Hildre was born in Tennfjord and has a background in product development, machine design and simulation. After 17 years as both a student and an employee at NTNU in Trondheim, he moved back home to Tennfjord and Sunnmøre in 2004. We have a suspicion that the main reason was the benefits of Sunnmøre's natural setting for both self-development and peace of mind. When Hildre is not at NTNU, chances are good that you'll find him in a boat on the fjord.

– "By nature, I'm a maritime person to the core. Fishing is my greatest passion and interest, and I have landed 61 cod so far this year. I live and breathe for boats and the sea, not only for the trip, but for harvesting from the sea. I practise that as often as I can."

Now it's cod season, and you can be sure that the last cod has not yet been caught. And after that, his boat will not be lying still for very long . Soon it will be haddock season and new trips on the fjord have already been planned.

– "I have different seasons with different catches all year round. Mostly in Tennfjord, but I also set out for the Nordøyene island cluster. So if the weekend brings good weather, I'll sail there. I keep trying my hand at halibut, but it's a bit tricky to land it."

A global centre

According to Hildre, the fjords around Ålesund are perfect both for his leisure activities and, not least, for the projects he runs at NTNU.

– "Here in Ålesund. you have some resources that are a pure gift from nature. It is only a few metres from the rocks on the shore to the open sea, from zero to 700 metres straight into the fjord, we have the world's oceans in miniature where you can test open waters with hurricanes and storms. You can go into sheltered areas where you can test deepwater components. And then we have a marvellous area with traffic, where you have fishing boats and other vessels that are suitable for testing traffic systems and autonomous sailing. When you have dense traffic with traditional boats that encounter autonomous vessels, that's when you get challenges. When you look at marine resources, we have the largest breeding ground for herring and

haddock right here on our doorstep. On top of that, you have all the shipyards located in our area, where naval architects can test their design. In essence, this is a global centre for full-scale maritime testing."

The bridge builder
Many know Hans Petter Hildre as a builder of bridges linking academia with business and industry. His guiding philosophy is how to make the most of the strengths and advantages that Campus Ålesund has.

– "I have been reflecting and looking long and hard at ways to leverage our strengths in Ålesund, and these strengths must be different from those we find in Trondheim, which has huge research communities – both broad-based and highly specialized . Campus Ålesund is a small campus with a very large business and industrial community around us. That's why 'close partnership', close to industry, close to the working world, is a mantra we have cultivated from day one, and here we can be unique. All our bachelor's and master's theses are linked with companies, and we are also working towards making all our research projects close to industry and in teamwork with the industrial cluster that we have here in the northern regions of Western Norway," he says.

According to Hildre, Norway has drawn all the golden tickets it is possible to draw in the lottery of the world.

– "We have a long coastline where we have found an abundance of fish, oil and gas and ideal conditions for aquaculture. We are a fortunate nation in terms of natural resources and their management," he says with delight.

The value of being "close together" has also been noticed outside the campus. This was recognized a few years ago when he was awarded the Medal of Honour from the Chamber of Commerce. This was first awarded in 1949, and Hans Petter Hildre was number 36 in the series of those who have received this accolade.

– "Hildre has a long track record as an author of both publications and books. He distinguishes himself in many forums, with his knowledge, his good rhetoric, and in his work – especially within activities in the oceans," was the reason given by the Chamber of Commerce.

Close to industry
For Hildre, being close to industry is more a matter of culture.

– "To be close to industry is very important, but it is very much a question of culture. At a university it is very easy to close the door, turn off the light, and sit behind the screen, scribbling and digging up all manner of weird things. But here in Ålesund and outside the core and outside the 'big university', I think that close partnership with industry is what can build and strengthen us to become good, and to gain recognition and power. This is a culture that must gradually be developed," he emphasizes.

The mindset of keeping in close contact with industry proved its value during the SFI collaboration, when the partners could draw on each other's strengths despite the challenges along the way.

– "The big offshore crisis struck halfway through the period, when several players went bankrupt and others merged. It was an extremely demanding time, with most of the players clinging to the mast and fighting for survival. What I am really proud of is that the companies have stayed involved through it all despite difficult times and weathered the storm together.

Together, they also made a major change to the project portfolio midway, to make it more direct and concrete about where the focus should be.

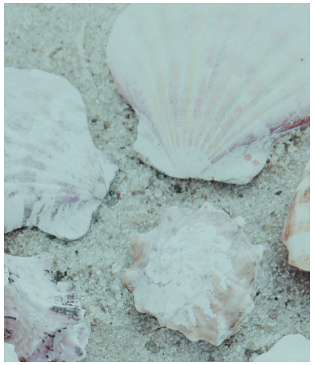
– "We shifted our direction towards more immediate benefits than what we originally had in mind. For example, at the very beginning we were working with subsea mining, but as none of the actors involved had this in their portfolio, we chose to remove this. When the crisis struck, along with all that it brought, we set aside this operation and focused on the activities that the companies were already involved in. Don't get me wrong, mining may well become an area in 20 years' time, but we were concentrating on a shorter horizon and so we shifted our focus to what was relevant."

Now the project is ending. But for Hans Petter Hildre, this is when the job starts in earnest.

– "Now I've said that for the moment I do not want another SFI, but smaller projects to put into practice what has now been developed. Now, I'm simply looking forward to applying these building blocks that we have created, rather than starting to make new building blocks," he concludes.

Then the rest of us will have to live with the prospects of less cod and haddock in the Borgundfjord, when he can spend more time in his boat.

Research projects



Completed projects:

Project 1:
OW: Low Cost Installation and Maintenance of Fixed Offshore Wind Structures
– was completed in 2016

Project 2:
Subsea: Safe – All Year – Cost-efficient Subsea Operation
– was completed in 2017

Project 3:
Simulation Technology and Virtual Prototyping as a Common Approach from Design to Operation
– was completed in 2017

Project 4:
Seabed Mining: Exploration of Technologies to Develop Seabed Mining as a New Business Area
– was completed in 2018

Project 7:
Design for Workability
– was completed in 2020

Ongoing projects in 2022:

Project 5: OW: Innovative Installation of Offshore Wind Power Systems
Project 6: On-board Decision Tool
Project 8: Remote Operations /Dispersed Teams

Figure 1. Stern installation of OWT from a catamaran vessel

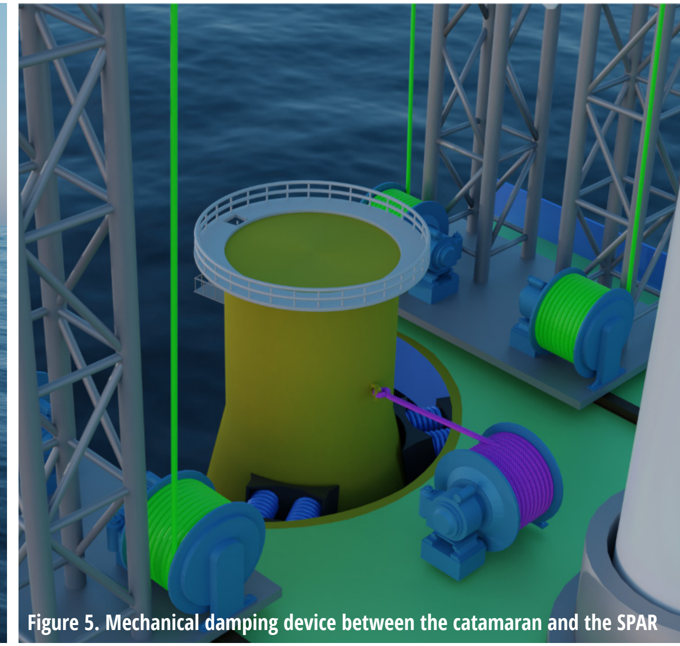


Figure 5. Mechanical damping device between the catamaran and the SPAR

Project 5

Project Leader:
Karl H. Halse, NTNU Ålesund

Figure 2. Alternative installation from midship

Innovative Installation of Offshore Wind Power Systems

The installation costs of a typical offshore wind power plant are a substantial part of the overall costs for the project (up to approx. 30 % of the total development costs). The Dogger Bank Wind Park Project is planning for several hundred offshore wind turbines to be installed in rather shallow water. Also, two areas in the Norwegian sector have recently been identified and opened for production of wind power. For Sørlige Nordsjø II (40–70 m) the conditions favour bottom-fixed installations, whereas for Utsira Nord (220-280 m), production of wind power must be carried out on floating installations. With this, the industrialization of wind energy production enters the Norwegian sector as well. During the summer of 2017, Statoil installed the world's first floating wind power park, known as Hywind Scotland. The installation was performed by assembling the parts in a sheltered Norwegian fjord, and the complete floating OWT was towed across the North Sea to its final destination outside Scotland. This is a time-consuming and costly operation, giving motivation to find a more cost-efficient way of installing floating offshore wind parks. In the SFI MOVE project we have proposed an alternative installation method using a floating installation vessel and a low height lifting system (see Figure 1). Figure 2 shows how the proposed concept appears compared with a traditional heavy-lifting vessel (SAIPEM 7000). The project has also developed a simulation workbench for wind turbine installation systems using an FMI-based co-simulation approach (see Figures 3 and 4).

Simulation workbench for wind turbine installation systems

- Response predictions of marine operations require hydrodynamic models, structural models, hydraulic winch models, control system models, and so on.
- Co-simulation techniques allow for a combination of various specialized domain tools to act together in concert.
- To succeed with the co-simulation approach, we need to
    1. ensure proper connectivity between the FMUs (avoid tight coupling problems),
    2. ensure both dynamical and numerical stability of the system,

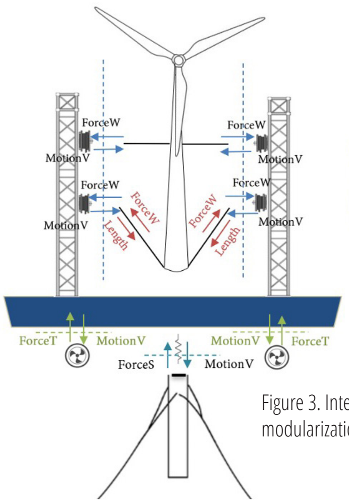


Figure 3. Interfaces in modularization.

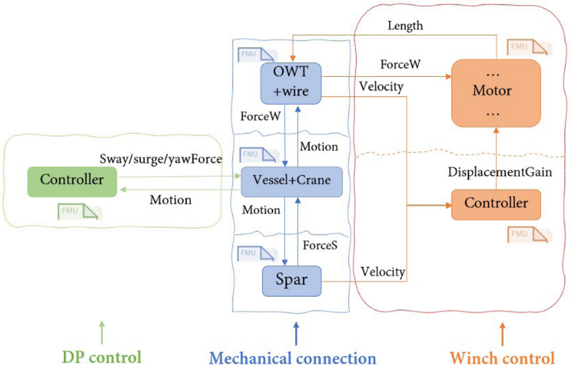


Figure 4. FMUs based on proposed modularization.

    3. reach a satisfactory accuracy by using proper communication time step
    4. and to be useful in an onboard decision support system, we need to ensure close to real time behaviour.

- We have tested the co-simulation approach on a simplified system to get control with the approach and improve the various challenges mentioned above. Based on this we improved the computational performance significantly by using the software AGX to make the FMUs instead of the initial OrcaFlex attempt.
- We have developed a preliminary modularization solution for the FMI-based co-simulation of the whole system (Figure 3). Separate FMUs are established for the OWT, vessel, and SPAR based on the AGX software. Secondary controlled winches are packaged as FMUs in 20-sim for the lifting and stabilization. In addition, controllers involving simplified control algorithms are made as FMUs for winch control and DP control, respectively.
- The Vico platform developed by NTNU Ålesund is used to test the co-simulation performance. All the FMUs (Figure 4) are parameterized and connected with each other based on the system structure and parameterization (SSP) standard. The results have been compared with the relevant monolithic simulation.
- The approach has also been tested on both stern and port side installation cases, So far, the results are promising.

Case studies to support the FMI-based co-simulation approach

The main challenge with the proposed concept is to reduce the relative motion between the lifted OWT tower and the floating substructure (the SPAR buoy), see Figure 1. During 2022, several case studies have been completed to support the performance of the simulation workbench.

1. We have introduced a mechanical damping device (consisting of fenders and pretensioned wires) between the floating SPAR buoy and the vessel, to reduce the relative motion. We have varied the spring stiffness of the fender and the pretension in the wires to study the effect on the system response (Figure 5).
2. A finite element model of the jacket-like crane structure was simulated in a dynamic analysis and

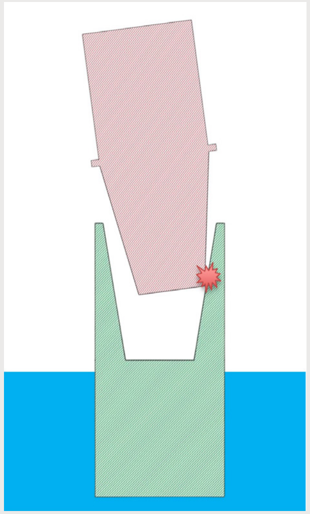


Figure 6. Impact analysis for Quick Connection Device.

   the response of the crane top was compared to the response from simulations where the crane was assumed to be a part of the rigid vessel body.
3. A comparative study with an alternative installation vessel (a SWATH) has been completed. The conclusion is that the response of the SWATH is less than that of the catamaran and consequently that the relative motion between the vessel and the SPAR is reduced.
4. A quick connection device between the OWT and the SPAR has been designed to reduce the time needed for mating of the OWT and the SPAR. Analyses were performed to study the impact loads between the two objects during mating (see Figure 6).

Short term deterministic forecasting of wave fields

Offshore operations become challenging in marginal/harsh weather conditions. Accurate, timely forecasts of the actual wave conditions can increase the efficiency and safety of short-duration offshore operations.

The main idea in the present project is to use measured elevation of the sea surface to predict the phase-resolved wave propagation with the purpose of providing useful information in a decision support system.

Figure 7 shows how the method can predict the wave propagation 60 and 120 s into the future based on a "snap-shot" of the surface elevation at a given time instant.

Installation hybrid modelling to update ship models

Work related to this activity has focused on developing short-term trajectory predictions using neural networks that quantify uncertainty in their predictions. The moti-vation for this is to enhance the interpretability, and trustworthiness, of the black box model by communicating the amount of uncertainty it has about its own predictions.

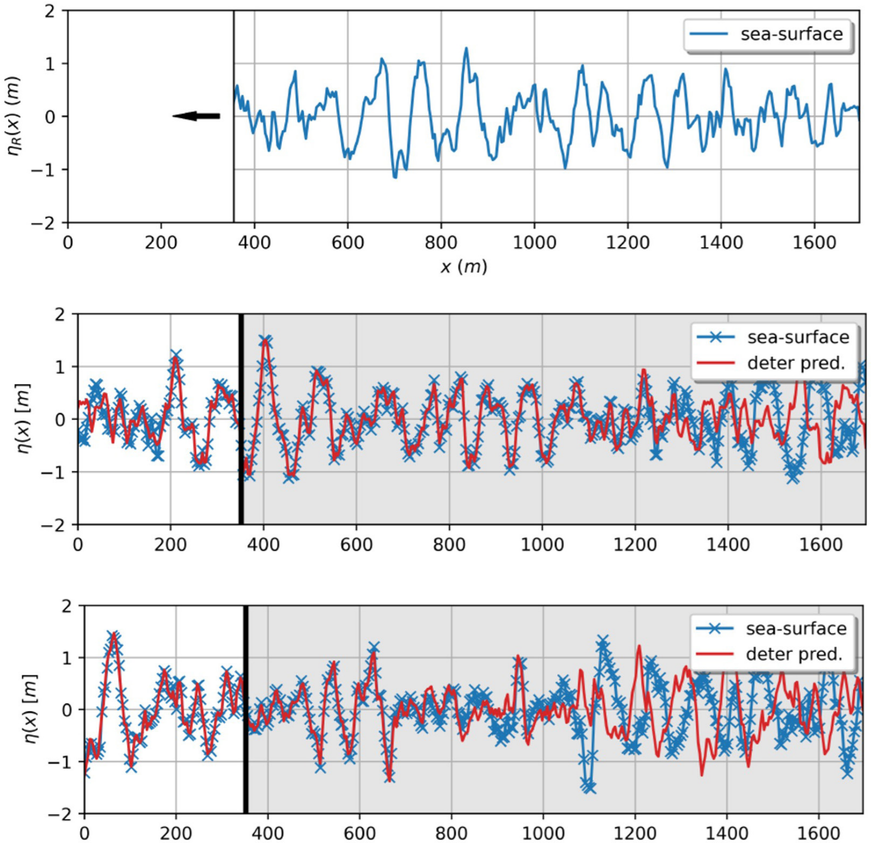


Figure 7. Forecasting of wave fields. Based on a "scan" of the sea surface (top), the wave field is predicted after 60 s (middle) and 120 s (bottom). The figures show both the predicted and the actual wave elevation.

Project 6

Project Leader:
Egil Giertsen, SINTEF Ocean

On-board Decision Tool

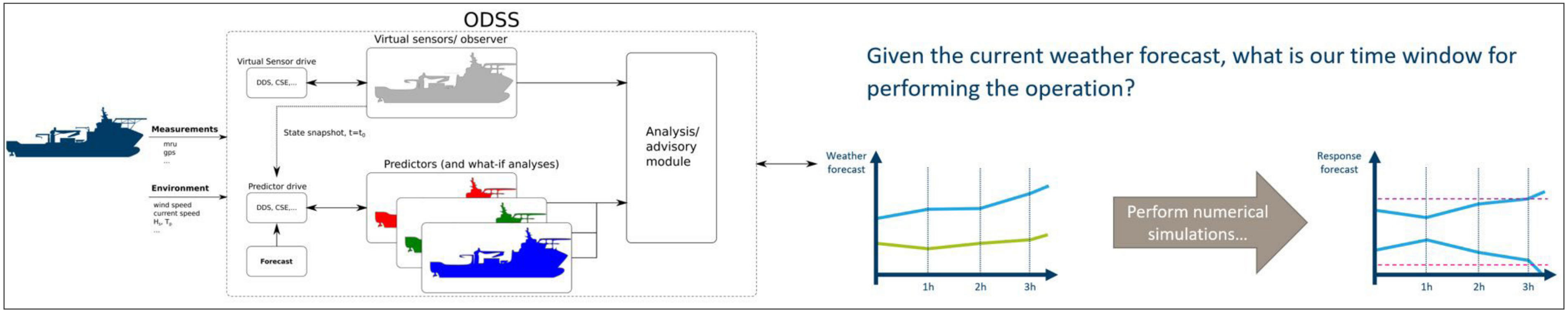


Figure 1.

The On-Board Decision Support System (ODSS) project is developing knowledge, methods and technology on how to use operational data from ship sensors, combining these with physics-based models, to monitor and predict the response of the vessel and its working tools (e.g. lifting equipment), and based on this information, to give advice to the crew performing a marine operation on how to operate safely and efficiently. The technology developed will give an important contribution towards response-based decision making in marine operations.

The work in 2022 included an activity on amplitude dependent hydrodynamic coefficients. The aim of this work was to develop a methodology to address such effects, supported by a case study. The behaviour of objects being lowered by crane through the splash zone and further down towards the seabed must be modelled with adequate accuracy. Such bodies are often of blunt and irregular shape, may have openings for the water to flow through, and internal cavities where water can be entrapped. The hydrodynamic forces will be predominantly viscous, and the model will in general be time variant and non-linear. There may also be non-linear memory effects. The mathematical model for such bodies cannot be built from theory but must be based on empirical data.

A large number of model tests of objects of different shapes have previously been carried out within SFI MOVE. Based on these tests, coefficients of damping and added mass have been estimated. The damping force can in most cases be split into a linear and a square term, which is conventional. The linearized added mass, however, shows dependency on the amplitude of oscillation, which is less common and indicates non-linear added inertia.

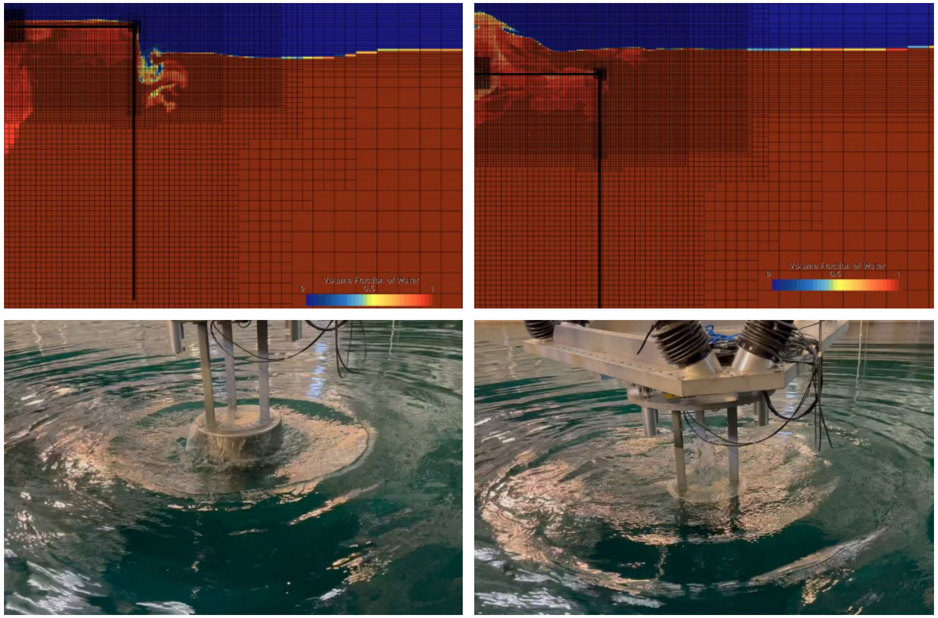
In a simulation model, such as SIMO, frequency and amplitude are not useful parameters in the general case when the motion of the object is non-sinusoidal. Instead, it has been attempted to formulate a numerical model that is free of these parameters, still reproducing the amplitude and frequency dependence when subjected to the conditions of the experiments. The model is formulated as a differential equation on state space form. To preserve the effect of amplitude and frequency dependence, but made more general, the RMS values of the object's position and velocity are used. RMS value can be estimated continuously from the motion during simulation. The case study object was chosen based on its shape and the richness and variation of the experiments it had been subjected to. The result of this work is a description of a methodology to address the effects shown by the experiments, suitable as basis for numerical specification and implementation.

In previous years, the model tuning method and software have been tested with data from model tests and simulations. Havfram AS has made a large amount of measured ("real") data of motion and waves from the OSV Normand Vision available. In addition, field experiments with the vessel RV Gunnerus were carried out in 2021 and 2022. The wave data from the two vessels were measured with wave radar, which also provides information on the directional spreading. A numerical model for Normand Vision exists from previous years. For RV Gunnerus, a numerical model was established and reported in 2022. Both models are ready for tuning.

The amount of data from Normand Vision is large and was recorded continuously in time, regardless of what the vessel was doing (i.e. during transit, when loading at quay, as well as during operations). In 2022, considerable effort was devoted to finding the time intervals when the data was relevant as well as being of good quality. This work is described in a separate report. The data from RV Gunnerus was measured during a planned offshore campaign, and all the data are relevant and suited for tuning.

Going forward, an important goal for the work in 2023 is to see if wave data obtained with radar can be used for model tuning. It is expected that considerable uncertainty exists in the wave spectra. The measured vessel motion, on the other hand, is of good quality. The numerical model has some initial uncertainties. Loosely speaking, the measured wave spectra are therefore useful only if they are "less uncertain than the parameters of the initial model".

The work conducted in 2022 in the onboard decision support activity was a direct continuation of the work from previous years. In 2018 and early 2019, basic concepts and architecture of the framework were formulated, illustrated in figure 1. Examples of framework components were implemented, and at the 2019 MOVE Autumn Conference a simulation fed with real-time measurements was demonstrated. The simulation can be combined with "virtual sensors" that provide additional information which are not available through direct monitoring. This was demonstrated in the context of the "load in air" phase of a lifting operation. At the 2020 MOVE Autumn Conference another piece of the puzzle was demonstrated, namely how predictive simulations can give useful information about the limiting criteria for an operation. In this demonstration the focus was on the "load in splash



Snapshots from CFD simulations and model tests from forced-motion simulation/tests.
Left; Suction anchor above the surface at the end of motion cycle.
Right; Suction anchor below the surface at the end of motion cycle.

zone". In 2021 the focus was geared towards adaptive vessel models, where historical and/or live measurements were used for tuning key vessel parameters to improve the system understanding as well as the operational safety and to increase the available operational window.

In 2022 the work on writing a document named "An architecture for on-board decision support systems" was started. A rough draft was distributed to selected industry partners for review and feedback, and the report is planned to be finalised in the first quarter of 2023. This report summarises the work and findings from the ODSS part of SFI MOVE project 6. It is believed that this document can become a solid foundation for the next stages of development, e.g. as a spin-off innovation project with the goal of lifting the ODSS research results from SFI MOVE to an industrial product. In addition to a description of the architecture, the document includes several case studies that demonstrate and validate the flexibility and robustness of the approach and design.

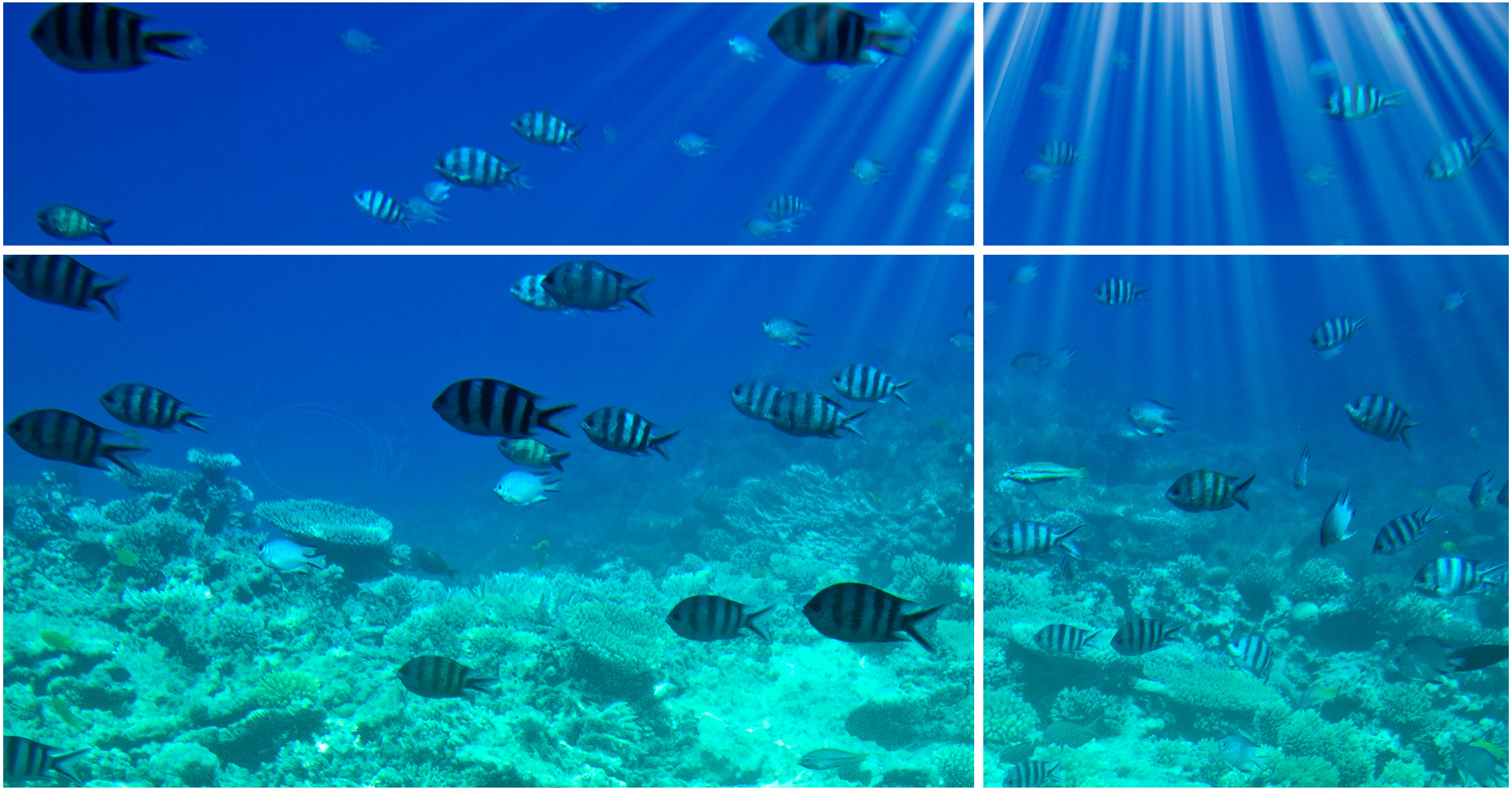
The activity on hydrodynamic coefficients for generalized subsea modules was completed in 2022 and summarized in a journal paper to be published in Journal of Offshore Mechanics and Arctic Engineering in 2023. The findings will also be included in the "Guide on numerical modelling and simulation of offshore lifting operations".

A numerical model for including shielding from the vessel on an object lowered through the sea surface was developed in 2021. In 2022 this model was applied in the Johan Sverdrup ITS installation case, which was also studied in detail in 2017. The results were compared with full scale measurements of the hoist wire tension during installation and the numerical simulations performed without shielding. The results show that when taking shielding into account, the simulated results are closer to the measurements than without shielding. The work illustrated how the dynamics in the lifting gear are reduced when the effect of shielding is included in the simulations. The study also illustrates how the effect of taking shielding into account is reduced if the crane tip motions are increased due to increased vessel roll in quartering sea.

The activity on splash zone hydrodynamics in 2022 mainly focused on suction anchors and modelling of hydrodynamic forces for such structures in SIMO. SIMO models need hydrodynamic coefficients to estimate the corresponding hydrodynamic forces. Estimation of hydrodynamic coefficients was performed using both model tests and CFD (Computational Fluid Dynamics) in the free surface zone. Wave tests were also performed to have validation data for excitation forces when the SIMO model was examined. Snapshots from model tests and CFD simulations are shown below. In the CFD simulations 1/4 of the suction anchor was modelled due to double symmetry.

A SIMO model was also prepared to use the calculated hydrodynamic coefficients for simulations of the suction anchor in waves. Extensive studies were performed using WAMIT (commercial code for computation of hydrodynamic forces) to examine the SIMO model for estimation of excitation forces near the free surface. Fine-tuning of the SIMO model is ongoing work. In 2023, the splash zone activity, with suction anchor as case, is further pursued to come up with a model with acceptable accuracy to be shared with the industry partners. The results of the CFD simulations, model tests and SIMO model will be reported in 2023.

The aim of the Vessel *condition adapted response model* activity is to provide a tool to simplify the optimization of ship motion characteristics and to improve seakeeping performance for specific operational tasks and sea areas. This mission-dependent optimization approach involves adjusting hull dimensions and loading conditions to ensure that important responses like pitch and roll are distinct from dominant wave periods. The approach can also be utilized in the onboard decision support context, allowing a more accurate prediction of the loading condition dependent roll response. In 2022, the seakeeping optimization tool for parametric studies was further developed and tested. The parametric vessel optimization tool is integrated in the existing seakeeping code VERES and will be made available to project partners as updates to the ShipX 4.2 workbench in the second quarter of 2023.



Project 8

Project Leader:
Marie Haugli-Sandvik
NTNU Ålesund

Photo: Rolls-Royce

Remote Operations/ Dispersed Teams

Introduction

The focus of this project is to investigate how use of digital twin technology can enable collaboration between shore and vessel, development of cyber security solutions, and how dispersed teams and digital transitions in remote operations can optimize workflow and organizational change.

Project activities 2022

The HTO framework (Human-Technology-Organization) is used to structure the project activities. In 2022, the activities have been centered on simulator experiments, attending conferences, course development and site visits. To learn about how industry is working with remote operations, we went on site visits to our industry partners Kongsberg and SubSea7. Lessons learned from these visits were presented at the SFI MOVE autumn conference.

Human

During 2022 we conducted a second simulator experiment. We tested the communication between operators in our remote operation center and the deck officers on the research vessel Gunnerus when collaborating on performing a task together. Results indicate that existing communication solutions (voice/video/chat) can make it possible to solve a simple task. Still, there will be a need for more integrated communication solutions if the task is complex and the collaborating team is highly dependent on each other. The simulator-study was presented at the SFI MOVE spring conference and at Fjordkonferansen on 17 June 2022. Two papers compiling this work will be published in 2023.

PhD candidate Marie Haugli-Sandvik has continued her research on maritime cyber risk perception, and in her second paper she presents recommendations on cyber risk mitigation measures for shipping companies. This work has also contributed to the development of a maritime cyber security course, which will be given to maritime personnel in the beginning of 2023.

Technology

The system performance of the remote operation center was additionally tested during the second simulator experiments, and the system still faces the same challenge with loss of signals due to topography and 4G coverage. Future work should address how the remote operation center can be made more technically resilient, look at development of operator-specific dashboards, and investigate integrated communication solutions.

Organization

Associate Professor Viktoriia Koilo is using a business case of remote ROV-operations to look at structural changes and business models. At the SFI MOVE spring conference, she presented a framework for cost-benefit analysis of a business model within that case study. Results show that organizations should focus on sustainability performance and long-term value creation when implementing new technological solutions.

PhD candidate Bjarne Pareliussen has been looking at how interorganizational relations can be changed when organizations go through digital transitions, and we are happy to announce that he successfully defended his thesis “Maritime organizations facing a new era – Servitization, technology implementation and professional work” in December 2022.

Plans ahead

2023 is the final year of SFI MOVE, so the focus will be on wrap-up activities:

- Write final project report with a compilation of the results, reported as case deliveries.
- Descriptions of scenarios used for testing remote operations with dispersed teams and digital twin technology.
- Evaluation of cyber security course for maritime management and operational personnel, and recommendations for cyber security training and cyber risk management.

Planning of simulator experiment in the remote operation center.

Site visit to Kongsberg and Yara Birkeland’s remote operation center in Horten.

Site visit to SubSea7 in Stavanger.

- Model for cost-benefit analysis when implementing new technology.
- Recommendations for further research of interactional communication systems between ship and shore.

Research cooperation

Text: Hans Petter Hildre

Ocean Space Centre, Trondheim

An open simulation platform

Today, simulations are widely used in all stages of the life cycle of a vessel. However, the potential of simulations is not fully utilised as the initial cost of establishing simulation models is considerable, and re-use of models is limited. Based on a standard developed by the automotive industry we aim to establish a maritime ecosystem for co-simulation enabling re-use of models and collaborative system simulations.

Partners in SFI MOVE, DNV, Kongsberg Maritime, SINTEF Ocean and NTNU, have agreed to act on this challenge together. 20 key industrial stakeholders have joined the project and the work defining a standard enabling exchange of simulation models – reducing cost and complexity related to simulations.

[1]https://opensimulationplatform.com/

The Open Simulation Platform[1] provides the maritime industry with key tools and working processes for technical systems engineering, enabling efficient and effective construction and maintenance of digital twins for system integration, testing and verification. Building on the Functional Mockup Unit (FMU) standard, the key principles are to:

- Enable the re-use of simulation models and digital twin equipment across organizations without exposing sensitive IP by protecting models and control system software inside black-box executables.
- To establish a standard for connecting models and control systems from any simulation tool or programming language in one, large co-simulation to enable virtual system integration.
- To enable cross-organization cooperation and platform interoperability by transparency and open-source principles.

The Norwegian Ocean Technology Centre – Fjord Lab Ålesund

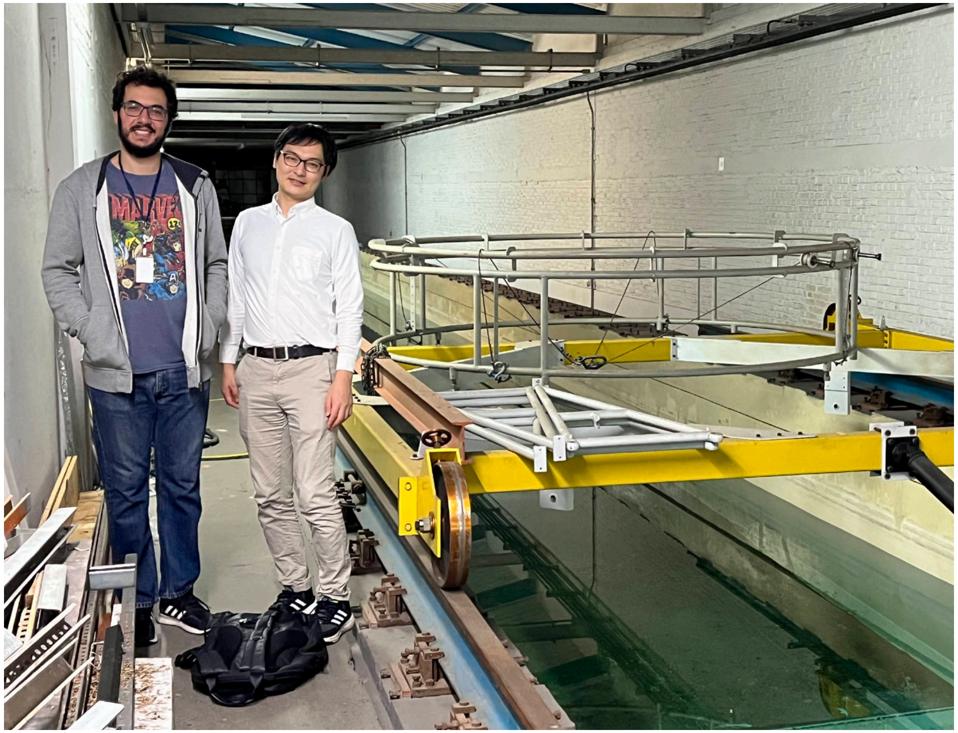
The centre will become the national knowledge centre for ocean space technology. The purpose of the Norwegian Ocean Technology Centre is to secure Norway's position as a leading ocean nation and contribute to the green shift in Norwegian ocean industries.

The centre will:

- educate future specialists within the field of ocean space technology
- ensure that industry and authorities enjoy access to leading expertise and infrastructure
- contribute to effective utilisation of national expertise and increased knowledge through collaboration with Norwegian and foreign institutions and companies
- actively contribute to increased innovation in ocean space technology
- contribute to the restructuring and development of ocean industries

The Norwegian Ocean Technology Centre includes several laboratories and will be built on the site where the Marine Technical Centre is located today. The construction started in the summer of 2022. The centre will have 45 000 square metres and will be fully finished in 2028.

A new addition to the Norwegian Ocean Technology Centre is full-scale laboratories in the ocean space (Fjord-Lab). The Fjord Lab will have «hubs» in Trondheim, Hitra/Frøya and Ålesund. This provides unique possibilities for testing new technology right from the drawing board to completed design at full scale.



International cooperation

Text: Henrique Gaspar

During the last period the SFI MOVE have been active in strengthen the existent international cooperation with the University of São Paulo (USP, Brazil), University College London (UCL, UK), as well as establishing a new and productive collaboration with the National Maritime Research Institute (NMRI, Japan).

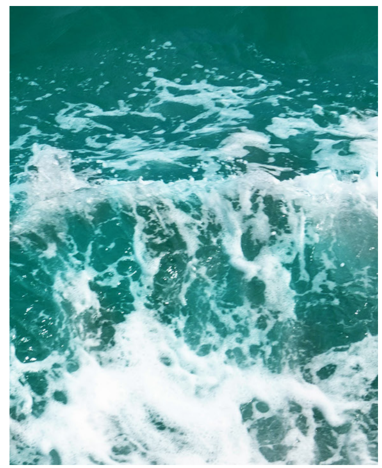
The first is exemplified by the research stay of Mehrnoosh Nickpasand, PhD candidate at the Dept. of Ocean Operations and Civil Engineering (IHB, NTNU) and Senior System Engineer at Siemens Gamesa Renewable Energy (SGRE, Denmark) at USP. Her work on Agility of Offshore Wind Turbine Manufacturing has been connected with many topics from SFI MOVE, as well as an on-going research at USP, via Professors Kazuo Nishomoto and Eduardo Tanuri (USP) and Henrique M. Gaspar (NTNU). Mehrnoosh was a visiting researcher at USP in Q4 2022 and is currently working on joint articles between the three institutions. Such initiative is paramount to connect university to the real challenges of the industry.

The collaboration with UCL is exemplified by the visit of Prof. David J. Andrews in Ålesund, in November 2022. Prof. Andrews is widely known for his contribution in the design of large and complex products. Among other activities, he gave a lecture on What makes Early Stage Design of Complex Vessels Sophisticated? – A Ship Architecture Based Approach: Designing Inside Out, covering topics on the novelty, style and challenges in maritime design. One result of this collaboration was published last year, in an article co-authored by Professor Gaspar (NTNU) and Prof. Andrews (UCL).

The cooperation with NMRI (Japan) is done via Dr. Yasuo Ichinose, Chief Researcher at the Fluid Control Research Group. Dr. Ichinose is currently a visiting researcher at NTNU in Ålesund, promoting the integration of many research topics between the Norwegian and Japanese institutions. Dr. Ichinose gave diverse lectures in Norway and Brazil promoting the advancements in flow simulation of marine structures, using modern neural-network, machine learning and web-based methods. This collaboration is resulting in diverse scientific articles, and it is expected the visiting of a NTNU scholar in Japan in 2024.

Personnel

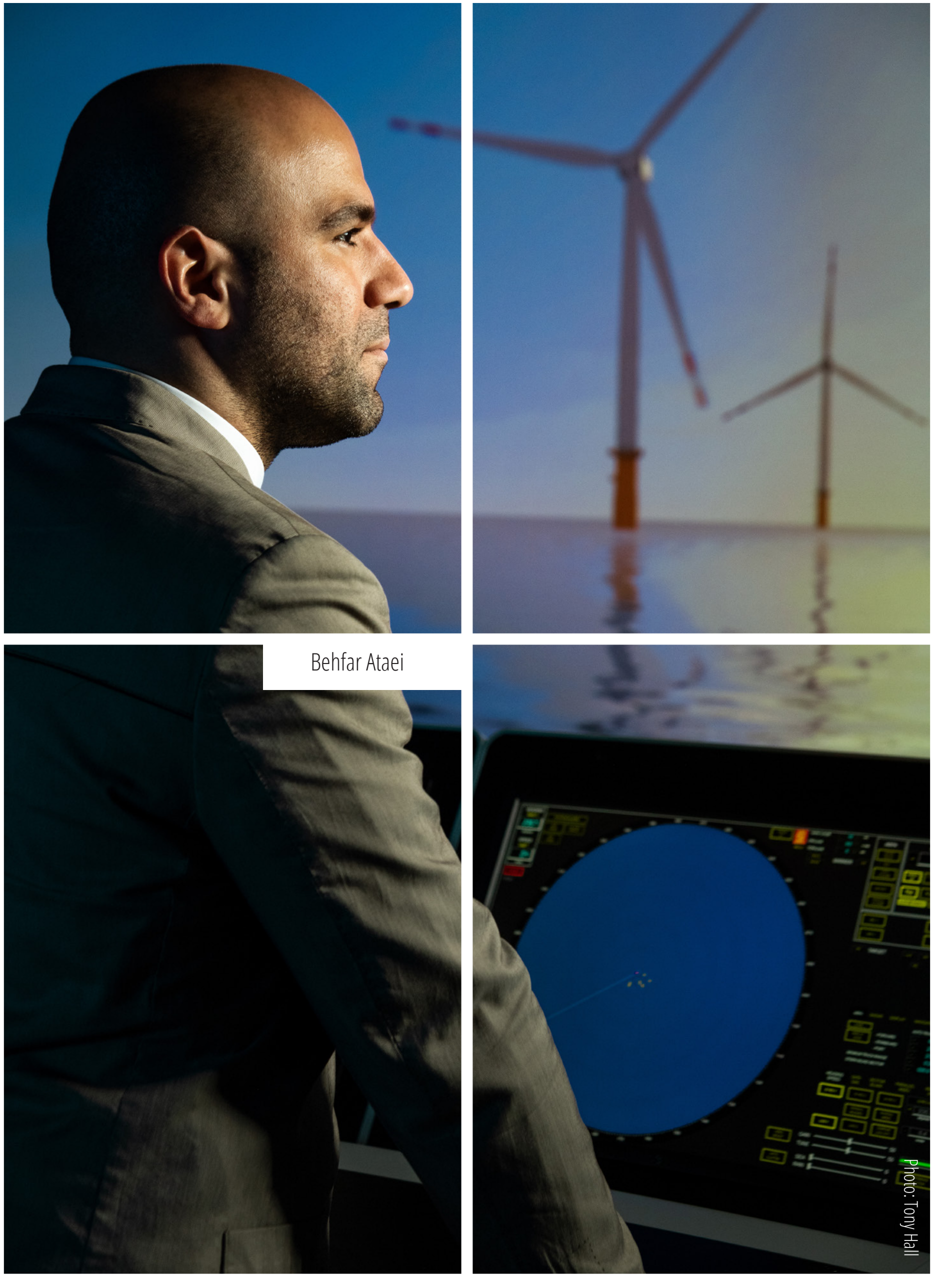
Key Researchers		
Name	**Institution**	**Main research area**
Karl Henning Halse	NTNU Ålesund	RA4 Integrated simulator environment
Houxiang Zhang	NTNU Ålesund	RA4 Integrated simulator environment
Henrique Gaspar	NTNU Ålesund	RA4 Integrated simulator environment
Marie Haugli-Sandvik	NTNU Ålesund	RA4 Integrated simulator environment
Viktoriia Koilo	NTNU Ålesund	RA4 Integrated simulator environment
Finn Tore Holmeset	NTNU Ålesund	RA4 Integrated simulator environment
Frøy Birte Bjørneseth	NTNU Ålesund	RA4 Integrated simulator environment
Svein Sævik	NTNU	RA2 Numerical models and tools
Zhen Gao	NTNU	RA2 Numerical models and tools
Trygve Kristiansen	NTNU	RA2 Numerical models and tools
Roger Skjetne	NTNU	RA3 On-board systems
Bernt Johan Leira	NTNU	RA3 On-board systems
Egil Giertsen	SINTEF Ocean	RA3 On-board systems
Halvor Lie	SINTEF Ocean	RA2 Numerical models and tools
Lars Tandle Kyllingstad	SINTEF Ocean	RA3 On-board systems
Karl Erik Kaasen	SINTEF Ocean	RA3 On-board systems
Stian Skjong	SINTEF Ocean	RA3 On-board systems
Reza Firoozkoohi	SINTEF Ocean	RA2 Numerical models and tools
Frøydis Solaas	SINTEF Ocean	RA2 Numerical models and tools
Martin Gutsch	SINTEF Ocean	RA1 Vessel performance



Recruitment

Due to late start of the SFI MOVE we had a minor delay in hiring PhD students from the start. We are very pleased with the number and quality of applications, but would like to see that there were more women among them.

PhD candidates and Postdocs					
Name	**Start**	**End**	**Project**	**Nationality**	**Gender M/F**
PhD candidates with funding from SFI MOVE					
Martin Friedwart Gutsch	2015	2020	Vessel performance	German	M
Fredrik Mentzoni	2015	2019	Numerical models and tools	Norwegian	M
Zhengru Ren	2016	2018	On-board systems	Chinese	M
Amrit Shankar Verma	2016	2019	Numerical models and tools	Indian	M
Robert Skulstad	2016	2020	Integrated simulator environment	Norwegian	M
Maël Moreau	2017	2020	Numerical models and tools	French	M
Jiafeng Xu	2015	2018	Integrated simulator environment	Chinese	M
Xu Han	2018	2021	On-board systems	Chinese	M
Behfar Ataei	2019	2022	Integrated simulator environment	Iranian	M
Marie Haugli Larsen	2019	2023	Integrated simulator environment	Norsk	F
Gowtham Radhakrishnan	2019	2022	Numerical models and tools	Indian	M
Sunghun Hong	2020	2023	Integrated simulator environment	South Korea	M
PhD candidates with funding from other sources					
Tor Huse Knudsen	2014	2018	Numerical models and tools	Norwegian	M
Svenn Are T. Værnø	2014	2017	Numerical models and tools	Norwegian	M
Senthuran Ravinthrakumar	2016	2019	Numerical models and tools	Norwegian	M
Øyvind Rabliås	2017	2021	Numerical models and tools	Norwegian	M
Tore Relling	2017	2020	Integrated simulator environment	Norwegian	M
Rami Zghyer	2017	2021	Integrated simulator environment	Jordanian	M
Raheleh Kari	2018	2021	Integrated simulator environment	Iranian	F
Bjarne Pareliussen	2019	2022	Integrated simulator environment	Norwegian	M
Mengning Wu	2020	2021	Integrated simulator environment	Chinese	F
Postdocs with funding from SFI MOVE					
Mia Abrahamsen-Prsic	2016	2019	Numerical models and tools	Croatian	F
Zhiyu Jiang	2016	2018	Numerical models and tools	Chinese	M
Mats Jørgen Thorsen	2016	2018	Numerical models and tools	Norwegian	M
Niranjan Reddy Challabotla	2016	2018	Numerical models and tools	Indian	M
Zhengru Ren	2019	2021	On-board systems	Chinese	M
Ting Liu	2020	2022	Integrated simulator environment	Chinese	F
Mohammad Mahdi Abaei	2021	2021	On-board systems	Iranian	M
Robert Skulstad	2021	2023	Integrated simulator environment	Norwegian	M
Rafael Salles	2022	2023	On-board systems	Brazilian	M
George Jagite	2022	2023	Numerical models and tools	Romanian	M
Postdocs with funding from other sources					
Shuai Yuan	2020	2021	Integrated simulator environment	Chinese	M



Behfar Ataei

Photo: Tony Hall

Title
Virtual Prototyping of Installation of Offshore Power Systems.

Short project description
The industries, houses, and transportation equipment are producing extensive amounts of emissions, therefore, they are threatening the living species by polluting the planet. To reduce emissions and protect the environment, it is required to utilize cleaner sources of energy such as wind. Wind turbines are designed to convert wind energy into electricity and can be located onshore and offshore. The wind velocity is higher and more stable at the sea and it increases the production potential of Offshore Wind Turbines (OWTs) while project costs are considerably higher than the inland structures.

Installation of offshore wind turbines is a challenging operation and that is mainly due to complexities in the environment such as waves, winds, and currents. Besides, there are multiple structures involved in these operations such as OWT assembly, lifting vessel, floating spar, etc. (depending on the installation arrangement). The response of each of these structures to the environment and interaction between them is cumbersome which increases the complexities in the operation. In the current research, the main focus will be on understanding the underlying physics and the way the competitive advantage of this technology can be increased.

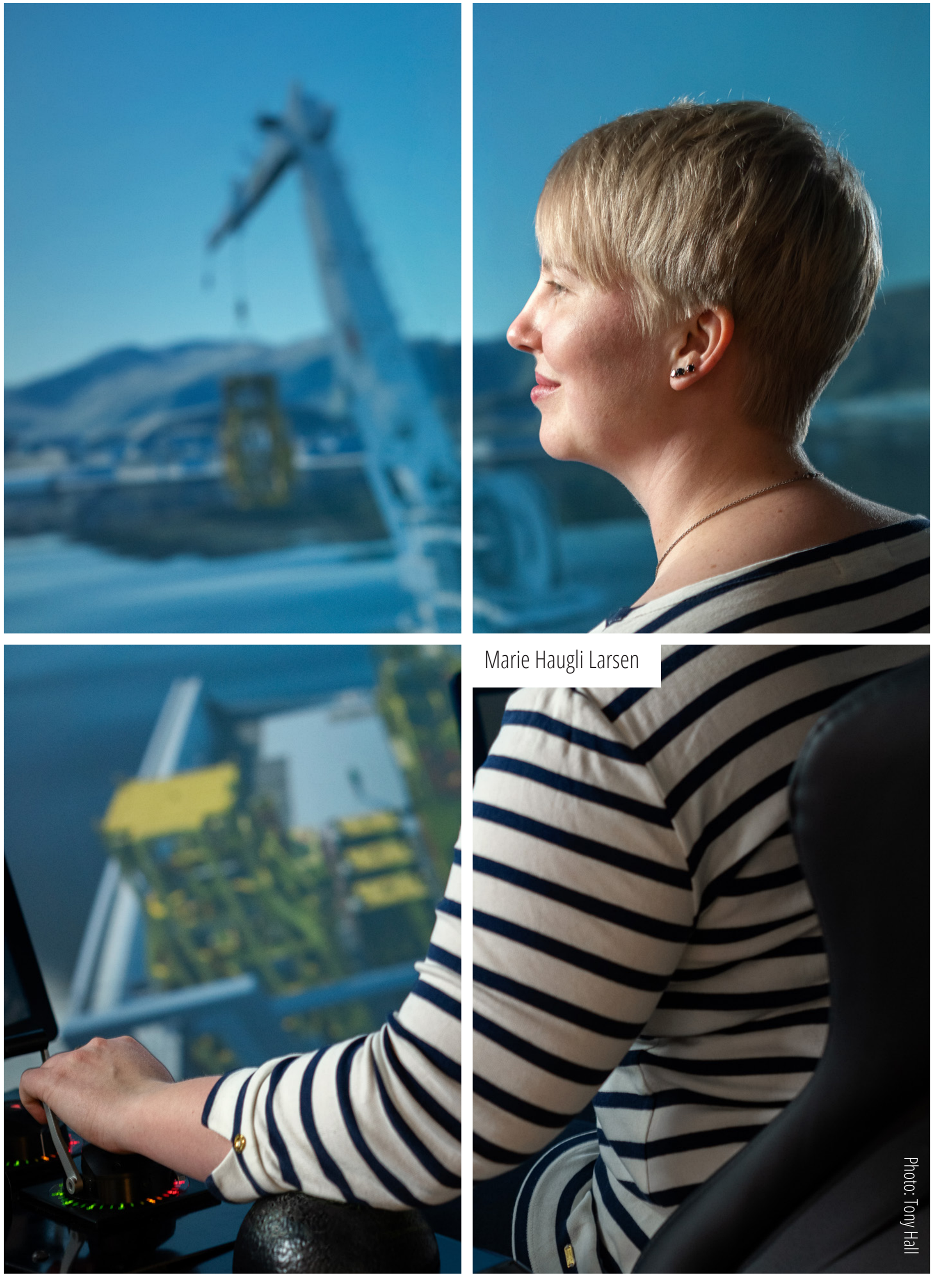
Industrial goals
1. Knowledge transfer from offshore oil and gas industry and implement in OWT installations.
2. Development of innovative concepts for OWT installation operation to increase efficiency.
3. Development of a unified virtual prototyping environment following Functional Mock-up Interface standard.

Scientific questions
1. What are the main physical phenomena governing OWT installations?
2. How these phenomena can be defined numerically that is possible to integrate into different simulation environments?

Innovations
Conventional installation methods in this field are not efficient and there is a demand for innovative installation concepts. The development of a unified simulation environment increases the flexibility of the operation while reduces error.

Cooperating company
Technip FMC

Supervisor: Karl Henning Halse (NTNU)
Co-supervisor: Zhengru Ren



Marie Haugli Larsen

Photo: Tony Hall

Title

Perception of cyber risks in offshore operations.

Short project description

In today's maritime operations there is an increasing reliance on digitalization, integration, automation and networked-based systems. The increase of technology and connectivity makes operations at sea vulnerable to cyber-attacks.

Risk perception plays a vital role in identifying cyber risks and achieving risk awareness. Research into this side of cyber security in the maritime domain is limited, but it can be valuable to identify and understand seafarers' cyber risk perception. By understanding cyber risk perception, we can create targeted education, develop policy to improve behavioral compliance, and design technical solutions more effectively. This study will therefore focus on achieving in-depth understanding of cyber risk perception in the maritime domain.

Industrial goals

Achieve better understanding of deck officers cyber risk perception, in order to give the maritime industry recommendations on cyber policies, operational cyber training and the development of dispersed bridge crew.

Scientific questions

1. How can perception of maritime cyber risks be understood in the context of offshore operations?
2. How does the deck officer perceive cyber risks in offshore operations?
3. In what way can knowledge about deck officer's perception of cyber risks contribute to the development of dispersed bridge crews?

Innovations

A new model of cyber risk perception in offshore operations, and recommendations for how this can be used in the development of training programs, policies and dispersed bridge crews.

Supervisor: Frøy Birte Bjørneseth (NTNU)
Co-supervisors: Runar Ostnes (NTNU), Sokratis Katsikas (NTNU), Mass Soldal Lund (HINN)

Gowtham Radhakrishnan

Photo: Thor Nielsen

Title
Onboard decision support systems based on mathematical and data-driven models for predicting vessel response during marine operations in realistic conditions.

Research topics
- Pursuing integration of realistic metocean conditions (corrected forecasts/observations) to mathematical models for predicting the operational behaviour of vessels in real environment, both in short range and long range.
- Achieving optimal real time response evaluation through blending vessel's sensor measurements into models.
- Using state-of-the-art data-based algorithms for estimating vessel's futuristic response from historical data.

Industrial goals
- Rapid and dependable predictive simulations on board for studying vessel's operational characteristics both in real time and in future.
- Identification of critical situation beforehand for certain acute operations.
- Deducing essential intelligence from the support systems for making pivotal and flexible decisions.

Scientific questions
- Quantification of uncertainties inherent in weather forecasts using probabilitistic & oceanographic methods; Application of satellite and insitu observations for yielding reliable environmental forecasts.
- Utilisation of cloud based data storage, data transfer & computing.

Innovations
- Employment of cutting edge machine learning, deep learning, bigdata, IoT & cloud architectures in vessel response prediction.

Supervisor: Bernt Johan Leira (NTNU)
Co-supervisors: Svein Sævik (NTNU), Zhen Gao (NTNU)

Sunghun Hong

Photo: Tony Hall

Title

Global dynamic analysis of on-site offshore installation of floating offshore wind turbines.

Research topics

With increasing global demand for clean energy resources, floating offshore wind energy has been considered one of the main alternatives to fossil-based resources. Towing assembled wind turbine and floating foundation units from the quay to the operation site is currently the primary installation method for floating offshore wind turbines. 'On-site offshore installation' was proposed as an alternative method for geographical challenges that required deep water depth. The main goal of the PhD program is the global dynamic analysis of offshore installation of floating offshore wind turbines with the specific scopes as follows:

- Numerical modelling and global dynamic analysis of the multibody system (floating installation vessel, lifted offshore wind turbine, and floating foundation) during the offshore heavy lifting operation.
- Development of coupling methods to mitigate the relative motion between the lifted wind turbine and the floating foundation for mating preparation.
- Suggesting limiting criteria and guidelines for estimating the operable weather window.

Industrial goals

- Reduce the cost of installing floating offshore wind turbines using new methods.
- Increase operational efficiency by establishing appropriate limiting criteria and guidelines for the weather window estimation.

Scientific questions

- What are the critical responses in the on-site offshore installation of floating offshore wind turbines?
- What are the mitigation measures to reduce the global dynamic responses of the multibody system?
- What are the thresholds and limiting criteria for weather window estimates for floating offshore wind turbines installation?

Innovations

- Methods for the on-site offshore installation of floating offshore wind turbines.

Supervisor: Karl Henning Halse (NTNU)
Co-supervisor: Torodd Skjerve Nord (NTNU)

Ting Liu

Photo: Tony Hall

Title
Optimization of low-height lifting system for installation of offshore wind turbines (OWT) by using floating vessel.

Research topics

- Hydro-aero-dynamic response prediction of the installation system
- Prediction of extreme response for the installation and estimation of the reliability of the system
- Optimization of the installation concept and prescription of the response-based criteria

Industrial goals

- Provide new and accurate response estimation model for installation of offshore wind turbines
- Contribute to the development of the response-based criteria and improved regulations

Scientific questions

- How to improve the design concept of this low-height lifting system while ensure both economy and safety
- How to enhance the numerical models to provide a more realistic prediction for the dynamic responses of the installation system.

Innovations

- Novel methods for OWT installation leading to cost-reducing as well as improved safety and operability.

Cooperating company
SINTEF Ocean

Supervisor: Karl Henning Halse (NTNU)
Co-supervisor: Bernt Johan Leira (NTNU)

Title
Hybrid modelling for ship motion prediction.

Research topics

- Hybrid modelling, using physics-based models as well as data-based models, to describe and predict ship motion
- Time series prediction models and input selection

Industrial goals

- Decision support for manned and unmanned ships

Scientific questions

- How can data from sensors on ships be combined in hybrid models to provide accurate predictions of ship motion?

Innovations

- Methods for prediction of ship motion leading to improved efficiency and increased safety at sea

Supervisors: Houxiang Zhang and Hans Petter Hildre (NTNU)


George Jagite
Photo: Thor Nielsen

Title
Short-term deterministic forecasting of waves fields.

Research topics
- Fundamental research on the theoretical models for the short-term forecasting of wave fields.
- Development of real-time forecasting models for linear and nonlinear short-crested waves using limited spatiotemporal wave surface measurements.
- Research on the development of an integrated onboard decision support system to predict the wave-induced motions and loads for the next few tens of seconds into the future.

Industrial goals and Innovations
The main goal is to improve the safety and efficiency of marine operations using accurate, timely forecasts of wave conditions. Moreover, this research work aims towards short-lasting marine operations possible all-year-round.

Scientific questions
- What are the needs and limitations regarding the forecasting of wave fields using limited spatio-temporal seasurface measurements?
- How can the position-keeping capabilities of a vessel be improved by using a feed-forward system using the forecasted wave-induced loads?

Supervisors: Zhen Gao (SJTU/NTNU), Roger Skjetne (NTNU), Karl Henning Halse (NTNU)

Title
Reliable online predictions on lift marine operations, considering installed object failure modes and inherent uncertainties.

Research topics
- Online evaluation of critical loads present in a given marine operation condition, considering installing object and vessel dynamical responses
- Short-term prediction of failure modes due to hydrodynamic interactions
- Usage of an open simulation platform to evaluate the uncertainties inherent to the object installation operation

Industrial goals
- Determination of critical temporal windows to execute lift marine operations

Scientific questions
- How to make on-board decisions of "go" and "no-go" installation windows and their uncertainties from vessel and installing object data responses, considering short-term predictions of the sea behavior in advance

Innovations
Methods to execute short-term predictions and uncertainties of lifting marine operations using online simulations of vessel and installing object data in an open simulation platform.

Supervisors: Bernt Johan Leira and Svein Sævik (NTNU)

Communication and dissemination activities

The SFI MOVE home page is frequently updated, see www.ntnu.edu/move

The project has arranged following main conferences/ workshops in 2022:

- Spring conference, at NTNU Ålesund 14.06.22
- Workshop, at NTNU Ålesund 15.06.22
- Autumn conference, at Teams 29.11.22

The SFI MOVE-program is now in its final phase. There is a half year left and there is now a focus on completing sub-projects. We are also working on what we can achieve after the project is finished, and this will also be one of the topics at the final conference.

The program has the following objectives for the final delivery:

Overall plan for the final delivery of SFI MOVE

1. Established a leading research and innovation centre for demanding marine operations
2. System simulation workbench for real responses:
   - Modular set of models allowing simulation of subsea operations and offshore wind installations (FMI/FMU modules)
   - Ship behaviour & data-driven tuning of ship models
   - Prediction of future weather responses
   - Backbone of simulation capabilities from sales, engineering, onboard and remote operations
   - Front-end modelling and visualisation environment including libraries
3. Methods and set-up for remote operations (based on simulation)
4. Demonstrators of technology. On-board and remote operations demonstrated for Gunnerus and an offshore vessel (case: subsea lifting/ installation)

Publication highligts

We want to highlight some of the publications from 2022, one related to project 5 (Innovative Installation of Wind Power Systems), two related to project 6 (On-Board Decision Tool) and one related to project 8 (Remote Operations/Dispersed Teams).

Project 5
Hong, Sunghun; Zhang, Houxiang;
Nord, Torodd Skjerve; Halse, Karl Henning.
Effect of fender system on the dynamic response of onsite installation of floating offshore wind turbines.
Ocean Engineering 2022; Volum 259. NTNU

This paper discusses a new installation method for floating offshore wind with installation procedure, essential variables, and fender system effects on the dynamic responses. The conventional installation method involves mating wind turbines and substructures in calm and protected waters and towing the assembled units to an operating site. Due to geographical, time, and economic disadvantages, this method may be challenging to meet the rapidly surging demand for floating wind power worldwide. The new onsite installation method was introduced as an alternative, using a catamaran to install fully assembled wind turbines at the operation site. The proposed concept can be employed to install and maintain fixed and floating offshore wind turbines in any location. While the conventional installation method consists of a series of installation processes, the proposed installation steps can be performed in parallel, suggesting more flexible operation planning. Fenders and wires were applied as a mechanical coupling system to enable onsite installation in harsh offshore environments. The fender system with pretensions on wires showed reduction effects on the relative horizontal displacement, relative vertical displacement, and relative alignment by approximately 78 %, 64 %, and 32 %, respectively. Therefore, the fender system application can significantly increase the practicality of the onsite installation method.

Project 6
Abrahamsen-Prsic, Mia; Solaas, Frøydis;
Kristiansen, Trygve.
Hydrodynamic Coefficients of Generic Subsea Modules in Forced Oscillation Tests – Importance of Structure Parts.
41st International Conference on Ocean, Offshore and Arctic Engineering; 2022-06-05 - 2022-06-10. NTNU OCEAN

A systematic study of the hydrodynamic coefficients for simplified subsea modules has been performed, to support the estimation of the coefficients needed for planning of subsea installation operations. The coefficients are assessed for a nearly two-dimensional test setup. The tests are performed as forced oscillations at various amplitudes and periods, representing the forces on the module lowered through the water column. The importance of each of the main components of the subsea modules – mudmat, protection roof and process equipment of different shapes inside the modules are studied at fully submerged condition. Results for the module elements, generic contents and different combinations of these elements are presented.

For the tested modules, damping is generally the dominating hydrodynamic force. However, the presence of the content inside the modules will generally increase the importance of added mass.

Estimation of the hydrodynamic coefficients by summation of the coefficients for the individual structure elements generally overestimates the damping, compared to the coefficients measured for the complete modules. For added mass, estimation based on summation gives generally good results.

Keywords: Hydrodynamic coefficients; Marine Operations; Subsea modules; Added mass and damping.

Project 6

Ren, Zhengru; Han, Xu; Yu, Xingji;
Skjetne, Roger; Leira, Bernt Johan;
Sævik, Svein; Zhu, Man.

Data-driven simultaneous identification of the 6DOF dynamic model and wave load for a ship in waves.

Mechanical systems and signalprocessing 2022 ; Volum 184. s.1-16 NTNU

In marine operations, the performance of model-based automatic control design and decision support systems highly relies on the accuracy of the representative mathematical models. Model fidelity can be crucial for safe voyages and offshore operations. This paper proposes a data-driven parametric model identification of a ship with 6 degrees of freedom (6DOF) exposed to waves using sparse regression according to the vessel motion measurements. The features of the complex ship dynamics are extracted and expressed as a linear combination of several functions. Thruster inputs and environmental loads are considered. The hydrodynamic coefficients and wave-induced loads are simultaneously estimated. Unlike earlier studies using a limited number of unknown functions, a library of abundant candidate functions is applied to fully consider the coupling effects among all DOFs.

The benefit of the proposed method is that it does not require the exact construction of the library functions. Based on the estimated model, short-term motion prediction is achievable. The algorithm is verified through experiments. The method can be extended to other types of floating structures.

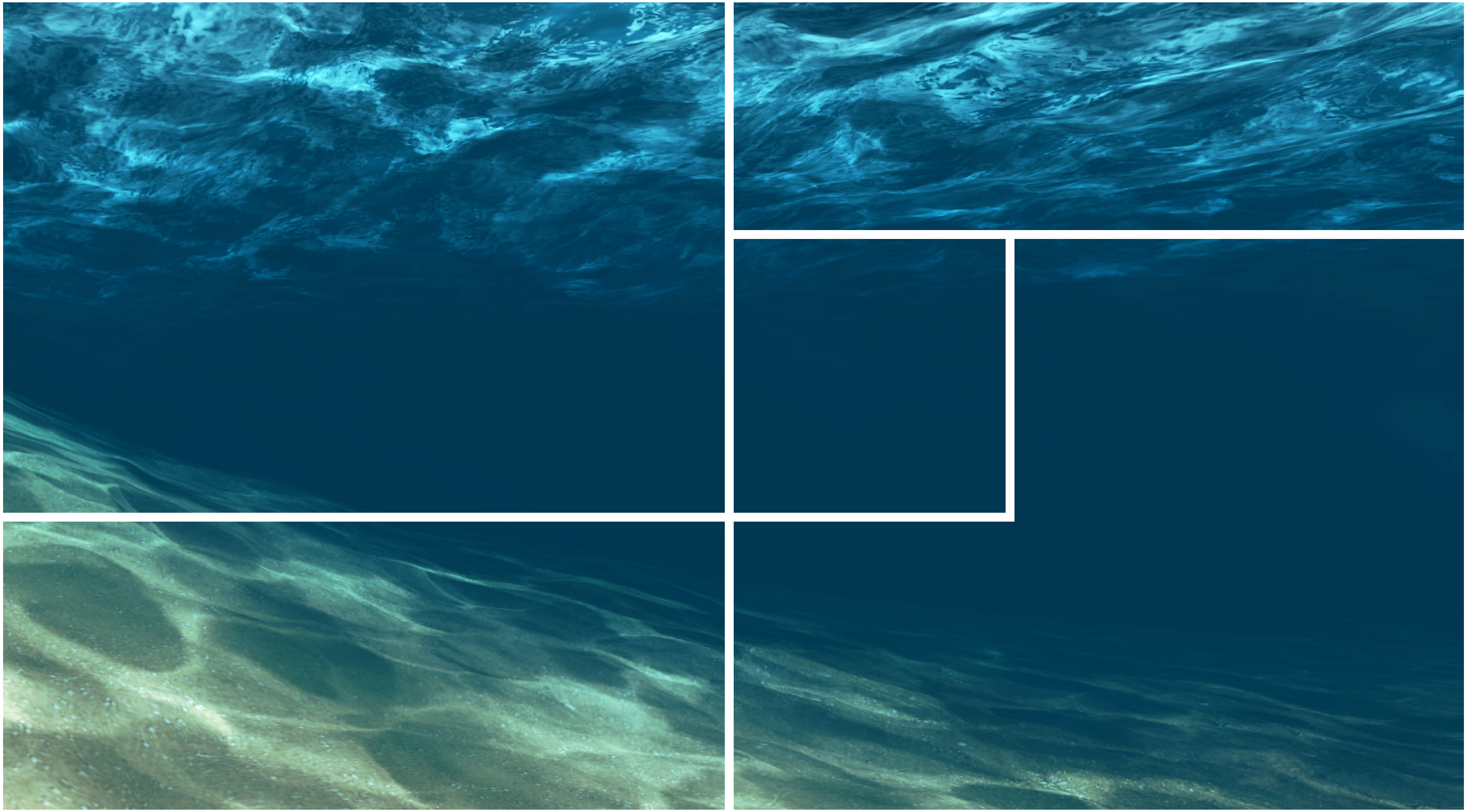
Project 8

Koilo, Viktoriia.

Business model for integrated sustainable value creation: A supply chain perspective.

Problems and Perspectives in Management 2022 ;Volum 20.(1) s.93-107. NTNU

In the context of globalization, the process of value creation is becoming more complex, exposed to greater risks for companies, partners, and customers. Moreover, modern digital technologies, such as the use of digital twin technology, can increase the use of geographically dispersed work teams and contribute to sustainable value creation in the future. However, the digital transition creates new organizational models and influences relationships in supply chains, thus affecting structural changes in business models. Hence, the study aims to investigate, from the whole value chain perspective, how the next generation of digital services is affecting business value and changing the business model concept. In addition, this paper discusses the stakeholder and social responsibility value creation perspective on business model for integrated sustainable value creation. To investigate this, it was decided to use a quantitative methodology in the form of questionnaires, which were distributed among different interested parties: two contractors, three suppliers, and an operator. The results indicated that all respondents, such as an operator, shipping companies, and subsea service providers, are positive about future digital technologies, which should ensure environmental sustainability, improve human interaction and communication. At the same time, they emphasize the importance of integrated join work within the value creation element. Overall, all participants are interested in reducing costs, they expect initiatives from each other in offering sustainable and innovative solutions, and to achieve these, innovative cooperation is needed.



Publications

2022

Abrahamsen-Prsic, Mia; Solaas, Frøydis; Kristiansen, Trygve.
Hydrodynamic Coefficients of Generic Subsea Modules in Forced Oscillation Tests – Importance of Structure Parts. 41st International
Conference on Ocean, Offshore and Arctic Engineering; 2022-06-05 - 2022-06-10
NTNU OCEAN

Abrahamsen-Prsic, Mia; Solaas, Frøydis; Kristiansen, Trygve.
Hydrodynamic Coefficients of Generic Subsea Modules in Forced Oscillation Tests – Importance of Structure Parts. I: ASME 2022 41st
International Conference on Ocean, Offshore and Arctic Engineering Volume 1: Offshore Technology. The American Society of Mechanical
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Online wave direction and wave number estimation from surface vessel motions using distributed inertial measurement arrays and phase-timepath-differences. Ocean *Engineering* 2022 ;Volum 249.
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Erstad, Erlend; Larsen, Marie Haugli; Giskeødegård, Marte Fanneløb.
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2022-06-14 - 2022-06-15
NTNU

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Distributed teams in remote operations - Communication and situational awareness. SFI-Move autumn conference 2022; 2022-11-29 - 2022-11-
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OCEAN

Jagite, George.
On the deterministic prediction of waves using real X-Band radar measurements. SFI MOVE Conference;
2022-11-01 - 2022-11-01
OCEAN

Koilo, Viktoriia.
A framework for cost-benefit analysis of business model within maritime remote operations. SFI- MOVE autumn conference; 2022-06-14 - 2022-
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Business model for integrated sustainable value creation: A supply chain perspective. Problems and Perspectives in Management 2022 ;Volum
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16 - 2022-06-17
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The interplay between technological innovation, energy efficiency, and economic growth: Evidence from 30 European countries. Problems and
Perspectives in Management 2022 ;Volum 20.(3) s.448-
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Larsen, Marie Haugli; Erstad, Erlend.
Maritime cyber security training and awareness. SFI-Move spring conference 2022; 2022-06-14 - 2022-06-15
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Experiences from testing of our Remote Operation Center. SFI-Move spring conference 2022; 2022-06-14 - 2022-06-15
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Installation of OWT with alternative vessel concept. SFI MOVE Spring conference; 2022-06-14 - 2022-06-15
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Mitigating Force Oscillations in a Wave Energy Converter Using Control Barrier Functions. I: ASME 2022 41st *International Conference on Ocean, Offshore and Arctic Engineering Volume 8: Ocean Renewable Energy.* The American Society of Mechanical Engineers (ASME) 2022 ISBN 978-0-7918-8593-2.
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Wang, Chunlin; Wang, Tongtong; Nord, Torodd Skjerve; Zhang, Houxiang; Li, Guoyuan; Osen, Ottar.
Uncertainty and sensitivity analysis for the performance evaluation of ship dynamical model. I: *Proceedings of The Thirty-second (2022) International OCEAN AND POLAR ENGINEERING CONFERENCE ISOPE-2022 Shanghai, China (Hybrid) June 5–10, 2022.*
2022 ISBN 978-1-880653-81-4. s.2309-2314
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Wu, Mengning; Gao, Zhen; Zhao, Yuna.
Assessment of allowable sea states for offshore wind turbine blade installation using time-domain numerical models and considering weather forecast uncertainty. *Ocean Engineering* 2022 ;Volum 260.
NTNU

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FMI-Based Co-Simulation of Low-Height Lifting System for Offshore Wind Turbine Installation. I: *ASME 2022 41st International Conference on Ocean, Offshore and Arctic Engineering Volume 8: Ocean Renewable Energy.* The American Society of Mechanical Engineers (ASME) 2022 ISBN 978-0-7918-8593-2.
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NTNU

Zhou, Hongyu; Ren, Zhengru; Marley, Mathias; Skjetne, Roger.
A Guidance and Maneuvering Control System Design With Anti-Collision Using Stream Functions With Vortex Flows for Autonomous Marine
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NTNU

Master's degrees

Name	Sex M/F		Topic
Saravanan Bhaskaran	M	Spring 2022	Operational Limit Assessment of Offshore Wind Turbine Blade Root Mating Process Using Response-based Criteria
Siren Huse	F	Spring 2022	Forankring av flytende vindmøller
Maiten Kase Corona	M	Spring 2022	Tensegrity-Based Semi-Submersible Support Structure for a Floating Offshore Wind Turbine
Servaas Sanders	M	Spring 2022	Feasibility assessment of novel on-site installation methods for offshore Ultra Large Wind Turbines
Lucas Lillie	M	Spring 2022	Offshore hydrogen production - Analysis of different methods for hydrogen production using offshore wind
Vignesh Balasubramaniyan	M	Spring 2022	Load transfer from coupled analysis to structure design of FWTs
Yu Ma	M	Spring 2022	Novel modeling and fatigue analysis for early-phase design of a 15MW FOWT
Fredrik Håland	M	Spring 2022	Combining fully coupled analysis and linear potential theory time domain analysis to obtain cross sectional loads in the substructure of a floating offshore wind turbine
Elias Strømmen Ravnestad	M	Spring 2022	Time-domain wave estimation and prediction using wave radar on R/V Gunnerus
Bjørn Theodor Torp Brørby	M	Spring 2022	Wave load compensation in DP control systems

Accounts

Project 1: OW: Low Cost Offshore Wind Installation and Maintenance – was completeted in 2016
Project 2: Subsea: Safe – All Year – Cost-efficient Subsea Operation - was completed in 2017
Project 3: Simulation Technology and Virtual Prototyping as a Common Approach from Design to Operation – was completed in 2017
Project 4: Seabed Mining: Exploration of Technologies to Develop Seabed Mining as a New Business Area – was completed in 2018
Project 7: Design for Workability – was completed in 2020

(All figures in 1000 NOK)

Funding		Project 5	Project 6	Project 8	Lab/Dissemination	Management	Total
The Research Council		**3 970**	**6 355**	**471**	**149**	**1 411**	**12 356**
The Host Institution, NTNU in Ålesund		**377**	**-**	**1 299**	**-**	**-**	**1 676**
Research partners:		**-**	**1 994**	**-**	**-**	**-**	**1 994**
	NTNU	-	319	-	-	-	319
	SINTEF	-	1 675	-	-	-	1 675
Enterprise partners:		**1 171**	**2 222**	**1 066**	**200**	**100**	**4 759**
Total		**5 518**	**10 571**	**2 836**	**349**	**1 511**	**20 785**

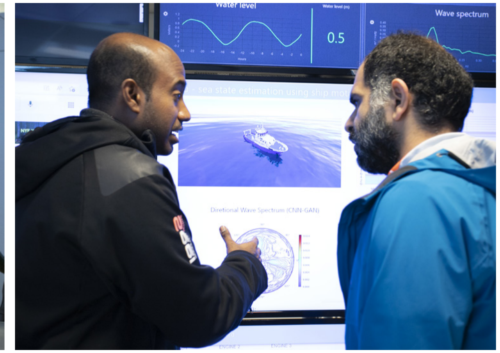
Costs		Project 5	Project 6	Project 8	Lab/Dissemination	Management	Total
The Host Institution, NTNU in Ålesund		**3 810**	**1 624**	**2 170**	**349**	**1 225**	**9 178**
Research partners:		**1 137**	**8 325**	**-**	**-**	**286**	**9 748**
	NTNU	1 137	2 125	-	-	286	3 548
	SINTEF	-	6 200	-	-	-	6 200
Enterprise partners:		**571**	**622**	**666**	**-**	**-**	**1 859**
Public partners		-	-	-	-	-	**-**
Equipment		-	-	-	-	-	**-**
Total		**5 518**	**10 571**	**2 836**	**349**	**1 511**	**20 785**

Name of ongoing projects in 2022:
Project 5: OW: Innovative Installation of Offshore Wind Power Systems
Project 6: On-board Decision Tool
Project 8: Remote Operations / Dispersed Teams
RA 5: Lab/Dissemination
RA 6: Management

Spring Conference

Ålesund, June 14

Text: Else Britt Ervik



Solutions of the future for the maritime industry

The maritime industry in Norway depends on research to sustain its position as a global leader. Technology in offshore wind, autonomous ships and cyber security are among the issues on the radar of the research community at NTNU when they meet their industry partners in the million-krone SFI MOVE project.

The many partners meet regularly for status reports as well as updates on new research and new directions in the industry. This time, Herbjørn Haslum from Equinor had the opportunity to tell the story of Hywind Scotland, and he emphasized the importance of being connected with the academic world.

– "We are involved in sponsoring the project run by NTNU, and we provide guidance to PhD candidates."

Hywind uses floating wind turbines – that is, they are moored to the seabed with an anchor system at great depths. At SFI MOVE, extensive research has been conducted on transport and installation of the large components out to the offshore wind farms. Extensive simulator testing takes place at NTNU before the marine operations start.

– "Offshore wind costs more, but the potential for greater capacity is an important factor. Hywind is the offshore wind farm with the highest capacity factor," Haslum notes.

Research with direct benefits for industry

The Department of Ocean Operations and Civil Engineering is leading the eight-year research project SFI MOVE. A wide range of major players in the maritime sector are involved, working together with researchers on future solutions in areas such as offshore wind, autonomous vessels and cyber security.

In the sphere of cyber security, participants were given a demonstration of an exercise using digital twin technology. The expert community took the opportunity to present important exercises that can be achieved using simulation.

– "Digital twins are something everyone talks about, but few people have actually seen," said the Head of Department, Hans Petter Hildre.

He leads the prestigious project with a budget totalling hundreds of millions of kroner. One aim of frequent gatherings in the large project is specifically to enable researchers to learn more about the challenges facing the industry and get to grips with them. This leads to results with direct benefits for the various sectors.

Knowledge and development through cooperation

One of these is Pål Slotterøy from technology provider Deep Ocean.

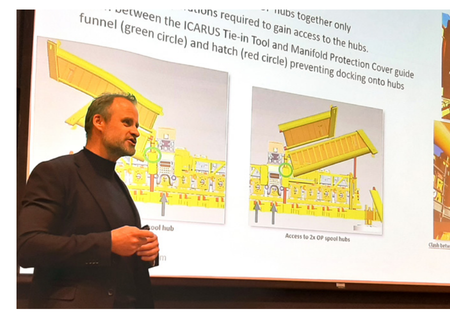
– "We keep track of ongoing development," said Slotterøy. "One has to do that to gain more knowledge and development. The SFI MOVE project has many interesting focus areas for us, and we find it especially interesting that there are different ways to do simulation."

Gowtham Radhakrishnan is a PhD candidate at NTNU, and greatly appreciates the regular meetings with industry players.

– "The ability to calculate the movements of vessels based on data on wave and wind conditions is one of the aspects I am exploring in my research."

In his research, he gets access to data collected by the industry partners, which is important for making progress in the field. Such data is not usually easy to access, and it comes at a price. According to Gowtham Radhakrishnan, working at NTNU is interesting and goal-oriented.

– "SFI MOVE creates a fantastic networking platform through regular conferences that make it easier for me to interact with other researchers and industry personnel."



Autumn Conference
on Teams,
November 29

Agenda

12.00	**Introduction Hans Petter Hildre**
12.20	**Simulation capabilities**
12.20	Splash zone hydrodynamics – Challenges, analysis methods and case studies Reza Firoozkoohi, SINTEF Ocean
12.50	Coffee break
13.10	Hybrid simulation case, OWT Karl Henning Halse, NTNU
13.40	Co-simulations Shuai Yaun, NTNU
13.40	Coffee break
13.50	**Predictions**
13.50	On the deterministic prediction of waves using real X-band radar measurements George Jagite, NTNU/SINTEF Ocean
14.20	Restricted and unrestricted operations – Some thoughts on how to maximize the operational sea state for a restricted marine operation exceeding 72 hours Robert Indergård, Senior Advisor, SINTEF Ocean
15.00	**Remote operations, the future of marine operations**
15.00	Examples; NTNU/Gunnerus, Kongsberg and Subsea 7 Marie Haugli-Sandvik, NTNU
15.20	Distributed teams Marie Haugli-Sandvik, NTNU
15.40 Closure	

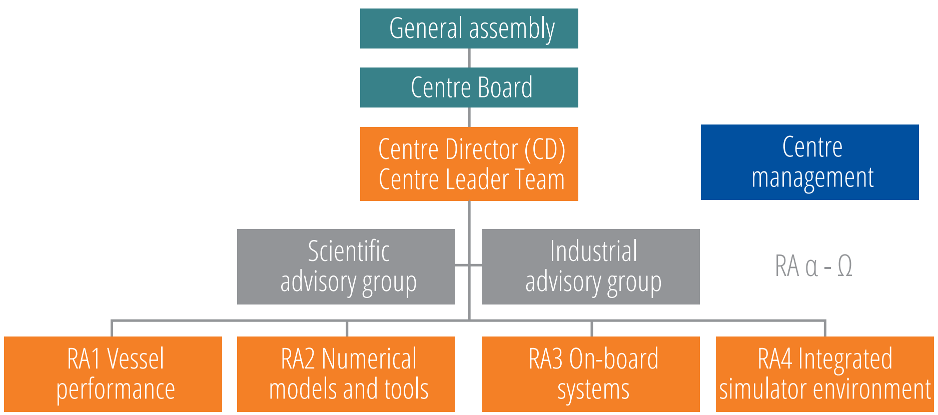
Research organisation

The following research partners were involved in 2022:

- NTNU in Ålesund (former Ålesund University College)
- NTNU
- SINTEF Ocean

Ålesund University became a part of NTNU in 2016, and MARINTEK and SINTEF Fisheries and Aquaculture became SINTEF Ocean in 2017. We are very pleased for the restructuring of the research partners in few and strong organisations.

The project is organised as shown in the figure.



Organisation chart

The project leaders are:

Project	Project Leader
Innovative Installation of Offshore Wind Power Systems	Karl Henning Halse, NTNU
On-board Decision Tool	Egil Giertsen, SINTEF Ocean
Remote Operations/Dispersed Teams	Marie Haugli-Sandvik, NTNU

The Board of the Centre had the following Members in 2022:
Rafael Rossi, Chairman (TechnipFMC)
Erling Myhre, (Equinor)
Tore Ulstein (Ulstein Group)
Sverre Torben (Kongsberg, former Rolls Royce Marine)
Hans Petter Hildre (NTNU in Ålesund)
Sverre Steen (NTNU)
Harald Stenersen (Havila)
Arne Fredheim (SINTEF Ocean)
Runar Stave (Olympic)

Centre Director:
Hans Petter Hildre, Professor, Head of Department of Ocean Operations and Civil Engineering, NTNU in Ålesund

Administrative key personnel:
Magnhild Kopperstad Wolff, Finance & Administrative Coordinator, SFI MOVE, Adviser at Department of Ocean Operations and Civil Engineering, NTNU in Ålesund

Industrial partners:
Two of our partners, Statkraft and Cranemaster, decided to withdraw from SFI MOVE from January 2017. A third partner, EMAS-AMC, closed the business in February 2017. In addition, Farstad and ÅKP/GCE Blue Maritime decided to withdraw from the project from January 2020. On the other hand SFI MOVE got two new partners in 2019, Subsea 7 and TechnipFMC.

The industrial partners in the project in 2022 were:
Olympic Shipping
Havila Shipping
Kongsberg (former Rolls-Royce Marine)
Ulstein International
OSC
Vard
NTNU Ocean Training
Equinor (former Statoil)
Havfram (former Ocean Installer)
DNV (former DNV-GL)
Subsea 7
TechnipFMC