Annual Report 2019

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SFI MOVE

Marine Operations in Virtual Environments

SINTEF NTNU

sfi Centre for Research-based Innovation

MOVE
SFI Marine Operations

Industrial partners:

Research partners:

MOVE
SFI Marine Operations

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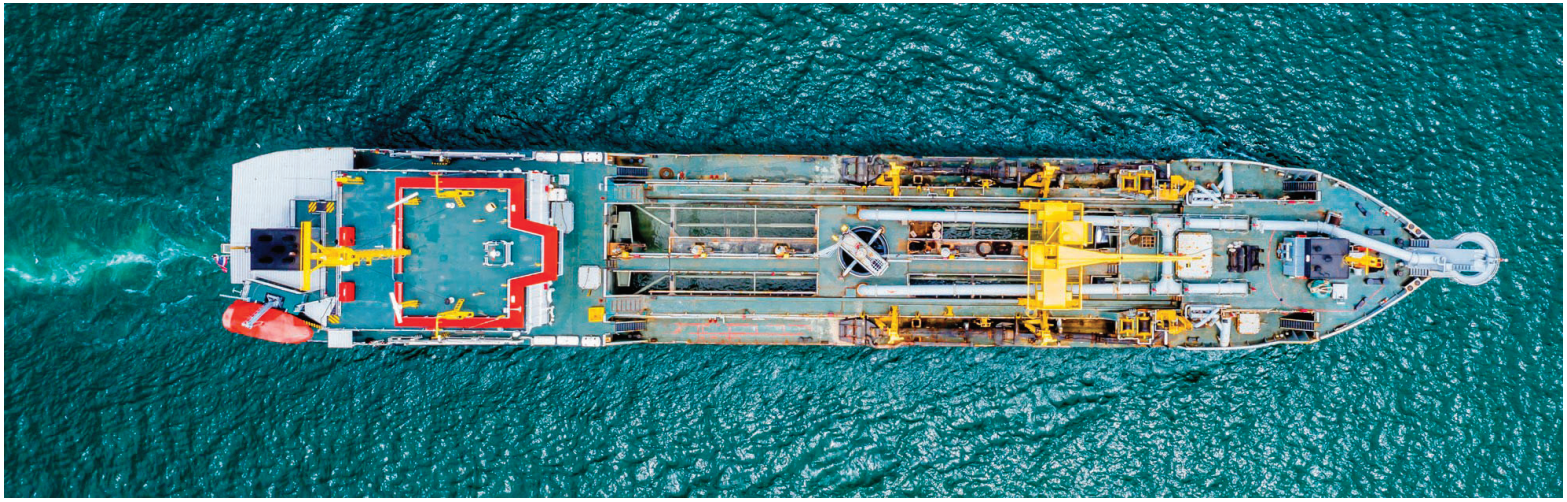
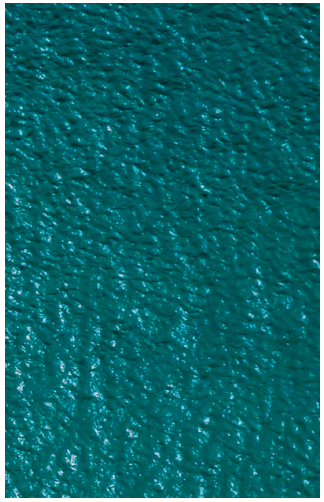




Our vision

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

Simulation has been used for decades to test the physical aspects of marine operations. Simulators are used to train crew to perform demanding operations. Next generation technology has the potential to provide Virtual Prototyping to pre-test marine operations, including the human component.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

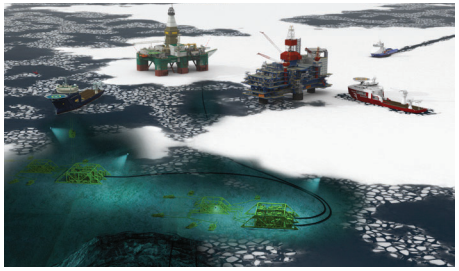
The idea is to optimize operations, from planning to execution, by better understanding of the responses. This is a simulation oriented approach where models are re-used throughout the value chain. To fulfil this goal the following is of vital importance:

- 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)

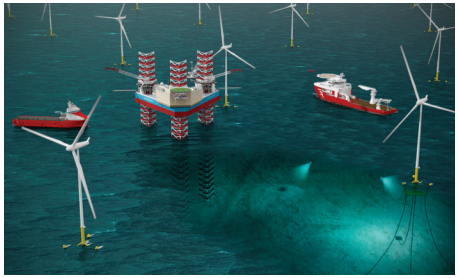
Business areas

The business areas focused on in 2019 are:

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



- Installation and maintenance of offshore wind



- Management of marine operations and shipping

Foto: Kristoffer Furberg, Universitetsavisa

Directors' report

Professor Hans Petter Hildre is the leader for SFI MOVE

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

SFI MOVE passed the halfway mark of the programme period in 2019. It is time to reflect on what we have achieved up to now, and visions and plans for the last half of the programme.

At the end of 2019, SFI-MOVE had produced the following scientific merits

- 49 journal papers,
- 132 conference contributions,
- 76 MSc theses
- 5 PhD
- 4 Post Docs

The project team met the Scientific Advisory Group (professor Torgeir Moan and Odd Faltinsen) for assessment and advice in February 2019. The feedback with respect to scientific production was very good. They recommended to increasing the cooperation with other centres and investigating splash zone responses.

On 11 April an evaluation team met the Centre Director, board members, project leaders, industry representatives, postdocs, PhD students and representatives for the host institution, NTNU.

The feedback from the evaluation committee was also very positive. The committee advised the centre to put effort into increasing international collaboration, improve gender balance and focus on ensuring that all partners benefit from the project.

Measures for improving international co-operation have been implemented. See the paragraph regarding international co-operation. Measures relating to how we can increase interaction with the companies is ongoing and will be the main theme at the SFI MOVE Conference on 27 May this year.

Plan for the final program period

The following projects are planned for the final period.

Ship responses.
Case: Design for workability

The focus in hydrodynamic optimization for most vessels is mainly on energy efficiency often in calm water for sea trial purposes at ballast condition. This remains important, but for some vessel types, vessel motions will limit operational performance significantly. Thus, a more balanced approach including the assessment and optimization of efficiency and workability in other operational modes is required especially in marine operations. Design for workability focuses on development of tools providing guidelines for design optimization and vessel selection based on the requirements to be satisfied aiming at an improvement of operational performance over a wider range of criteria.

Project leader: Martin Gutsch

Operational responses.
Case: Installation of OWT

Fewer restrictions on size and height than their onshore counterparts, offshore wind turbines are becoming giants. 12 MW turbines design at 260 metres height is launched. Installation is moving further from shore, tapping better quality wind resources and pushing up capacity factors. Next generation giant turbines demand new methods for installation. Installation methods for floating wind that can be used on a global scale do not exist. SFI MOVE is committed to continuing our work to contribute to ideas and technology to reduce costs of installation and maintenance of offshore wind installations. SFI MOVE has been working with methods to handle and compensate for forces and movements cause by waves, wind and current. It is a clearly defined goal to find new innovative methods to do installation at low cost and on a global scale. It is also a goal to establish a simulation workbench for such operations.

Project leader: Karl Henning Halse

On-board decision support system.
Case: Subsea installation operations

Historically, the operational limits for various marine operations have typically been limited by wave height level. The goal for this project is to develop tools calculating real responses. The idea is to add the possibility of performing on-board simulation where the theoretical hydrodynamic models are corrected by real-time measurements for vessel motion and response. Combined with information about development of environmental conditions through weather reports and the development over time for the actual measured responses for the vessel, this will form the basis for prediction of vessel behaviour. Based on these predictions the system shall be capable of predicting the present and near future vessel response and lifting equipment forces. Combined with limiting criteria for operations, required weather window, safety factors etc. real time advice on feasibility of performing the marine operation in question shall be given. The core of the project will be effective on board predicted simulation and predictive analytics tools. The idea is to reuse models from engineering for briefing, at position, on operations, and finally in de-brief.

Project leader: Henning Borgen

Remote operations.
Case: Dispersed teams

We are facing a wave of digitalisation in the industry. The introduction technologies such as IIoT, cloud computing, digital twins and AI are opening new possibilities for dispersed ship crews. Increased use of advanced tools for evaluation system performance and safety are generating a range of digital models of a vessel and its equipment. The idea is to have crew that is partly on-board and partly in a support centre. We can see following benefits.

1. Improved quality of operation by access to needed competence.
2. Reduced cost due to reduced crew on board.

Project leader: Frøy Birte Bjørneseth

An overall plan for the final delivery for the ongoing projects

The Centre Board has underlined the importance of digitalisation of marine operations. How to draw benefit of data in models and decisions. Work to include machine learning in the project will be an important task in 2020. We have defined the following key deliveries for each project at the end of the period:

Ship Responses – Design for workability
- Holistic seakeeping optimisation strategy
- Methods and tools for the ship behaviour implemented in the industry

Operation responses – Installation of offshore wind
- Simulation workbench for offshore wind installations
- A novel design for floating offshore wind

On-board decision support – Subsea installation operations
- On-board decision support for subsea lifting operation, from lift off to landing
- Simulation tool, covering from sales, engineering, on-board and remote operations.

Remote support, dispersed teams
- Fully demonstrations of remote operations & dispersed teams
- A remote operation centre implemented as a demonstrator at NTNU

A road map for each project is defined to describe the step-by-step deliveries needed to achieve the final deliveries.

The table shows the final goal for the project.

1. Established world leading research and innovation centre for demanding marine operations
2. System simulation workbench for real responses:
   - A. Modular set of models allowing simulation of subsea operations and offshore wind installations (FMI/FMU modules)
   - B. Ship behaviour & data-driven tuning of ship models
   - C. Prediction of future weather responses
   - D. Backbone of simulation capabilities from sales, engineering, on-board and remote operations
   - E. 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)

Foto: Halvard Aasford

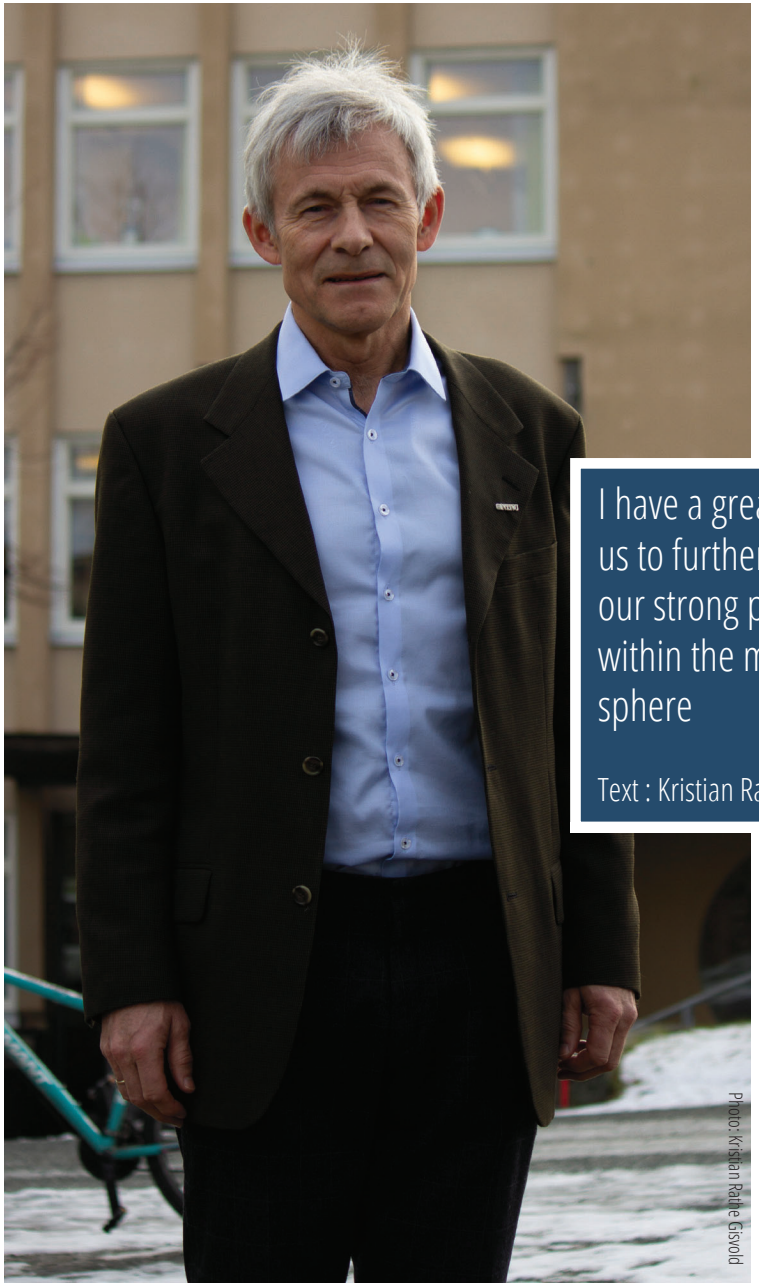


Photo: Kristian Rathe Gisvold

I have a great wish for us to further develop our strong position within the maritime sphere

Text : Kristian Rathe Gisvold

For landlubber Olav Bolland the ocean has become one of the most importand areas of concentration. He is of the opinion that the key to success is interdisciplinary co-operation.

Main profile:
Olav Bolland

Professor and dean at Fauculty of Engineering. Project administrator, SFI MOVE

« It is probably such that I do not have a very great relation to the sea. I am born a landlubber in Gauldalen, so my affiliation with the ocean is somewhat limited», replies Olav Bolland to questions regarding what the sea means to him personally, before he adds:

«It shall be said that I ended up by marrying someone from Hitra, and so through her I became familiar with ocean culture and fishing culture, and many new concepts and meals, such as salt fish balls. So in a way it was a revelation, especially the fishing culture. And only to have said it, I have still not reached the point where I *must* get out on the sea. It is very clear at Hitra that when people come home at the weekends, they have to get out on the sea. I am not there. For me it has always been to get out in the forests and nature».

Even though his experiences of the ocean in his childhood were limited to bathing at Øysand by Melhus, today Olav is in a position where the sea is difficult to avoid. As Dean of the Faculty for Engineering Science at NTNU, the ocean is a more important area than ever for research. The ocean is one of the approved areas of concentration at NTNU. Together with energy, sustainability, and health, the ocean areas are what NTNU shall concentrate most on towards 2023.

«When NTNU merged with the University College in Ålesund in 2016, the competence within maritime education and research, as well as the close contact with industry, was a lot of the motivation. And it shall also be said that the ocean has always been an important arena, both for the Norwegian engineering environment and industry, so it is something we have a lot of competence in», he explains.

The importance of working in an interdisciplinary environment

It is just here that something that Olav is passionate about comes into the picture: Interdisplinary co-operation, and using old knowledge in new areas. He is a professor in thermal energy production, and has worked very much with storage of CO2. It is important to him that the subject environments work together, in order to utilise existing and new knowledge as well as possible.

If we capture CO2, our storage possibilities are on the seabed. It is after all an oycean industry, in any case where storage itself is concerned. We see there, too, that there is a great need for developing technology and competence. We only know about capturing CO2 on a small scale, but so that it will help in a climatic context, it must take place on a very large scale. Here there is a lot that is transferable from our environments that work with geology and petroleum technology. We need much of the same competence to find out how CO2 can be safely stored far under the seabed, as is needed for finding and extracting oil and gas.

He also sees such utilisation of knowledge in the contours of what is to be one of NTNU's greatest projects of concentration: Ocean Space Centre.

It has been a very long process that has been ongoing since 2005. In the beginning the plan was to only build new laboratories at Tyholt. On the other hand, after the merger we saw that the professional environment at Ålesund had suitable competence for us so that we expanded the concept to include Ålesund. So now the plan is that in addition to building new laboratories at Tyholt, there shall be installations at Ålesund and along the Trøndelag coast. Ocean Space Centre will considerably strengthen our ability to operate with research and education.

«Important locomotives»

In that connection, Olav also includes the centres. NTNU is involved in several types of centres: Centres for excellence in research and education (SFF/SFU), Centres for research-based innovation (SFI), and research centres for environmental-friendly energy (FME).

We see that the centres are extremely important locomotives in our research. The centres entail long-term financing, and they provide a stable framework for achieving a lot of good research. The centres also connect students and tuition closely with research and industry.

For NTNU, and probably also especially the Faculty of Engineering Science, the co-operation with industry has always been important.

It is industry that to a large extent takes our students, and has a need for our research. NTNU's philosophy is to work closely with working life. And we have many projects that co-operate with others. Many of our projects are financed both by The Research Council of Norway and industry. It is also important with regard to education. The close co-operation provides students who become involved with these activities, such as SFI MOVE, the opportunity to get into close contact with industry, and provide them with knowledge on which challenges and problems the individual sector has. That gives the students increased relevance.

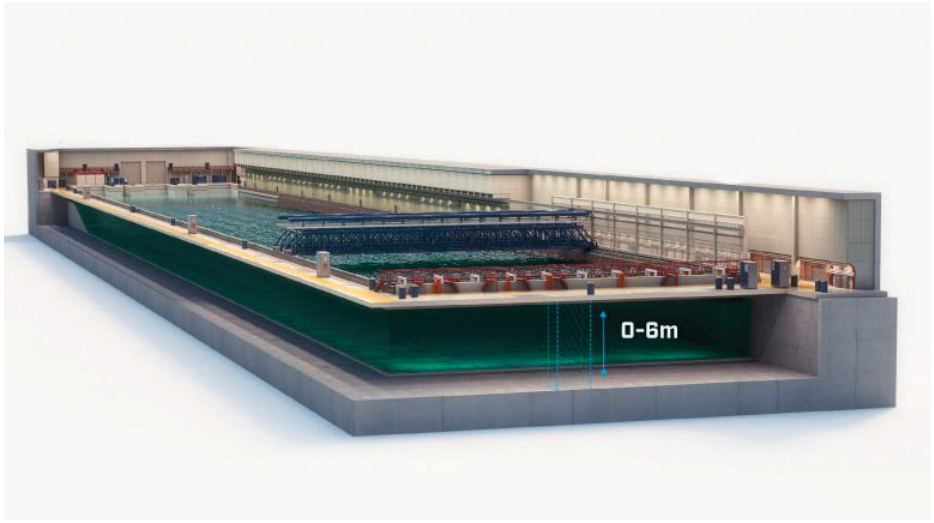
«Can outgrow oil and gas»

Olav is of the opinion that when it comes to using the ocean in the future, it will to a great extent be about how it can create values.

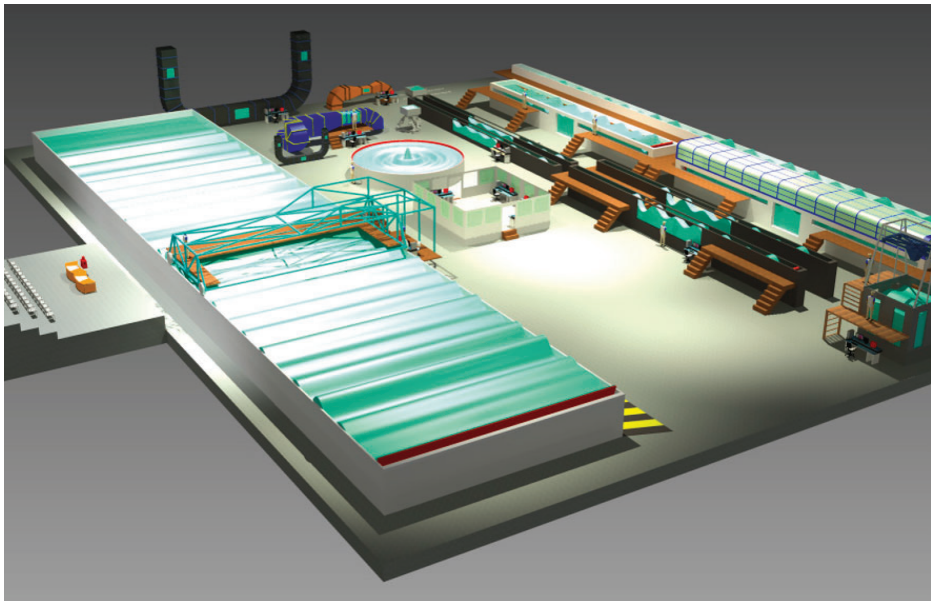
«Oil and gas have already been, and will probably still be important when it concerns value creation in the ocean. The extent of the activity in oil and gas will decrease over time. At the same time, other things such as offshore wind energy, will be very exciting. It is one of our large areas of effort concentration, and has been for a long time. There is great potential for installing offshore wind energy, even though it is not completely problem-free.»

He is of the opinion that the challenges also include that the costs so far have been too high.

«If they decrease it can be extremely profitable in a short period of time. We also have a challenge in that even though the ocean is large, it is not just to use area. If installations are set up in the ocean, there will be consequences for someone.»



Ocean Space Centre – Sjøgangsbassenget.



Ocean Space Centre – Undervisningslaboratorier – Flex lab area.

Somewhat as the same way on land, he sees it that there can be conflicts of interests. For example in connection with shipping traffic, fishing, and environment. Nevertheless, he thinks that it is important to concentrate efforts on it.

«There is a great potential, even though it is not straightforward. I think it is very important, and right, that we work with this.»

Another industry he has great faith will continue to grow is aquaculture, but that also requires a lot of development. To continue growth the industry must scale up further, and with that comes more challenges.

«It is a growth industry which in the future will possibly outgrow oil and gas, but then one has to go further out to sea, larger installations must be built, with increased need for transport. That is something we must ensure takes place in a safe and environmental friendly manner. Then ships of the future must be more environmentally friendly than the ships of today. Both where fuel is concerned and with regard to the propulsion macinery. If you are going to develop things, there are always challenges connected to it. A clear framework condition is that what we develop must be environmentally sustainable, and that challenge is very great. It is not always easy to combine economic growth with environmental sustainability. But is something of the most important we are working with.»

And here we are back to Olav's main message: We already have some of this technology and competence.

«An example is gigantic sea pens which take millions of fish. To build them we can utilise technology that is used at present within building of oil platforms. The knowledge we have can also be used to build offshore wind energy installations, and much more. It is about getting the various professional environments to find each other and co-operate. I have a great wish that we shall further develop our strong position within the maritime area, both in Norway and internationally. Then we need good research installations, such as Ocean Space Centre, but it is also important that we all pull in the same direction, and that our professional area are capable of working in a good and interdisciplinary manner. In that connection the centres such as SFI MOVE are extremely important.»

Trondheimsfjorden
- Autonomy and interventions
- Monitoring technology
- Digitalisation

Hitra/Frøya
- Fish farming technology
- Monitoring technology

Ålesund
- Full scale maritime testing
- Simulation center
- Monitoring technology

Ocean Space Centre – Fjordlaboratoriet

Mid-way evaluation of SFI MOVE

The Research Counsel of Norway performed a mid-way evaluation of SFI-MOVE in the spring of 2019. The following documents were developed:

A. The Centre self-evaluation
B. Fact sheet for the Centre
C. Host institution assessment
E. Project description for the final three-year period and further plans

The project team met the Scientific advisory group (professor Torgeir Moan and Odd Faltinsen) for assessment and advice in February 2019. Key facts: 36 journal papers, 91 conference contributions, 24 MSc theses in 2016, 15 in 2017 and 16 in 2018. The feed-back with respect to scientific production was very good.

They recommended to increasing the cooperation with other centres and investigating splash zone responses.

The mid-way evaluation was performed by an international expert group:

- Professor David Williams (Chair)
- Professor Knud Benedict
- Professor Atilla Incecik
- Professor Mattias Lundberg

On the 11th of April an evaluation team met the Centre Director, board members, project leaders, industry representatives, postdocs, PhD students and representatives for the host institution, NTNU. In the morning the discussion focussed on the research at the Centre and included a visit to the simulation facilities associated with the Centre. In the afternoon there was a meeting with students as well as a discussion on industry involvement, management, organisation of the future of the Centre. The evaluation was based on these interviews and the written reports, and self-assessment supplied beforehand.

The feedback from the evaluation committee was very positive:

> "The Centre has outstanding research activities and shows the development of an excellent competence profile."

> "The Centre is composed of excellent strategic research programmes which are well structured both as

individual programmes and as a portfolio. The team, both the management and the board, was able to very successfully overcome a turndown in some areas of the industry by developing new business and research areas in response to the needs of the industry."

"The centre has a clear identity and is visible within industry and locally. The centre partners are visible internationally. The centre clearly has excellent leadership and a good board. The centre is well organised and management is high performing. Communication between the sites of the centre is good."

"MOVE is an inspiring centre. It is delivering world class research that is of clear benefit and utility to its partners. It is well managed and all partners are clearly engaged in its work. It forms a key component of the local internationally important maritime cluster and is acting as a nucleation point for other significant initiatives."

The committee advised the Centre to put effort into increasing international collaboration, improve gender balance and focus on ensuring that all partners take benefit from the project.

The recommendations and corresponding actions are summarised as follows:

Recommendation 1: The Centre should consider carefully expanding complementary international research collaboration.

- Measures were already completed in the summer of 2019 and presented to CB. We carried out a visiting round to Perth in Australia. The companies Woodside, Subsea7, Chevron, Fugro, Conoco Phillips and Aker Solutions were visited. In addition, we accomplished a joint workshop with Curtin University and a mini conference with simulations and training within maritime operations.
- We have established a strategic co-operation with Harbin University (China). We have already had two visits from Harbin and we are visiting Harbin this coming March.
- We are working with co-operation partners within offshore wind.

Recommendation 2: The Centre must constitute a gender balanced and truly international scientific advisory board with clear terms of reference including the re-equipment to prepare short written reports capturing its feedback.

- The Scientific Advisory Board consists of Torgeir Moan (NTNU), Odd Magnus Faltinsen (NTNU).
- We are now taking up maritime operations within wind more intently, and with this starting point see some solutions we are working with. We anticipate having an expanded Scientific Advisory Board in place during 2020 and the appurtenant «approval» in CB in November 2020.

Recommendation 3: The Centre should maintain its focus on ensuring that all partners take benefit from its work. Master students' projects are a god mechanism to permit this.

- This problem has been communicated to and discussed with the persons involved at NTNU and SINTEF and we are systematising the work with connecting MSc assignments towards projects in SFI MOVE and company involvement. This theme will be extensively debated during the SFI MOVE Conference on 27 May 2020.

Recommendation 4: In its reporting the Centre must more clearly distinguish those associated projects and other initiatives directly arising from the work of the Centre.

- Our goal has always been to estabish connections with associated projects and associated PhD students. We think that this is the correct strategy, but we will improve our communication, so that what is financed under SFI MOVE can seen clearly.

Recommendation 5: The Centre has had some success in addressing its gender issues and should build on this by increasing its capability in this area with the target of increasing the rate of change in gender within the sector.

- We are working to find women PhDs and PDs within the area. This is a challenge, but we regard this as a particularly important task.

The Board at the Research council of Norway confirmed in the autumn of 2019 that SFI MOVE can continue without any corrective actions from the Council.

The mid-way evaluation has been a key issue at the Centre Board meetings in 2019. The Centre Board is satisfied with the evaluation and is focussing attention on the final programme period.

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*

Active projects in 2019:

Project 5: OW: Innovative Installation of Wind Power Systems
Project 6: On-board Decision Tool
Project 7: Design for Workability
Project 8: Dispersed ship crew/Remote operations

Project 5

Project Leader:
Karl H. Halse, NTNU Ålesund

OW: Innovative Installation of Wind Power Systems

The installation costs of a typical offshore wind power plant, form 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. Today, fixed Offshore Wind Turbines (OWT) are installed with the use of high lift cranes from jack-up platforms (or jack-up ships). This is a costly and time-consuming way of installing the turbines. 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.

A fundamental idea for much of the work in SFI MOVE is to be able to extend the concept of simulating marine operations to be more than a training tool. We want to use the simulator also as a demonstration and design tool.

Installation of a floating Offshore Wind Turbine from catamaran

The challenge with the proposed concept is to reduce the relative motion between the OWT tower and the floating foundation. During 2019, the project has evaluated various control strategies for the lifting mechanism. The present concept consists of a crane where the payload is held by a number of lifting wires, and the relative motion is controlled by winch control. Inspired by the knowledge of inverse dynamics and range-based localization, a model-free controller is developed. It has a simple control design and the freedom from building the control allocation matrix, but it can reduce the pendular payload motion regardless of the detailed system configuration

The design of the proposed lifting mechanism was modelled in SIMO to verify the hydrodynamic behaviour of the concept. The catamaran vessel and the floating SPAR were modelled and coupled dynamic analyses covering a wide range of waves were performed. Dynamic analyses with the coupled system have been carried out to study the relative motion and the performance of the active heave compensation (AHC) system over a range of waves. Waves covering significant wave heights from 0.5 m to 2.5 m and with a wide range of spectral peak periods. In the present phase of the work, we have studied the relative distance between the OWT tower and the floating SPAR. The AHC device has been very effective in reducing the relative motion characteristics between the OWT tower and the SPAR top, but to the expense of increased forces in on the lifting wires.

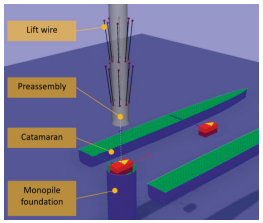
A more detailed system configuration design of the proposed concept was modelled in OSC simulator with the focus on mechanical behaviour. Different control algorithms were put into test on top of realistic physics model of winch, wire, joints and rigid body.

Installation of a floating Offshore Wind Turbine from a floating dock (the work by PhD student Maël Moreau)

An alternative concept, with a floating dock to shelter the assembly process, has been introduced to facilitate the offshore installation of floating wind turbines. Wave-induced motions of the dock and motion-induced waves inside the dock have been identified as potential challenges for the success of this concept. During 2019, hydrodynamic studies of the floating dock proposed by SFI MOVE have been conducted, focusing on the sloshing resonance under normal weather conditions. Model tests were carried out in the large towing tank at SINTEF Ocean for both the dock alone, and with the presence of a spar inside. Several damping devices were also tested to reduce the internal waves and the spar's motions, with a good efficiency achieved for annular baffles. In parallel, a fast potential code taking advantage of the dock and SPAR's revolution has been developed to extend the study to more geometries and sea states. This work will be continued by proposing a numerical model of the damping baffles.

Installation of an Offshore Wind Turbine on a fixed foundation.

The work in SFI MOVE related to fixed OWTs has been carried out as PhD studies. Two PhDs completed their work during 2019. A brief summary of their work is given below



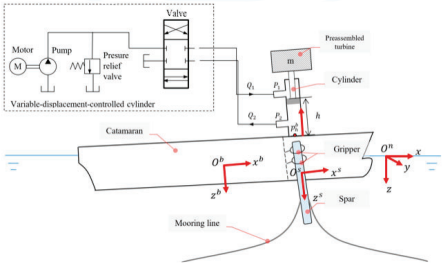


Figure 2. Illustration of the catamaran vessel for installing a pre-assembled rotor (left) and the motion compensation system (right)

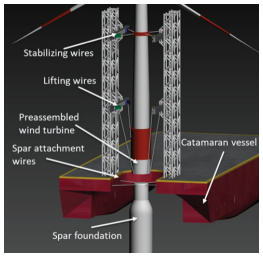


Figure 1. Catamaran vessel installing an OWT tower onto a floating SPAR-type foundation

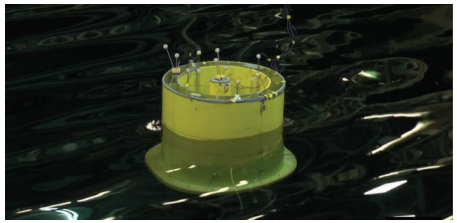


Figure 3a. Experimental test of the floating dock

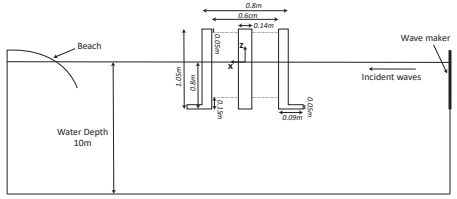
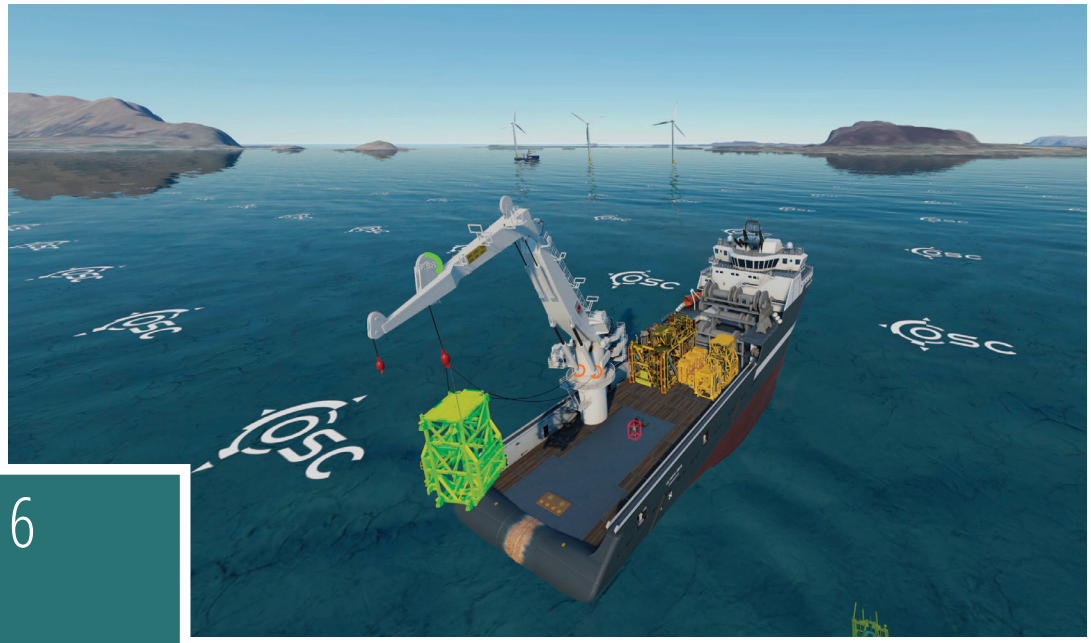


Figure 3b. Experimental set-up of the floating dock test

- **Wind turbine blade installation considering structural response-based criteria (the work by PhD student Amrit Verma).**
  A global response analysis of a single blade installation was studied. An assessment of the blade damage due to various impact scenarios was carried out. Subsequently a probabilistic responsebased method for assessing the limiting sea states for blade installation was developed and proposed. The candidate successfully completed his PhD work in 2019.

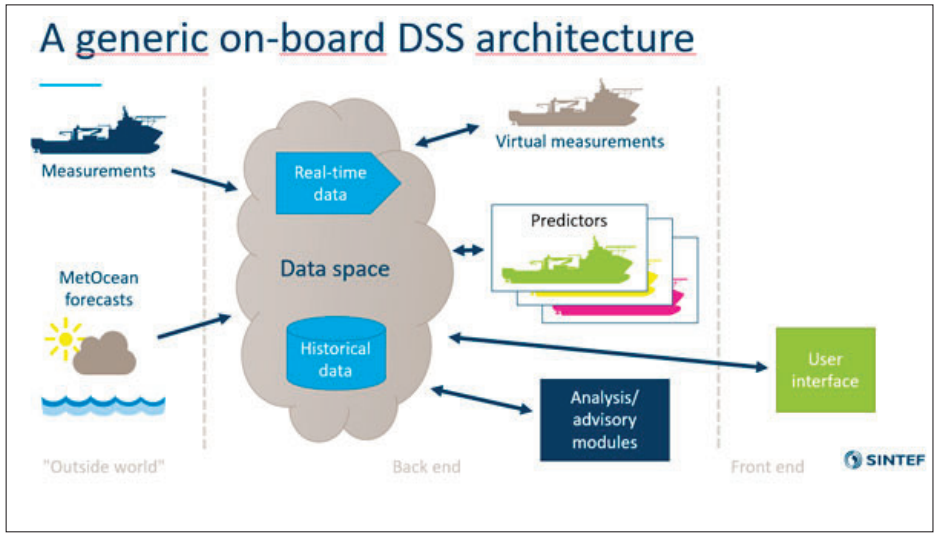
- **Optimal lifting control and real-time hub motion monitoring in single blade installation (the work by PhD student Zhengru Ren).**
  A nonlinear predictive control (NMPC) scheme is capable of controlling the relative motion and at the same time preventing snap loads and high axial peak tension. Automatic control theories are used to optimize the blade installation operation by minimizing the relative motion between the blade root and the hub. Global positioning systems (GPS) are integrated with an inertial measurement unit (IMU) to provide high fidelity hub motion estimations. The candidate successfully completed his PhD-work in 2019.

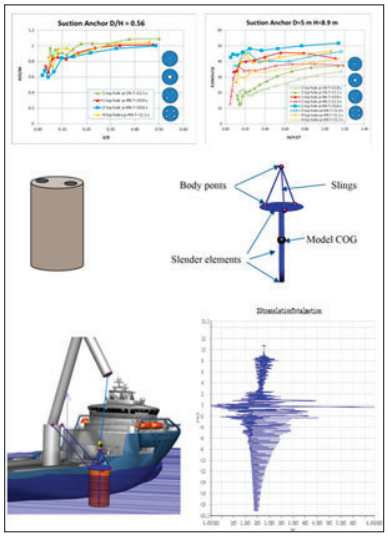


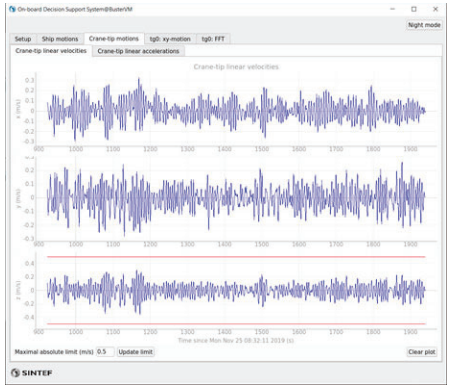
Project 6

Project Leader:
Henning Borgen,
SINTEF Ålesund/SINTEF Ocean

On-board Decision Tool







The personnel working on the On-Board decision tool (ODSS) project are developing technology on how to use operational data from ship sensors to monitor and predict the response of vessels and their lifting equipment. Based on this information, advice is given 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 *Olympic Challenger*, a light construction/ROV support vessel owned by Olympic Subsea, has been selected to serve as a case study for the project. During 2019, instrumentation and installation of logging equipment has been carried out. This equipment will continuously record the position, heading and motions of the vessel. We are using this information for development and testing of the ODSS. The plan is to demonstrate the system in actual operation onboard the Olympic Challenger.

In 2019 the project has continued the development of the flexible architecture for real-time onboard decision support software. There has been continuous development of the basic framework, and new functionalities are added, such as virtual measurements (observers and alternative realities) and predictors (near future predictions through simulations), including integration towards SIMO through the FMI/FMU standard.

The framework including a simple frontend (user interface) were demonstrated live at the SFI MOVE autumn conference based on playback of recorded measured data from the project case vessel Olympic Challenger for the load in air phase of a crane lift. In this demonstration, the current framework functionality and examples of use of the ODSS for producing KPI relevant information for the load in air phase were demonstrated.

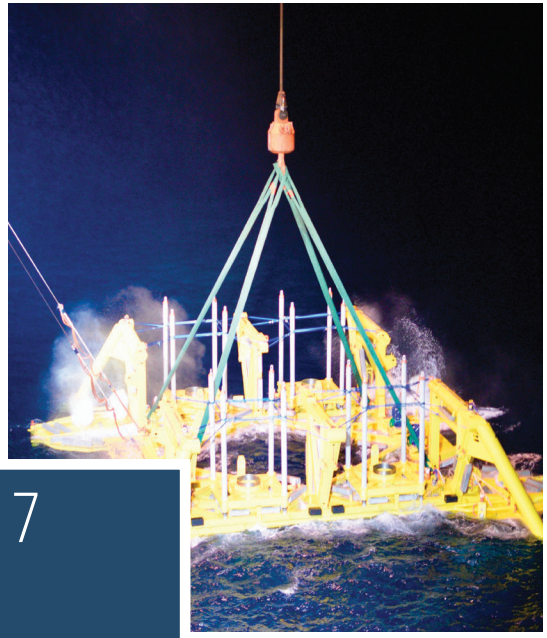
In 2019, the important task of establishing a method for live ship model parameter tuning based on full scale ship sensor data was started. This activity is in the core of the ODSS project, utilizing information from the operating vessel to improve the ship hydrodynamic model to a level as close as possible to the real vessel behaviour for the actual vessel setup during operation. Working as intended, the ship model parameter tuning method developed will take hydrodynamic ship models one step further in accuracy, closing the gap towards real digital twins of vessels. Such tuned models will also offer the possibility of improved accuracy of vessel models for future offline operation analysis onshore.

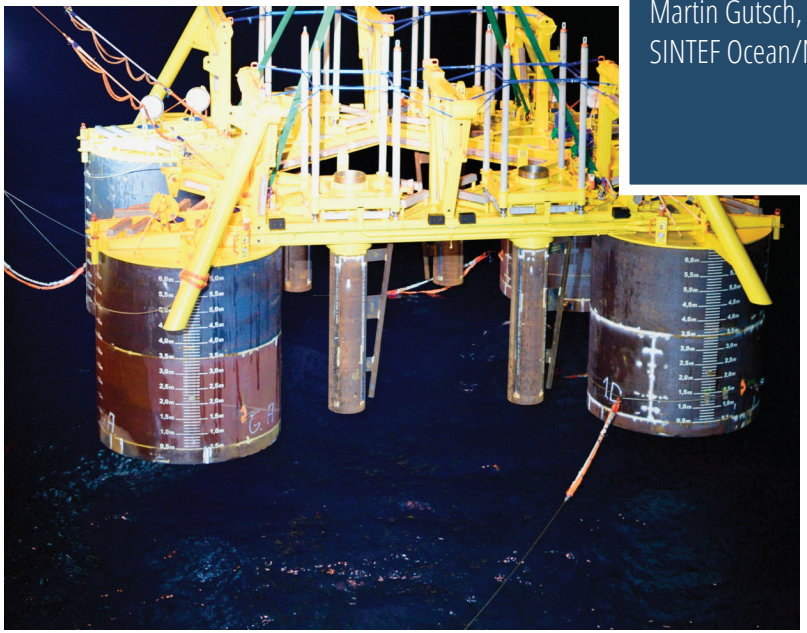
During 2019, a method was developed, implemented and tested towards model test data. The method shows promising results. In a model test, the environment data (waves) are however known down to a very detailed level, and the main remaining challenge will be how to establish a sufficiently good environmental data collection live offshore on a real vessel.

A good hydrodynamic model of the structure to be installed/ retrieved is essential for a reliable onboard decision tool for subsea lifting. In all cases, hydrodynamic coefficients for the structure to be installed have to be estimated. This is done by use of model tests, numerical CFD simulations or estimations based on experience and published data. Experience shows that the limiting sea□state will in many cases be dependent on the hydrodynamic coefficients used in the assessment.

In 2018, SINTEF and NTNU performed a comprehensive model tests series of conventionalized structure parts and combinations of structure parts. Totally 30 different structures parts and combinations were tested at fully submerged condition. In addition, some of them were tested close to and in the surface and in waves. In 2019 these model tests were analyzed, and the results are presented in two separate reports to the SFI MOVE consortium.

In 2019, the project has also produced a report on how to do numerical modelling of installation operations as a practical guideline on how to establish and use hydrodynamic coefficients for typical structures to be installed on the seabed.





Project 7

Project Leader:
Martin Gutsch,
SINTEF Ocean/NTNU

Design for Workability

The offshore industry operates increasingly large installations in exposed areas, requiring high reliability and availability. Downtime of complex offshore systems leads to significant financial losses. To enable year-round offshore installation and maintenance services, this research focuses on the development of tools and software for the time-efficient identification of weather robust vessel designs and operating scenarios as a requirement to operate safely in higher sea states. Even though it might be obvious that the response behavior of a larger vessel will be favorable over that to a smaller vessel, this assumption is not always true. The determination of the optimal hull size for a specific work task considering cost and operational aspects is not straightforward and requires a detailed comparative operability analysis.

The activites in Project 7, Design for workability, shall provide knowledge for a holistic ship design optimization approach. Numerical analysis tools shall be developed to enable ship designers to select a combination of main dimensions and loading parameters optimizing the operability of a new ship design for defined operational tasks and sea areas. A key aspect is the mission dependent optimization of hull dimensions, including loading condition parameters, aiming for a design where natural periods of important responses such as pitch and roll are significantly different from the dominating wave periods. An example is presented in Figures 1 to 3, analyzed for a comparative set of vessel designs with different main dimensions but equal hull shape and loading characteristics at zero speed and a wave heading of 30° head seas. This example shows an atypical behaviour extracted from a large study in which the smaller vessel shows favorable roll behavior presented by the percentage operability for the applied roll limitation of 2° RMS (root mean square, see Figure 1). The comparison of the limiting significant wave height for the non-exceedance of the used criterion is shown in Figure 2. Here, the smallest vessel appears to have the least sensitive behavior. As an explanation of this phenomenon the analysis of the Response Amplitude Operators (RAOs) shows that the sensitive period of the maximal response amplitude of the small designs is most distinct from the dominating wave periods. Hence, the roll motion response behavior of the smaller vessel is favorable above the large vessel due to certain design settings. This behavior is not necessarily expected but can be found for certain favorable design parameters to be identified for the design of the optimal vessel.

Main deliveries of Project 7:

- Release of final version of the Vessel Response Tool (VRT) openly accessible on http://vrt.sintef.no.
- Vessel response software user workshop for ship designers in SFI MOVE.

The Vessel Response Tool (VRT) is designed to provide guidelines for design optimization and vessel selection based on the specific requirements of marine offshore operations. The tool supports decision-making processes where quick comparative operability analyses of various ship designs for benchmarking and vessel selection are needed. The VRT is a postprocessing tool using pre-calculated motion transfer functions (RAOs) of 2835 ship geometries of different size and loading conditions for performance analysis. All pre-calculated RAOs are based on one generic hull geometry of a modern offshore construction vessel design. Although the results of the VRT are based on a single vessel design, the results are sufficiently accurate for the systematic identification of optimal vessel design parameters for an intended offshore operation. For the estimation of the dependency of motion responses on specific vessel design parameters, a study with a comparison of five significantly different hull geometries was performed, leading to an accuracy level for the benchmarking index (ORI) used in terms of standard deviation of 7.7% for roll, 3.3 % for pitch and 1.8 % for heave at COG (reference to OMAE2017□62307 proceedings: Design Parameters for Increased Operability of Offshore Crane Vessels).

However, the results from the VRT will provide valuable information for design and vessel characteristics optimization, a similar optimization procedure using the specific hull shape of a new individual vessel design would be beneficial. According to ship designers in SFI

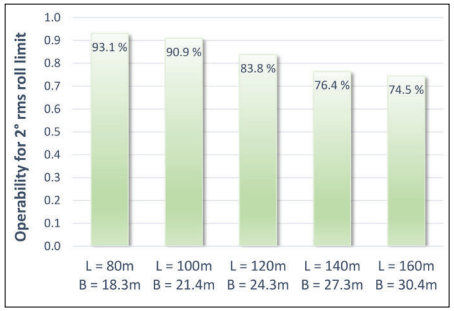


Figure 1: Percentage operability for 2° rms roll angle limitation for a specific sea area and season.

MOVE, tools for time-efficient seakeeping optimization are not available on the market. Therefore, the common practice is to perform only a few numbers of seakeeping runs for the approval of a final design. Active improvement of seakeeping capabilities during the design process are work-intensive and would require a more time efficient software to become common practice. Based on information gathered in workshops with participating designers in 2019, the project is utilizing the state-of-the-art seakeeping analysis tool VERES and shall further develop and direct the ongoing development process towards a direction, fulfilling the needs of the partners in SFI MOVE. The work in SFI MOVE shall provide the missing link to enable ship designers and researchers to efficiently perform optimization studies to improve seakeeping capabilities during the ship design process. Furthermore, this activity will be a preparation for the integration of the automated seakeeping optimization tool into the On-board decision support system (ODSS). This is of interest, since the seakeeping optimization tool will be able to provide high calculation speed and functionality in automated pre-operation evaluations, examples will be the evaluation of the optimal heading, possible loading condition adjustments, and estimation of non-linear roll damping terms for all possible weather scenarios.

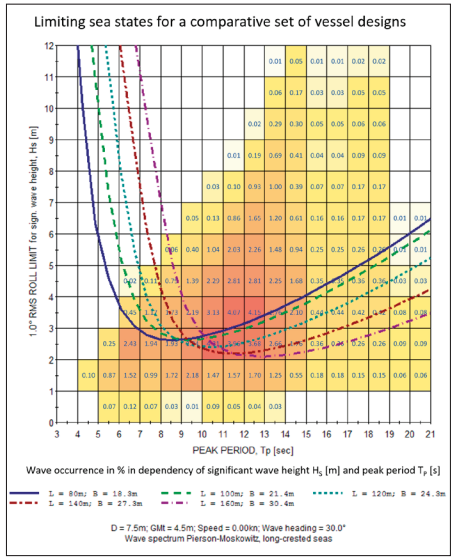


Figure 2: Wave height limitations for non-exceedance of a 2° rms roll angle criterion in relation to the observed occurrences of wave height and period in %.

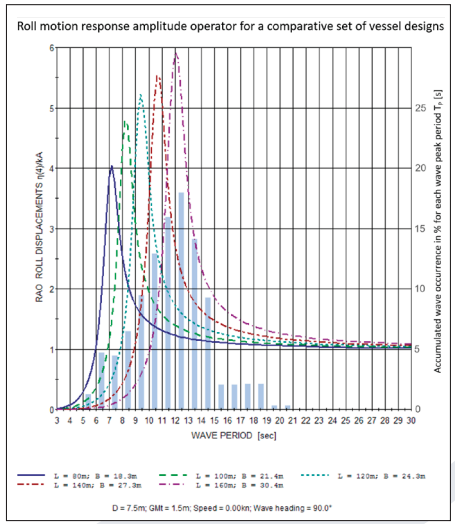


Figure 3: Roll motion RAO in relation to the wave occurrence, accumulated over the wave height per peak period.

Project 8

Project Leader:
Frøy Birte Bjørneseth,
NTNU Ålesund

Photo: Rolls-Royce

Dispersed Ship Crew/ Remote Operations

Technology

- *Handling of data: The Gunnerus test*

Logging and transfer of operational data from RV Gunnerus has been tested and is continuously being logged in the cloud.

OLEX (onboard) and OLEX Slave (Onshore) has been installed. The slave displays real-time information from the vessel enabling increased situational awareness for the crew on-shore. Routes can be planned on-shore and directly uploaded for instant availability to the master system onboard the vessel for verification by the onboard crew. This enables seamless interaction between ship and shore.

- *Operation centre design*

Mapping of previously done research on a similar topic has been carried out together with planning for centre setup. As the operation centre will be utilised as a tool in this project, it would be preferable to utilise previously done research to build the foundation of the centre setup. Collaboration with other projects focusing on operational centre design is preferable and necessary.

- *Machine learning and digital twin*

Collaboration with KPN TwinShip – concerning digital twins for vessel lifecycle service has been initiated looking at three particular case studies concerning:

1. RV Gunnerus docking experiment at Ålesund harbour
2. Palfinger crane operation
3. Fault prognostics where all results are made recently in co-simulation and real physical tests.

Rules & regulations and cyber security

– Making an overview of rules & regulations is ongoing.

– Two Maritime Cyber Security projects have been initiated.

– PhD candidate Marie H. Larsen is currently working on "Perception of cyber risks in offshore operations, and the development of dispersed teams", with focus on case studies and interviews with a qualitative approach to investigating the perception of risk in the maritime cyber domain.

– Bachelor project in Nautical studies concerning maritime cyber security with focus on threats, operative components, procedures and knowledge.

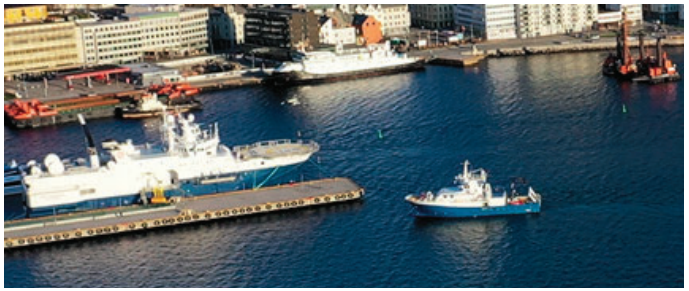
Dispersed teams performance

Mapping of team roles, tasks and organisation is ongoing and utilised as a base for pilot studies on simulator when remote operation centre setup has been installed in 2020. Performance testing and interaction investigations will be carried out in collaboration with other relevant projects.

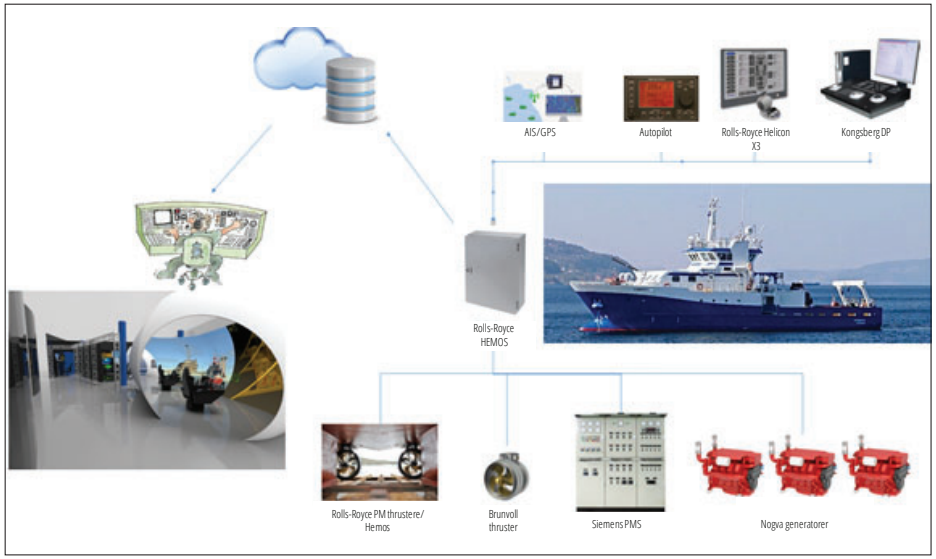
Industrial value

Business view on dispersed crew.

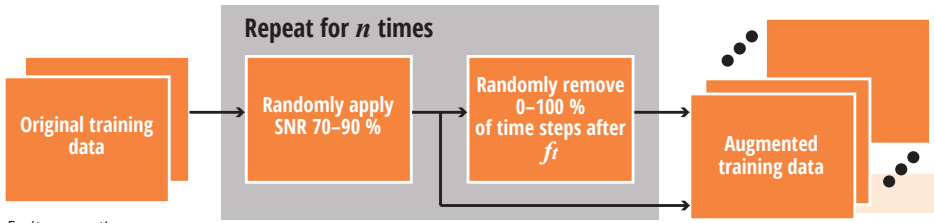
Initial work and proposed research questions have been investigated.



Twin ship docking.



Logging and transfer of operational data.



Fault prognostics.

An open simulation platform
Today, simulations are widely used in all stages in 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 standard also in the maritime industry, enabling re-use of models and collaborative system simulations.

Partners in SFI MOVE, DNV GL, 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.

Through a 2-year joint industry project we want to develop an open source simulation environment to facilitate model sharing and co-simulation for the maritime industry.

The output of the project will be a foundation for collaborative sharing of simulation models and an open industry platform for creating digital twins of products, systems and complete vessels. This can be used to verify system integration, aid system design, and plan and optimise vessel operation in a virtual environment.

Research cooperation

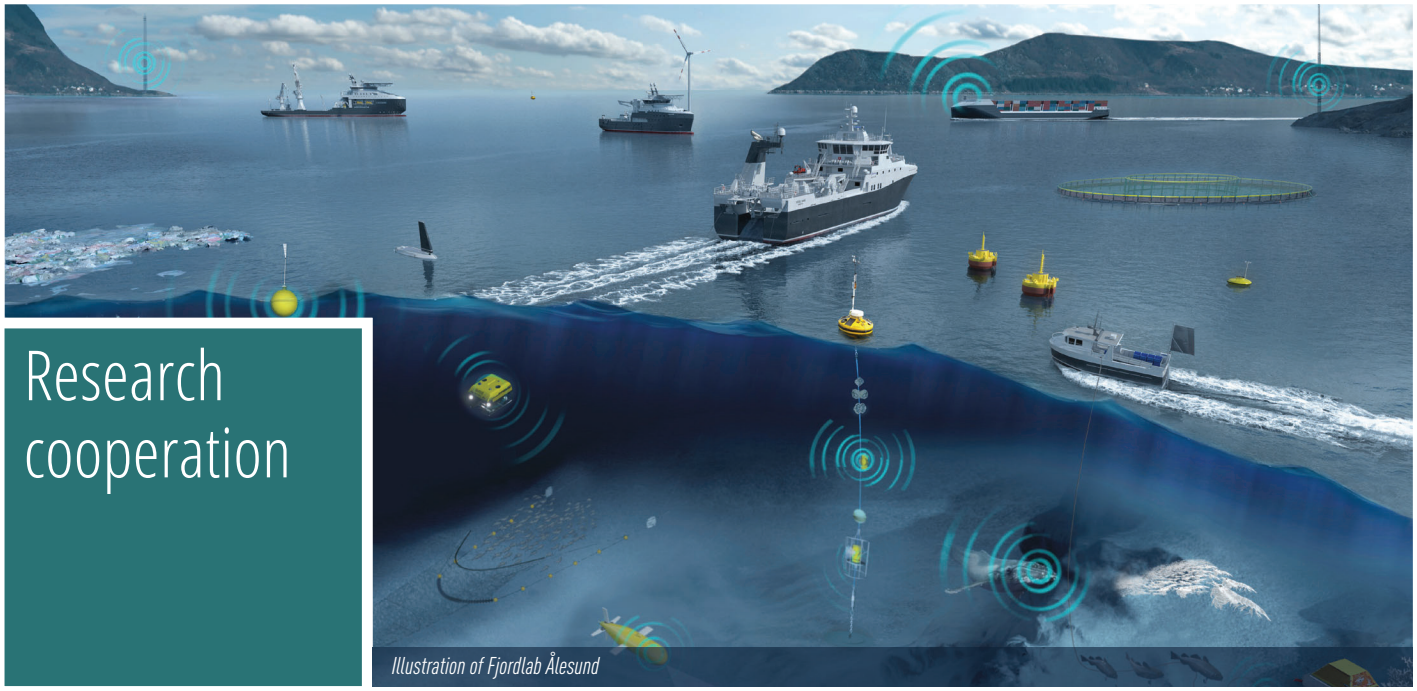


Illustration of Fjordlab Ålesund

Ocean Space Centre – Fjord Lab Ålesund
Planning of the Ocean Space Centre has been in progress since 2008, with broad support from authorities and business life. The government has decided to continue the work of realising the Ocean Space Centre at NTNU and SINTEF. Social policy goals are to ensure value creation through competitive Norwegian maritime industries. Quality assurance confirms that the initiative is socio-economically profitable, and the project is now entering a new phase.

A new addition to the Ocean Space 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 in the Ocean Space Centre.

The Fjord-Lab in Ålesund is an arena for the full-scale testing, design and innovation within:

- maritime technologies and operations
- near shore navigation and ship traffic control technology and methods
- the impact of the ocean on infrastructure along the coast
- environmental near shore ocean observation technology and methods

The laboratory for testing ships, ship equipment, fishery equipment, fish farms, wave energy and test facilities for technology for monitoring the ocean, coastal traffic and vulnerable coastal infrastructure.

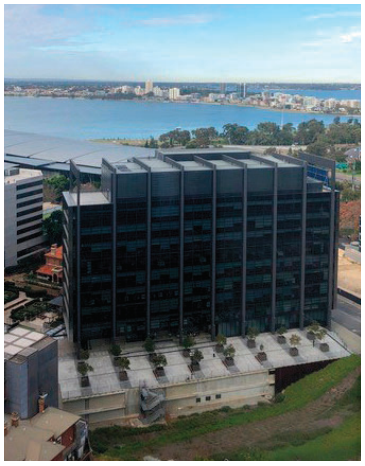
Research with the objective of supporting business development is in other words an important goal for this infrastructure. At the same time, we will develop digital twins and record data over time and make these available to researchers within the ocean space.

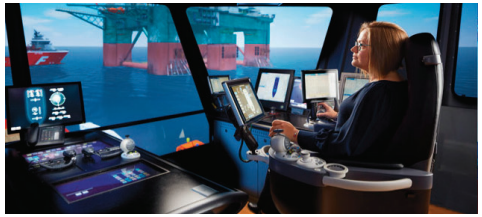
The Fjord-Lab Ålesund is in a unique marine area between Runde and Godøya and into Storfjorden including the World Heritage site Geirangerfjord. The area is in many ways a diverse miniature of the enormous ocean space Norway has control over, including exposed and more sheltered areas. The area is approved for testing of autonomous ships, as an arena for testing of energy from waves and currents, as an area for testing of fishery equipment at the seabed and has, as the only place in Norway, seabed maps with an accuracy of 1 × 1 metre.

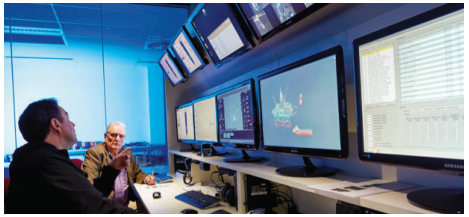
The area is thus an ideal test arena and innovation for technology in the ocean space. It is home to fisheries and to important spawning areas for herring, haddock and cod. The area is a focal point for shipping traffic, including the approach of large cruise ships to the fjords. The Norwegian Coastal Administration (Kystverket) is developing full radar coverage for monitoring the area.

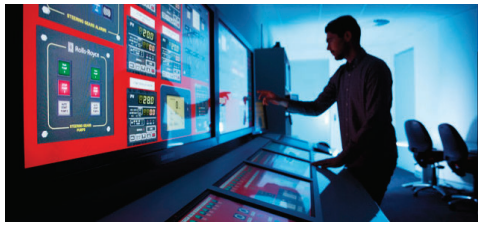
We see that this comprehensive instrumentation of one of nature's very exciting areas creates enthusiasm and inspiration for both businesses and researchers to make use of the area as a large R & D laboratory.

International cooperation









University of Sao Paulo (Brazil)
Professor Kazuo Nishomoto, the key person in the contact with the University of São Paulo (Brazil), visited NTNU in Ålesund, and participated in discussions on the current exchange of PhDs, common projects, and also gave a lecture on "Technology Transfer and Innovation Policy". Such initiative is paramount not only in developing the synergy between the two universities, but also intra-departmentally at NTNU, for instance, connecting SFI MOVE with the INTPART-SUBSEA project, in which Kazuo is also a collaborator. Kazuo's laboratory already hosted a PhD from NTNU as a guest researcher last year, and will receive another by the end of 2019, while NTNU is hosting a Post-Doc and a couple of Master students from USP in the same period. NTNU is planning a visit to USP in June 2020.

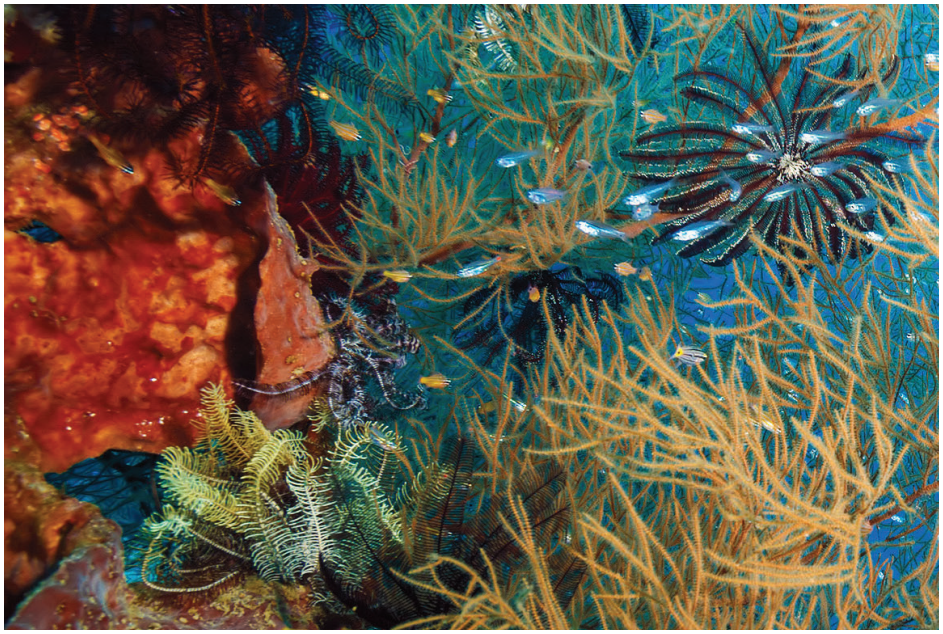
University College of London (England)
The cooperation with the University College London (UCL) is done via Professor Giles Thomas, BMT Chair of Maritime Engineering. Professor Giles' group has also received MSc students connected to the project in his group in the past, and sent a PhD student for a PhD workshop at NTNU, with a common publication as a result of the research. Over a period of the next few years more of this collaboration is expected, including another exchange of PhDs in the plan.

Harbin University (China)
NTNU Ålesund has established a co-operation with Harbin University in China. Harbin is one of the leading universities in China within maritime activity. Leading researchers from Harbin have visited NTNU Ålesund and we plan a visit to Harbin during the spring of 2020.

NTNU Ålesund, together with the Offshore Simulator Centre and Harbin University, has established a joint research project, "Remote Control Centre for Autonomous Ship Support» wih the objective of developing a future shipowner control centre of ships.

Perth (Australia)
We carried out a round of visits to Perth in Australia. The companies Woodside, Subsea7, Chevron, Fugro, Conoco Phillips and Aker Solutions were visited. In addition we accomplished a joint workshop with Curtin University and a mini-conference with simulation and training within maritime operations. Further collaboration is in a planning process.






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					
PhD candidates with funding from SFI MOVE					
Name	Start	End	Project	Nationality	Gender M/F
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	Norwegian	F
Gowtham Radhakrishnan	2019	2022	Numerical models and tools	Indian	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
Postdocs with funding from SFI MOVE					
Mia Abrahamsen-Prsic	2016	2019	Subsea: Safe All Year	Croatian	F
Zhiyu Jiang	2016	2018	Offshore Wind: Innovative Inst.	Chinese	M
Mats Jørgen Thorsen	2016	2018	Mining	Norwegian	M
Niranjan Reddy Challabotla	2016	2018	Mining	Indian	M
Zhengru Ren	2019	2021	On-boards systems	Chinese	M

Title
Performance Indicators for vessels performing challenging marine operations.

Research topics
The ongoing exploration of the maritime environment and the effort to use the sea as a source of energy in the context of increasing financial constraints leads to increasing global demands for more economical and weather independent services within marine operations. Although, ships and on-board equipment are designed to operate in harsh environmental conditions, the current practice is often to terminate an operation when a rigid and often conservative weather limitation is reached, usually specified in terms of the significant wave height as the exclusive criterion. Since the offshore industry is aiming for all year-round safe operations, a strong interest among ship designers, owners, and operators arises for operation-based design optimization and for task specific criteria aiming the full exploitation of the vessel-specific operational performance.

The main objective of the PhD work is to address the question what makes an offshore vessel perform better, especially in harsh environmental conditions. The identification of rational performance criteria for vessels fulfilling selected operational tasks shall provide knowledge for a better understanding of factors contributing to a successfully completed offshore work task and shall deliver tools to estimate ship specific operational limitations usable for a vessel selection and design optimization process.

Industrial goals
The use of rational performance criteria shall provide a methodology and tools to evaluate operational performance using vessel- and task specific limitations beyond a general H_s-limit. This addresses a primary concern of the offshore industry to increase operability and approach the objective of safe all year-round operations. The work shall provide strategies for the application of performance measures in order to support the vessel design process, the assessment of vessel performance in operations, and the selection of the suitable vessel for a specific task.

Scientific questions
- What is a good offshore vessel and why are some vessel performing better than others?
- What are vessel specific factors contributing to operational performance?
- What are performance indices to measure and quantify vessel specific operational potential?
- How can newly established performance indices be validated?

Innovations
The knowledge of operational performance criteria shall provide
- Guidance for vessel design with increased operability, cost-efficiency, and safety.
- Knowledge for the performance assessment of a vessel design in relation to a specific operational task and environmental condition aiming the selection of the most suitable vessel for a predefined task.
- Tools to identify task specific weaknesses for a given ship design and/or the planning of an operation providing guidance for improvements (e.g. the Vessel Response Tool accessible on vrt.sintef.no).
- Information for further development of on-board support systems.

Cooperating companies
Ocean Installer
Equinor

Supervisor: Sverre Steen
Co-supervisors: Florian Sprenger, Trygve Kristiansen

Fredrik Mentzoni

Photo: Thor Nielsen

Title
Hydrodynamic loads on complex structures in the wave zone.

Research topics
The purpose of the PhD work is to provide enhanced knowledge about hydrodynamic loads on complex structures during deployment. This includes performing new benchmark experiments for hydrodynamic loads in the wave zone. The end goal is to develop rational methods for load estimates on complex structures.

Industrial goals
Rational methods to calculate hydrodynamic loads on complex structures need to be developed to ensure proper load estimates for marine operations involving, among others, the replacement of complex modules for subsea installations. Experience show that planning of marine operations is of high importance. Load predictions in terms of rational load models are necessary in this respect. Rational methods have been developed for simpler geometries, but there still exists knowledge gaps on several fundamental issues as well as large uncertainties in the hydrodynamic load estimates for more complex structures.

The present research will focus on hydrodynamic loads on 2D and 3D structures in the wave zone – as the structure goes into water – with regards to off-the-side (crane) operations. Moon pool operations and loads as the structure is further submerged and lowered to its seabed destination may also be relevant.

Scientific questions
- Is it possible to accurately estimate hydrodynamic loads on complex structures?
- Which effects dominate the load response at different stages during deployment?
- How can rational models be simple and fast to use, and at the same time take into account the complexity of subsea structures?
- How can the current recommended practices be improved to increase accuracy of load predictions for complex structures?

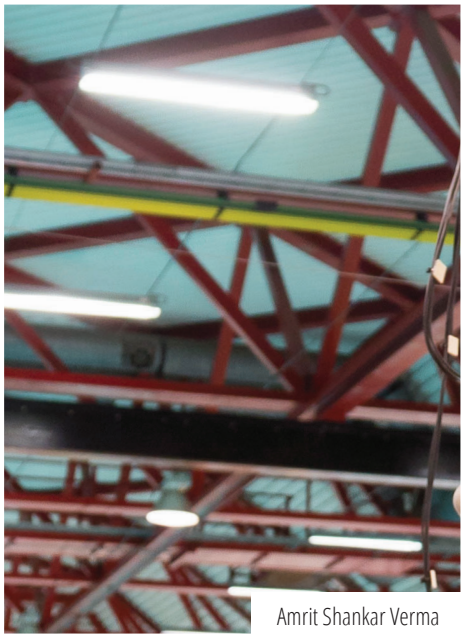
Innovations
Increased knowledge on hydrodynamic loads on complex structures in the wave zone can contribute to innovations and new solutions for offshore marine operations. This includes increased predictions of hydrodynamic loads that can be used for development of software, calculation methods, operational window predictions and new solutions for lowering of structures through the wave zone. In addition to potentially increasing the operability and reducing cost, research findings may also contribute to increased confidence in training and planing of marine operations.

Cooperating company
DNV GL

Supervisor: Trygve Kristiansen
Co-supervisor: Odd M. Faltinsen

PHD-STUDENT

DEPARTMENT OF MARINE TECHNOLOGY • FACULTY OF ENGINEERING



Amrit Shankar Verma

Photo: Thor Nielsen

Title

Response-based operability assessment for offshore wind turbine blade installation with emphasis to impact damages.

Research topics

1. Numerical modelling and analysis of impact induced damages in the wind turbine blade during lifting and offshore mating process.
2. Derive the response based operational limits for the mating process of blade (Hs, Tp and Uw) for safe installation.
3. Develop mitigation measures for reducing the impact damage effect, and extending the limiting sea states for blade installation.
4. Assess the safety levels of marine operations, and in particular blade installation from a long term perspective.

Industrial goals

1. To reduce costs in the installation of OWTs by estimating and obtaining response based limiting sea states for jackup vessel.
2. To develop explicit motion and structural response-based criteria for floating installation vessels.

Scientific questions

- What are the criteria for operability assessment in terms of allowable vessel motions or allowable structural responses of the blade during installation?

Innovations

- A new way to determine the operational limits for blade installation using structural response based criteria.

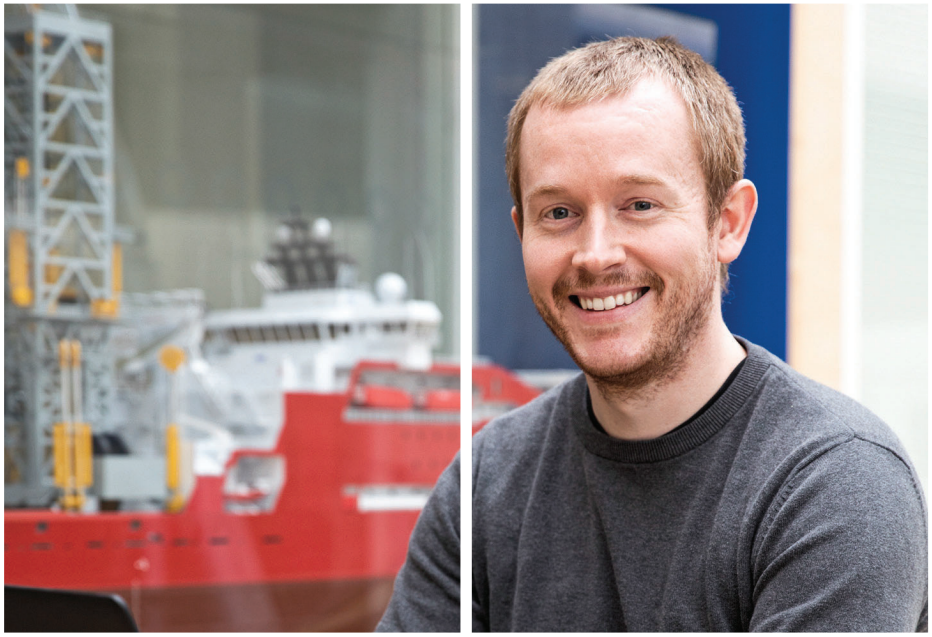
Cooperating companies

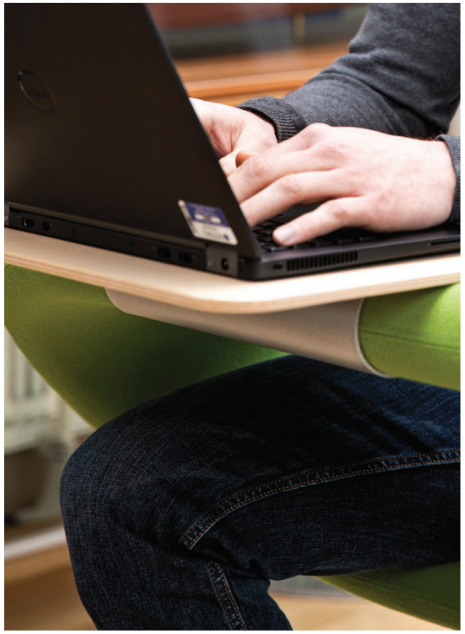
Equinor
DNV-GL

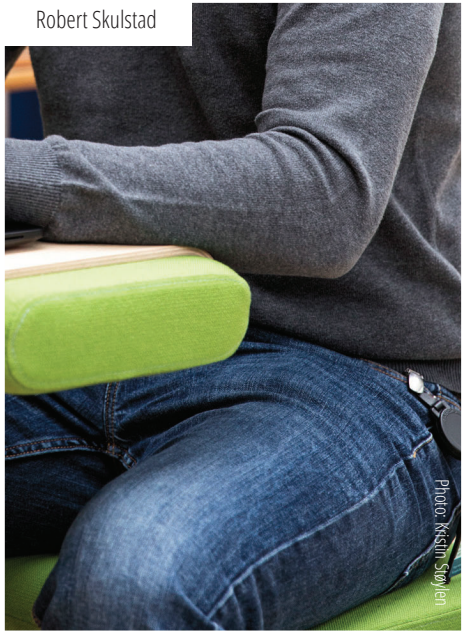
Supervisor: Prof. Zhen Gao
Co-supervisors: Karl Henning Halse, Nils Petter Vedvik

PHD-STUDENT

DEPARTMENT OF OCEAN OPERATIONS AND CIVIL ENGINEERING • FACULTY OF ENGINEERING







Robert Skulstad

Photo: Kristin Støylen

Title
Data based ship motion prediction in offshore operations

Research topics
- Ship motion prediction
- Time series prediction models and input selection

Industrial goal
- Decision support/controller feedback for autonomous vessels
- Fault detection

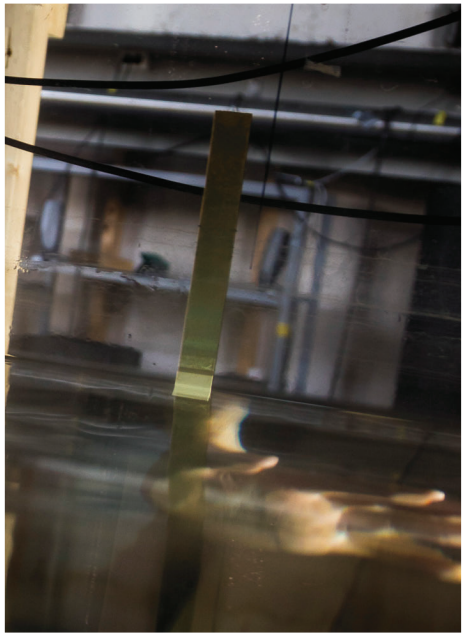
Scientific questions
- How can data from sensors on ships be combine to provide long-term prediction of ship motion?

Innovations
- Methods for long-term ship motion prediction leading to improved guidance and navigation of vessels and increased safety at sea

Cooperating company
OSC AS

Supervisor: Houxiang Zhang (IHB, NTNU)
Co-supervisors: Thor I. Fossen (ITK, NTNU) and Bjørnar Vik (Kongsberg)

Mäel Moreau



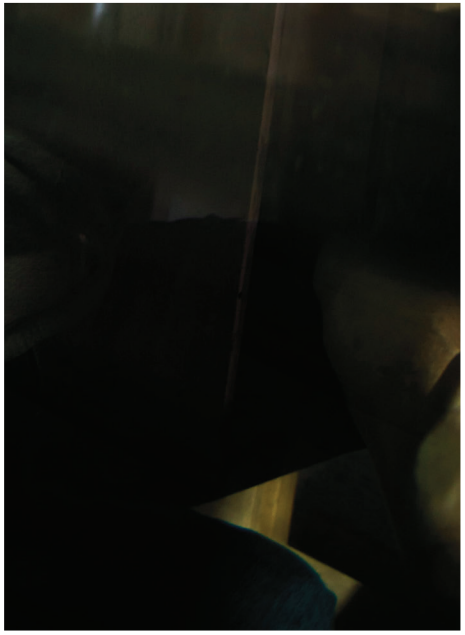


Photo: Thor Nielsen

Title
Hydrodynamic study of roll motion of offshore vessels in operation.

Research topics
The roll damping is crucial for the vessel performance. Since the damping is dominated by viscous loads due to flow separation from bilge keels or other appendages, state-of-the art industry codes based on potential flow theory cannot predict this, and rely on empirical methods. Empirical methods have been developed for conventional type of hulls with bilge keels for several decades, and good empirical methods (e.g. Ikeda 1976 to 1978) exist. 2D roll damping coefficients for mid-ship sections are found (in still water), and applied in a strip-wise manner along the ship. However, for other variations of the hull form than the conventional, Ikeda's formulas are not applicable. This applies particularly to novel designs of vessels used in offshore operations that deviate strongly from conventional hull.

Further, how to apply the formulas (roll damping coefficients) in a stochastic sea is not well-established, even for conventional hulls.

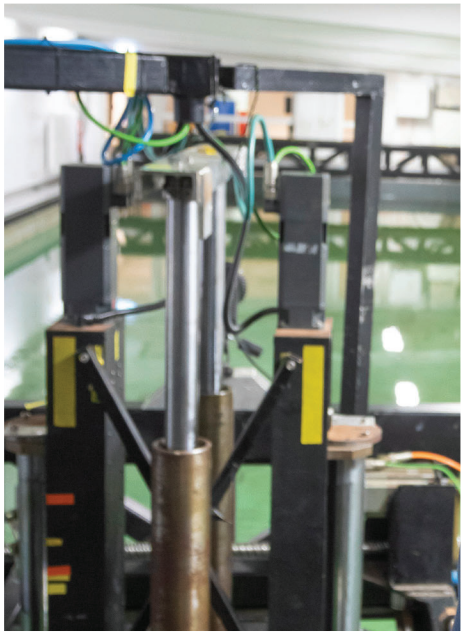
A main research task will be to design a method to predict roll damping (coefficients) for non-standard hull types, while another will be to investigate the applicability of the (still water) hydrodynamic coefficients when the ship is freely floating in waves. A 2D type of study will be conducted, including experiments and numerical work.

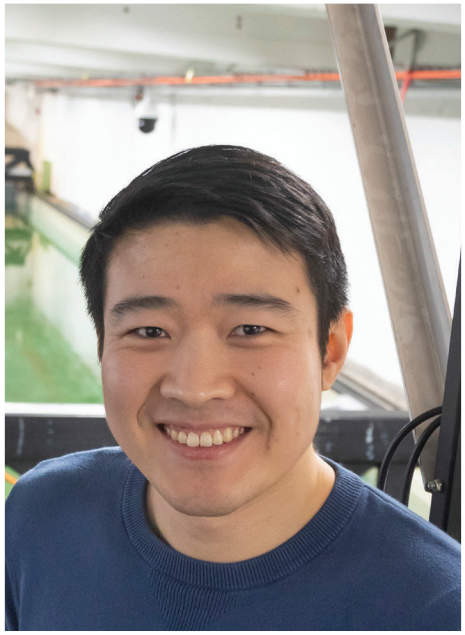
Industrial goals
- Provide a better understanding of the physics, and reliable estimations of the roll motion of offshore ships in operation
- Provide a better prediction of the roll response to irregular waves in view of defining an appropriate weather window

Scientific questions
- How to predict the roll damping accurately for unconventional hulls
- How to extend the equation of motion in still water to irregular sea states

Innovations
Propose a method of estimating the hydrodynamic coefficients that is adapted for the study of the roll motion of offshore vessels.

Supervisor: Trygve Kristiansen
Co-supervisor: Babak Ommani





Xu Han

Photo: Thor Nielsen

Title
Vessel Motion Prediction Based on Adaptive Numerical Model with Measurement Data

Research topics
- Modification of numerical model based on real-time onboard measurements and weather information
- Short-term and long-term vessel motion prediction
- Reliability of approach utilizing response-based operational criteria approach for marine operations

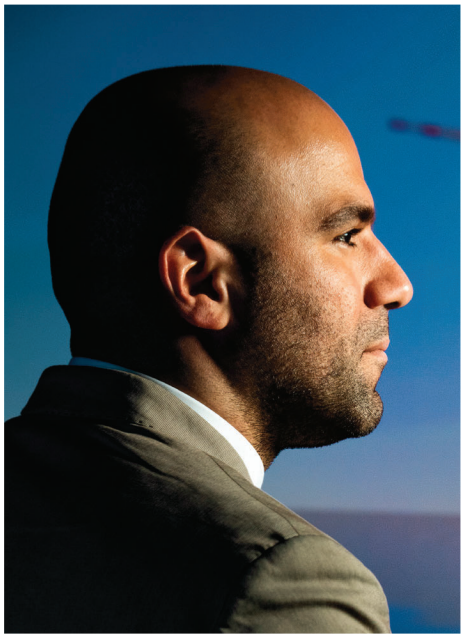
Industrial goal
- More accurate response-based approach for marine operations, to improve safety and operational limit
- Robust onboard decision support system for marine operations

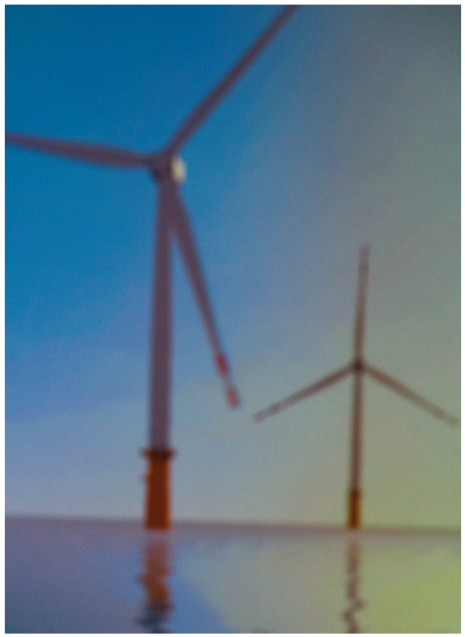
Scientific questions
How to modify model based on measurements, considering uncertainties and frequently shifted operating phases

Innovations
Methods for vessel motion prediction leading to improved safety and operability for marine operations

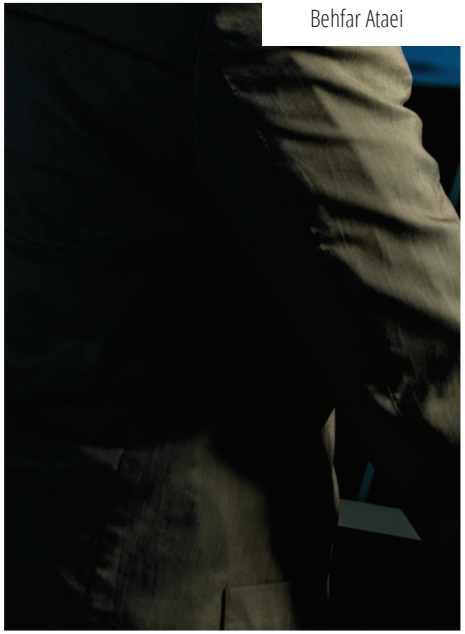
Cooperating company
SINTEF, Ocean Installer

Supervisor: Bernt Johan Leira (NTNU)
Co-supervisors: Svein Sævik (NTNU), Lars Tandle Kyllingstad (SINTEF), Stian Skjong (SINTEF)





Behfar Ataei



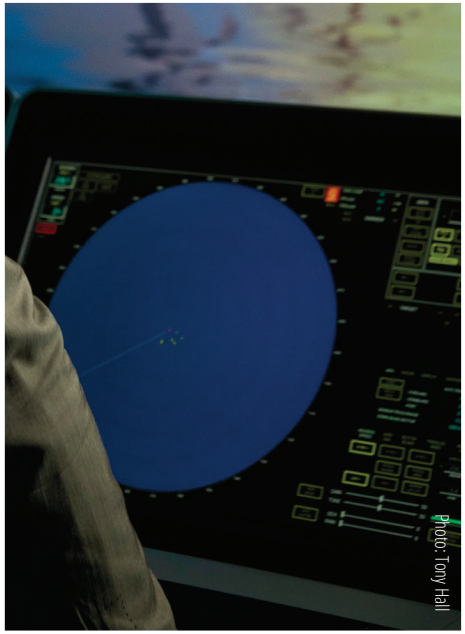


Photo: Tony Hall

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.

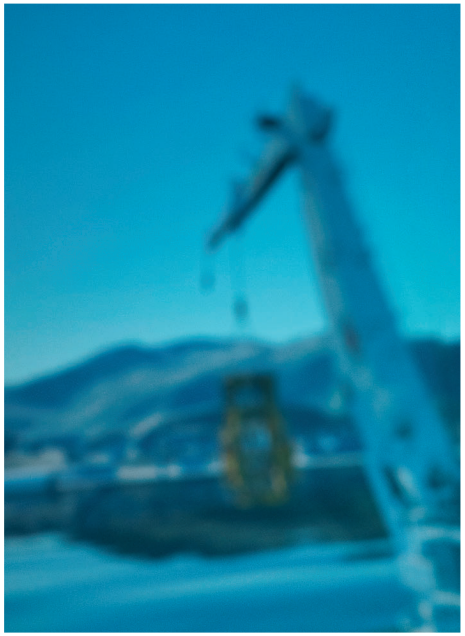
Industrial goals
1. Knowledge transfer from offshore oil and gas industry and implement in OWT installations.
2. Development of innovative concepts for OWT installation operation to increase efficiency.
3. Development of a unified virtual prototyping environment following Functional Mock-up Interface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

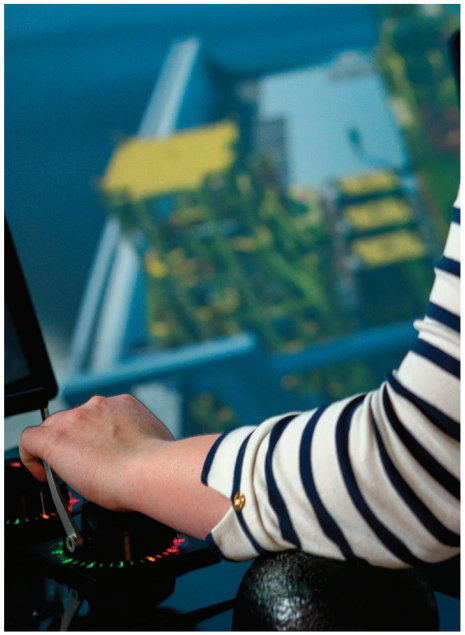
Scientific questions
1. What are the main physical phenomena governing OWT installations?
2. How these phenomena can be defined numerically that is possible to integrate into different simulation environments?

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
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.

Main supervisor: Frøy Birte Bjørneseth
Co-supervisors: Runar Ostnes, Sokratis Katsikas, Mass Soldal Lund

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.

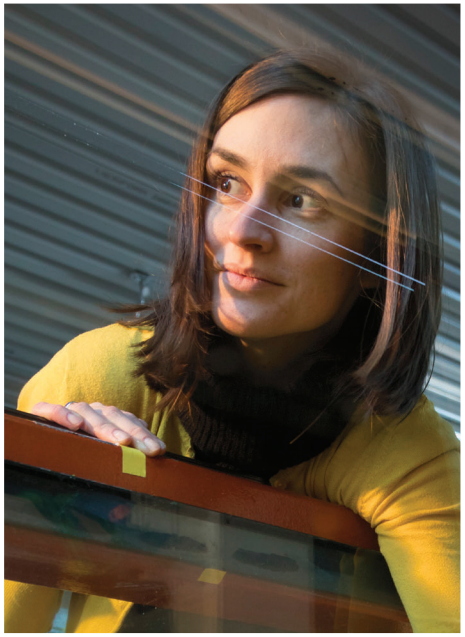
Research topics
- Pursuing integration of realistic metocean conditions (corrected forecasts/observations) to mathematical models for predicting the operational behaviour of vessels in real environment, both in short range and long range.
- Achieving optimal real time response evaluation through blending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

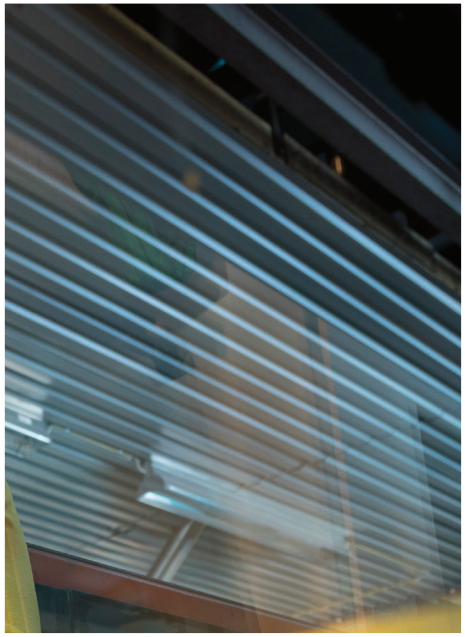
Industrial goals
- Rapid and dependable predictive simulations on board for studying vessel's operational characteristics both in real time and in future.
- Identification of critical situation beforehand for certain acute operations.
- Deducing essential intelligence from the support systems for making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

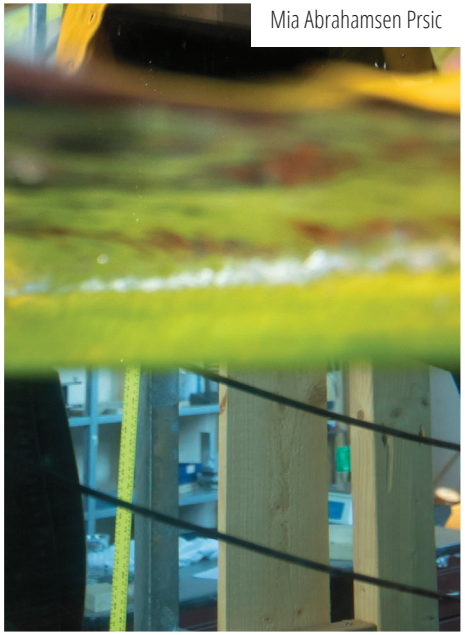
Scientific questions
- Quantification of uncertainties inherent in weather forecasts using probabilitistic & oceanographic methods; Application of satellite and insitu observations for yielding reliable environmental forecasts.
- Utilisation of cloud based data storage, data transfer & computing.

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)







Mia Abrahamsen Prsic

Photo: Thor Nielsen

Title
Hydrodynamic loads on submerged complex structures under the influence of waves and currents.

Research topics
The main goal of the postdoctoral research is to provide deeper understanding of the hydrodynamic forces exerted on the subsea modules during the structures' deployment. Due to the complexity of the structures, it is generally too demanding to model the realistic subsea modules, either experimentally or numerically. However, it is possible to represent the dominant parts of the structures by selected generalised elements, such as porous plates and cylindrical structures representing simplified module cross-sections.

Such elements are systematically examined, in different combinations, increasing the complexity, to explore the governing physical effects relevant for the hydrodynamic loads. Modelling is performed for the generalised structures subjected to the forced oscillations, representing the waves exerted on the fully submerged subsea modules.

The experimental results offer a systematic overview over the hydrodynamic coefficients for the various basic elements and their combinations, and are performed for a broad span of sea states that a real subsea module can experience.

CFD simulations complement the experiments by providing an insight in the details of the flow around the structures and the interactions in the flow field. Numerically simplified CFD models allow quick and efficient calculations of more complex structure combinations, and can thus be recommended for the practical, industrial use. They are compared to the detailed, three-dimensional turbulence CFD models to understand the limitations and advantages of various simplified approaches.

Industrial goals
Increasingly complex marine operations require safe and robust planning and all-year accessibility, relying on accurate calculations of the hydrodynamic loads. The goal of our project is to contribute to the current rational methods and recommended practice by systematic understanding of the hydrodynamic forces on various elements and flow interactions in the structures, providing guidelines for reliable use of the experimental and the numerical procedures.

Scientific questions
- What types of generalised, basic structures can be used to represent the dominant parts of the large, complex, three-dimensional subsea modules? How accurate are such representations?
- What are the main physical parameters and effects influencing the hydrodynamic forces on such basic structures and their combinations?
- When can the specific basic elements be observed as the individual contributors to the hydrodynamic forces of the complex modules, and when are the interactions between the various structural elements important?
- How precise and how applicable are various types of CFD calculations, varying from the detailed to the numerically simplified, fast models, when applied for the modelling of the basic structures and various combinations, subjected to the oscillatory flow?

Cooperating company
SINTEF Ocean

Supervisor: Prof. Trygve Kristiansen

Title
Onboard decision support system.

Research topics
- Multiple IMUs sensor fusion.
- Vessel and payload motion prediction.
- Onsite sea state estimation based on vessel responses.
- Cooperative control of floating heave lifting.

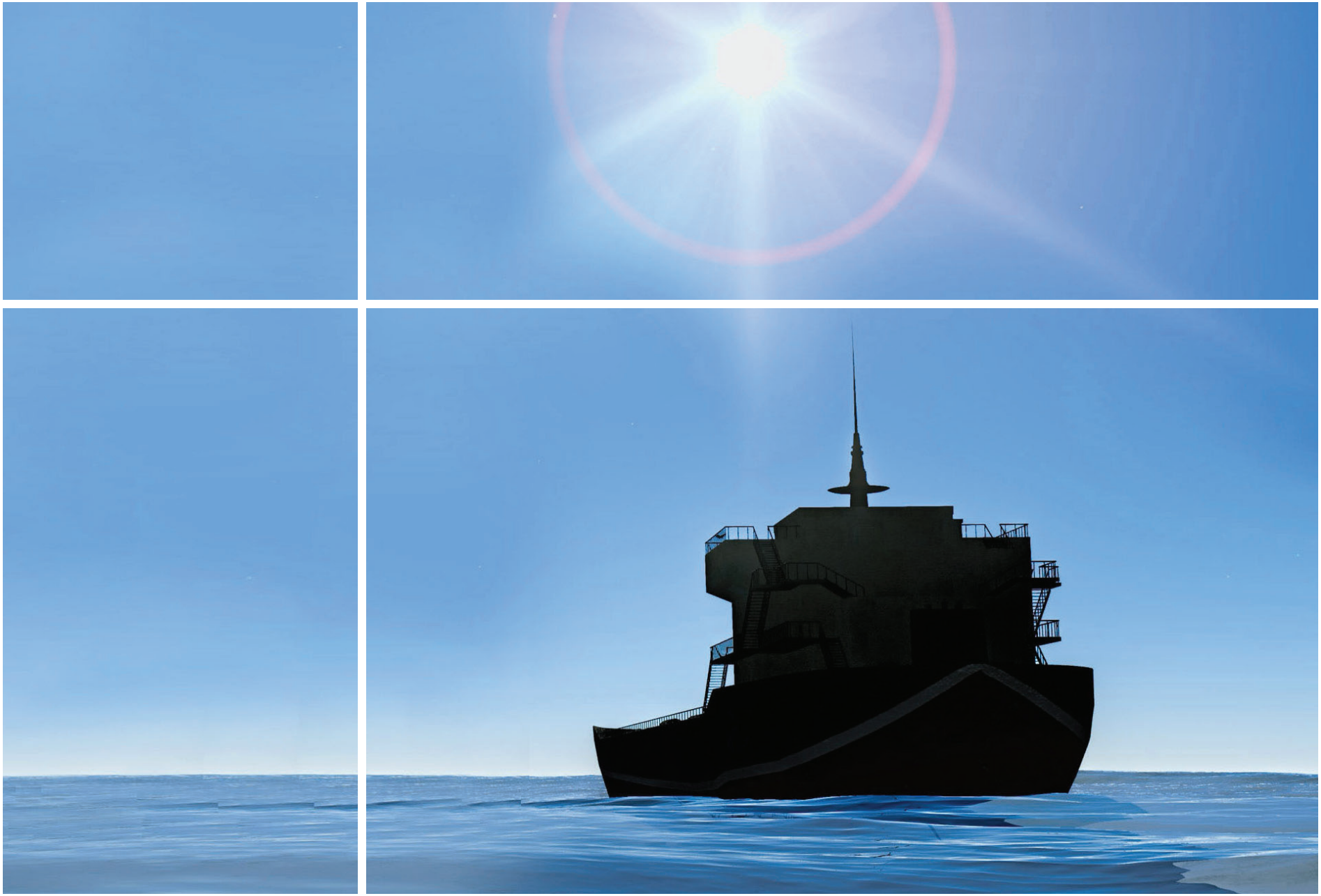
Industrial goal
- Design onboard decision support and decision making algorithms to enhance the safety and efficiency in various marine operations.
- Design control strategies to the offshore wind turbine preassembly installation scenario.

Scientific questions
- Realize high-fidelity vessel motion monitoring, including twist and bending, by sensor fusion of multiple IMUs placed on the vessel and integrate it into onboard design support system.
- Improve the robustness of onboard sea state estimation methods.

Innovations
- Smart onboard decision system
- Multiple IMU sensor fusion
- L1 optimization

Cooperating company
SINTEF Ocean

Supervisor: Roger Skjetne (IMT, NTNU)



Communication and dissemination activities

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

The project has arranged following main conferences/workshops in 2019:

- Workshop, Trondheim 01.03.2019
- Spring conference, Ålesund 10.05.2019
- Autumn conference, Ålesund 27.11.2019
- Workshop, 28.11.2019

Ocean Week, May 2019:
NTNU hosted Ocean Week 6–9. May. The last day of Ocean Week was held in Ålesund at NMK and NTNU.

One of the main topics was that the sea is changing and we must find good solutions for sustainable use of the blue resources. Speakers in Ålesund were Tina Saltvedt, Gunnar Bovim, Sveinung Rotevatn and others. After lunch there were parallel sessions where representatives from SFI MOVE were among the speakers.

Subsea Lifting Operations, Norwegian Society of Lifting Technology, December 2019, Stavanger:
Hans Petter Hildre presented the results from the SFI MOVE.

Digital Twin
Digital transformation is a hot topic at present. Digital Twin integrates sensor technology, IIoT, analytics, simulation technology, artificial intelligence, BigData, and satellite communication. A digital twin is a virtual model of a physical component or system which includes TLC information needed throughout the value chain. Digital Twin integrates artificial intelligence/machine learning and analytics to living simulation models that continuously learns and updates itself from multiple data sources to provide real-time working conditions. These learning systems learn from themselves in operation, as well as input from experts, and are used to optimize design, manufacturing, operations and service.

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2019

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OCEAN NTNU

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Verma, Amrit Shankar; Jiang, Zhiyu; Ren, Zhengru; Gao, Zhen; Vedvik, Nils Petter.
Response-Based Assessment of Operational Limits for Mating Blades on Monopile-Type Offshore Wind Turbines. Energies 2019 ;Volum 12.(10) NTNU UIA

Verma, Amrit Shankar; Jiang, Zhiyu; Vedvik, Nils Petter; Gao, Zhen; Ren, Zhengru.
Impact assessment of a wind turbine blade root during an offshore mating process. Engineering structures 2019 ;Volum 180. s. 205–222
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Verma, Amrit Shankar; Vedvik, Nils Petter; Haselbach, Philipp Ulrich; Gao, Zhen; Jiang, Zhiyu.
Comparison of numerical modelling techniques for impact investigation on a wind turbine blade. Composite structures 2019 ;Volum 209. s.856–878
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Vieira, Daniel; Oliveira, Felipe; Nishimoto, Kazuo; Rhodes, Donna; Gaspar, Henrique Murilo.
Simulation for construction and operation of offshore salt caves for CO2 storage. VII November Conference – Brazil Norway; 2019-11-11 - 2019-11-13
NTNU

Master's degrees

Name	Sex M/F	Topic
Ramees Kalathingal Thody	M	Dynamic Response Analysis of Catmaran Installation Vessel During the Mating Process of a Wind Turbine onto a Floating Spar Buoy
Hans Marius Remmen	M	Dynamic Response Analyses of a Semi-Sub Installation Vessel During the Installation of a Wind Turbine onto a Floating Spar Buoy
Martin Håbet Tangen	M	Rapid Prototyping for Estimating Hydrodynamic Coefficients of Scaled Experiments on Subsea Structures during Lifting Operations
Sondre Haug	M	Robust hybrid heading control of autonomous ships
Håvard Løvås	M	DP autotuning by use of derivative-free optimization
Merethe Tørresen	F	Multivariate Analysis of Ocean Currents in the Barents Sea
Brynjar Abrahamsen	M	Fault Tolerant Dynamic Positioning for the Autonomous Test Platform ReVolt
Karoline Vottestad	F	Experimental study on wave loads on porous plates in the splash zone
Marius Robsahm	M	Experimental study on slamming loads on subsea modules in the splash zone
Jon Kristian Voster	M	Experimental and theoretical study on porous plates in irregular waves
Jonas Ravndal Kildal	M	Experimental, numerical and theoretical study on moonpool-vessel interaction in operational conditions
Sunghun Hong	M	The effect of damping on the dynamic resopnses of a floating bridge in wind and waves
Mela Schabrich	F	Coupled dynamic analysis of a floating dock system for installation of a spar wind turbine
Johannes Bekker	M	Radial piston pumps: Performance and efficiency
Huhnt Malte	M	Concept design of a floating support structure for hydrophilic crop

Accounts

Project 1: Low Cost Offshore Wind Installation and Maintenance - was completeted in 2016

Project 2: Subsea: 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

(All figures in 1000 NOK)

Funding		Project 5	Project 6	Project 7	Project 8	Lab/Dissemination	Management	Total
The Research Council		**2 070**	**3 367**	**169**	**65**	**132**	**869**	**6 672**
The Host Institution, NTNU in Ålesund		**363**	**1 371**	**-**	**663**	**-**	**-**	**2 397**
Research partners:		**2 055**	**2 893**	**102**	**-**	**-**	**-**	**5 050**
	NTNU	1 736	1 604	-	-	-	-	3 340
	SINTEF	319	1 289	102	-	-	-	1 710
Enterprise partners:		**2 426**	**2 188**	**344**	**380**		**600**	**5 938**
Total		**6 914**	**9 819**	**615**	**1 108**	**132**	**1 469**	**20 057**

Costs		Project 5	Project 6	Project 7	Project 8	Lab/Dissemination	Management	Total
The Host Institution, NTNU in Ålesund		**2 365**	**1 371**	**-**	**828**	**132**	**1 383**	**6 079**
Research partners:		**3 713**	**7 260**	**471**	**-**	**-**	**86**	**11 530**
	NTNU	2 438	2 104	61	-	-	86	4 689
	SINTEF	1 275	5 156	410	-	-	-	6 841
Enterprise partners:		**836**	**1 188**	**144**	**280**	**-**	**-**	**2 488**
Public partners		**-**	**-**	**-**	**-**	**-**	**-**	**-**
Equipment		**-**	**-**	**-**	**-**	**-**	**-**	**-**
Total		**6 914**	**9 819**	**615**	**1 108**	**132**	**1 469**	**20 057**

Name of active projects in 2019:

Project 5: OW: Innovative Installation of Wind Power Systems
Project 6: On-board Decision Tool
Project 7: Design for Workability
Project 8: Dispersed ship crew/Remote operations
RA 5: Lab/Dissemination
RA 6: Management

Workshop

Trondheim, March 1

A workshop was arranged on Friday 1st of March in auditorium T2 at the Marine Technology Centre, Trondheim between the project leaders, researchers, PHDs, PDs, supervisors and the scientific advisory board consisting of:

- Prof. Torgeir Moan
- Prof. Odd M. Faltinsen

The purpose of the meeting was to provide the necessary information for the scientific advisory board to:

1. Evaluate the quality of the work performed up to now.
2. To give advice with regard to the research for the remaining period.

In order to ensure efficient time usage, the person for each project responsible was asked to provide presentations in cooperation with the involved researchers, the supervisors, the PhDs and the PDs based on the following format:

1. An overview of what has been done by the researchers
2. An overview of what has been done by the PhD and PDs
3. Which publications this has resulted in
4. The plan for the research in the next period
5. Presentations from the involved PHDs and PDs.

Also integrated into this was also time for questions and discussions with the advisory board.

The workshop had the following schedule:

0900–0930 Project Overview by Hans Petter Hildre, Centre Director, Professor, IHB, NTNU, Ålesund

0930–1000 Project 7 Design for Workability by Martin Gutsch, Project Leader. Researcher, SINTEF Ocean

1000–1130 Project 6 On-board decision tool by Henning Borgen, Project Leader, Managing Director, SINTEF Ålesund

1130–1200 Project 5 Innovative installation of Wind Power Systems by Karl Henning Halse, Project leader, Associate Professor, IHB, NTNU, Ålesund

1200–1245 Lunch

1245–1330 Project 5 Innovative installation of Wind Power Systems – continued

1330–1350 Project 4 Seabed mining by Svein Sævik, Professor, IMT, NTNU, Trondheim.

1350–1430 Project 8 Dispersed ship crew/remote operations by Hans Petter Hildre, Centre Director, Professor, IHB, NTNU, Ålesund

1430–1530 The scientific advisory board presents

a. Their impression of the work that has been done so far
b. Their advice regarding the research to be carried out in the next period.

A new Road Map for SFI MOVE

At the 2019 Spring Conference and workshop for SFI MOVE, the goal was to set a Road Map for research for the next 4 years.

«The SFI has a number of new participants, like Subsea 7 and Technip FMC, and there are also different factors in the maritime industry that forces the SFI to adjust it`s course», says leader Hans Petter Hildre.

The SFI is now half way in it's 8 year period, and so far the research has been focused on the topics Subsea mining, Offshore wind an Offshore oil and gas. During this time many factors have changed, especially within Offshore wind where there has been a significant change from fixed installations to floating installations.

«Now is the time to update projects and portfolio to fit the future demands», says Hildre. The main topic of todays workshop is to ensure that partners take benefit from the SFI research and work for the next 4 years.

The solutions have potential

To set the Road Map for the last 4 years of SFI MOVE, the participants worked in groups, and presented a summary for the rest of the audience.

The following were their main conclusions:
In On board decision support, many days could be spent just discussing technical details, but the group tried to focus on the use and benefit in the organisations.

«There is great potensial in this technology, but we need to hear the perspective of the users, those who carry out the marine operations», said the group.

They suggest individual meetings with the participants, or short online conferences to move forward.

On the topic Offshore wind, everyone who works together when you set up a whole windpark offshore, needs to be considered.

«This could possibly be a case for masterstudents in "experts in team"», suggested the group.

There is a lot of potential to do research on the motion in floating docks, like reducing motion so the operations are more stable.

The group for Design for workability said the products need to be adapted to different types of ships. Size and capacity will have to be adapted individually, and Equinor and DNV are already invited to contact researcher Martin Gütsch.

The future lies in autonomous ships, and the group for Dispersed teams – remote operations explained the way forward. In dispersed teams the personnel do not necessarily work on board the ship, but they can operate the vessel from shore.

«We discussed cyber security», said group leader Frøy Birte Bjørneseth. «The risk here needs to be more looked in to».

Bjørneseth also suggested the research should look to what other industries are doing in this field, to learn from their technology and experiences.

Spring Conference

Ålesund, May 10

Text: Else Britt Ervik

Offshore wind energy will be profitable in a few years

The turbines used for offshore wind energy are becoming steadily larger. During the course of a few years we have seen a development from 6 MW to up to 12MW. With a rotor of 220 metres, the turbine stretches 260 metres over the surface.

«Since 2010 the costs of taking into use renewable energy such as offshore windmills, have decreased substantially, and here the contributions by the environment around SFI Marine Operations are considerable», says leader Hans Petter Hildre during the autumn gathering for SFI MOVE.

Can ships be used to install offshore wind energy?

«An objective for decreasing costs is to assemble the installations as close as possible to the final placing,» says Associate Professor Karl Henning Halse. «Up until now, assembly has often been undertaken in a quiet fjord with cranes on land, then towing the large installations far away.»

SFI MOVE works with concepts where ships can be used to install towers, turbines and rotors in one lifting operation. This will mean efficient installation the world over. The challenges lie in the movement of the ship during installation.

«Here we are working with the smart concept that allows movement,» said Associate Professor Halse.

Profitability for Equinor witin 10 years

«We are included in defining the problems that NTNU are working with», said Senior Adviser in Equivor, Simen Moxnes.

Mr Moxnes sees that the progress in research, including assembling from a ship, will make the process considerably more efficient.

The development has made it much less expensive to work with wind energy than it was a few years ago, and Equinor envisages that floating installations can be operated cost efficiently and without subsidies within 10 years.

Mr Moxnes point out one of the challenges at present, which is to place wind farms in the vicinity of large consumer groups. He emphasises that NTNU's research with floating installations is a key factor, since the ocean depths at the location will not be a limitation. At present, Equinor is investing over 100 billion on floating installations with ocean wind energy and renewable energy.

Unmanned ships and safety

Another area that SFI MOVE is working with, is safety and technology on board remote controlled ships and unmanned vessels.

«The business opportunities and earnings are not our job to review», says Senior Engineer Nils Haktor Bua from the Norwegian Maritime Authority in his presentation during the autumn gathering. It is safety and efficiency that are important to the Norwegian Maritime Authority».

Mapping of safety

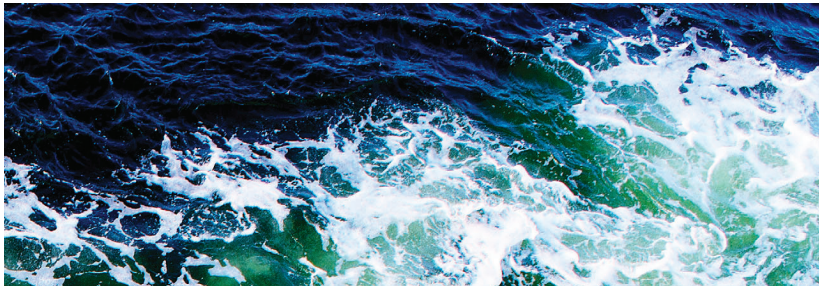
Safety must be mapped in order to make remote controlled ships function in practice,

«What happens if the satellite does not function. What is backup, and what is the plan if one experiences such a scenario. Shall the ship cast anchor? Shall it continue?»

Must be at least as safe as manned ships

Nils Haktor Bua says that there will be a regulation coming for this type of vessel both internationally, and in Norway. What type of criteria autonomous ships shall comply with so that they will be at least as safe as a manned ship.



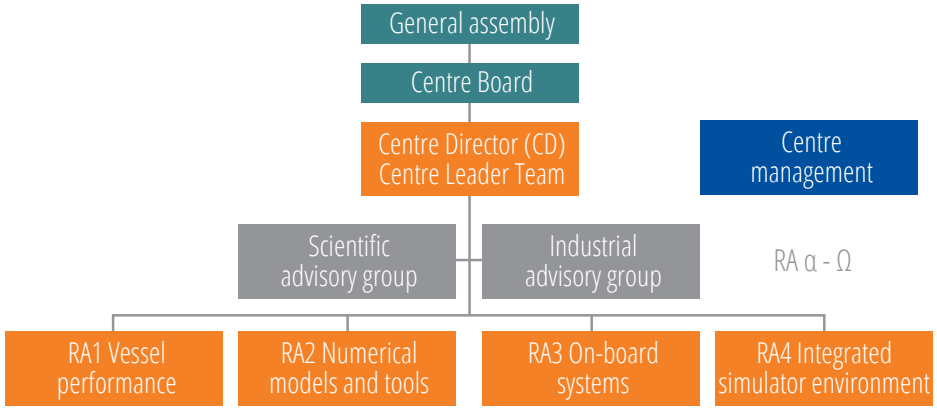
Research organisation

The following research partners were involved in 2019:

- 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
Offshore Wind - Innovative Installation of Wind Power Systems	Karl Henning Halse, NTNU
On-board Decision Tool	Henning Borgen, SINTEF Ocean
Design for Workability	Martin Gutsch, SINTEF Ocean/NTNU
Dispersed Ship Crew/Remote Operations	Frøy Birte Bjørneseth, NTNU

The Board of the Centre had the following Members in 2019:

Arnt Olufsen, Chairman (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)

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 decided to withdraw from the project from January 2019. On the other hand, we are pleased to announce that SFI MOVE got two new partners in 2019, Subsea 7 and TechnipFMC.

The industrial partners in the project in 2019 were:
Olympic Shipping
Havila Shipping
Kongsberg (former Rolls-Royce Marine)
Ulstein International
ÅKP/GCE Blue Maritime
OSC
Vard
NTNU Ocean Training
Equinor
Ocean Installer
DNV-GL
Subsea 7
TechnipFMC

Photo: Flickr

Campus Ålesund