Annual Report 2018

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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:

CONTACT – SFI MOVE
Hans Petter Hildre
Centre Director
Phone: +47 70 16 12 43
Mobile: +47 959 93 659

Magnhild Kopperstad Wolff
Finance & Administrative Coordinator
Phone: +47 70 16 15 60
Mobile: +47 482 25 391

Website:
https://www.ntnu.edu/move

Postal address:
SFI MOVE
NTNU in Ålesund, Department of Ocean Operations and Civil Engineering
Postbox 1517
NO-6025 Ålesund, Norway

Office location:
NTNU in Ålesund
Larsgaardsveien 2
Ålesund, Norway

Photos:
Else Britt Ervik
Sara Tran
Martin Gutsch
Rami Zghyer
Henrique M. Gaspar
Mykal Riley
OSC (animated photos)
Colourbox

Layout:
NTNU Grafisk Senter

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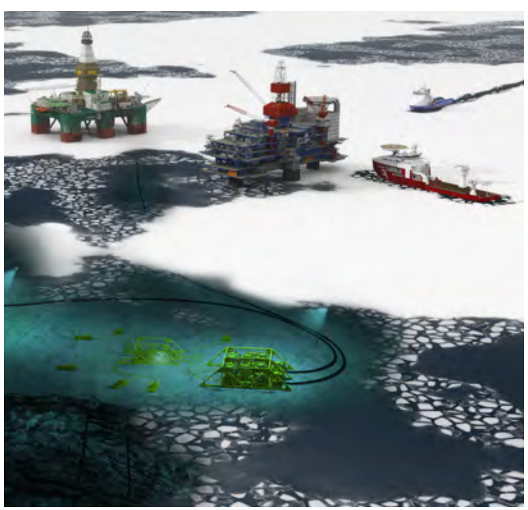
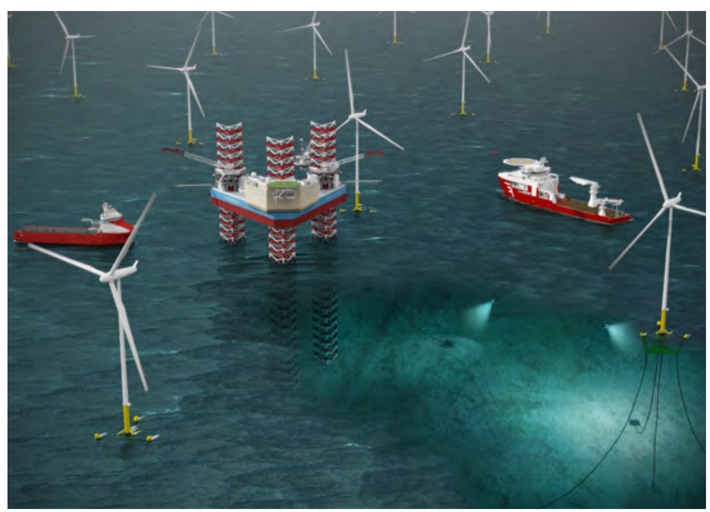
World leading position within demanding marine operations

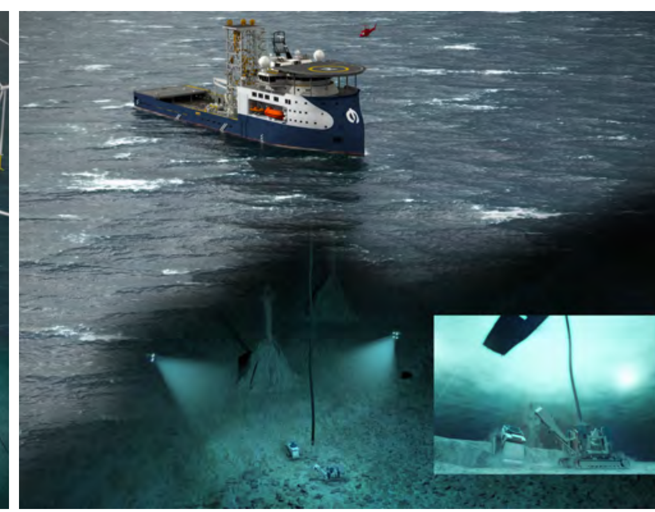
Photo: Sunnmørsposten, Staale Wattø

Our vision

Photo: Sunnmørsposten, Staale Wattø







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

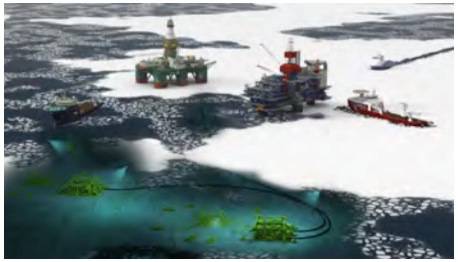
The idea is to optimise operations, from planning to execution, by better understanding of the responses. This is a simulation oriented approach where models are re-used throughout the value chain. To fulfil this goal the following is of vital importance:

- 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

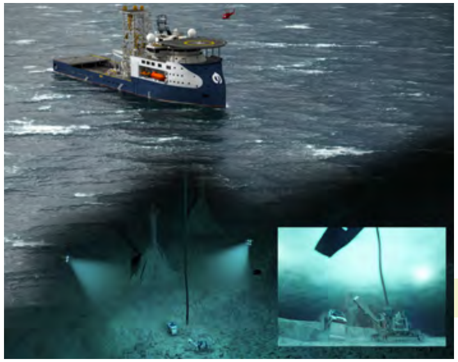
The business areas focused on in 2018 are:

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



- Installation and maintenance of offshore wind

- Subsea mining



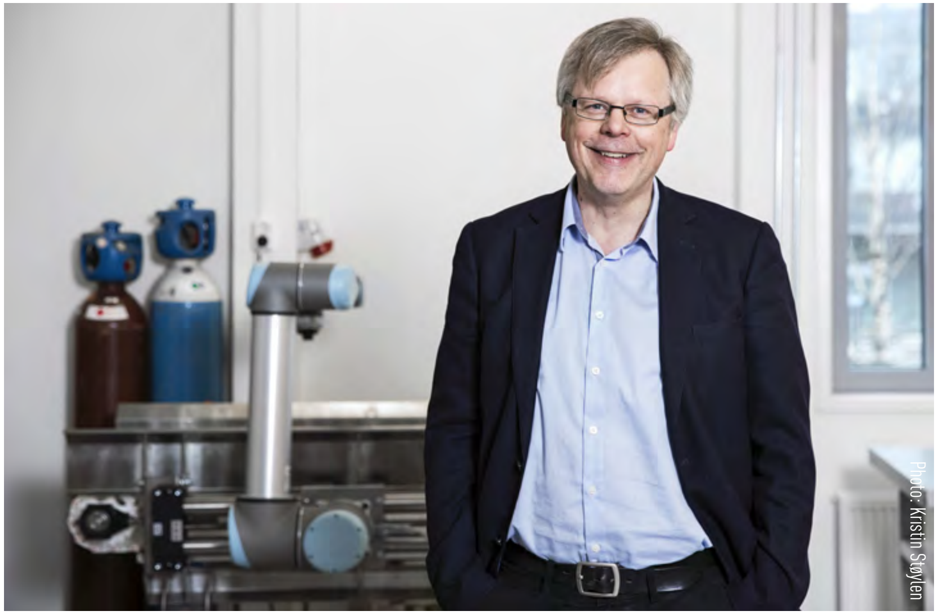
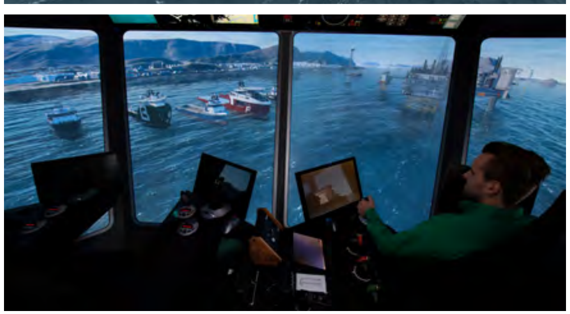


Photo: Kristin Støylen



Directors' report

Professor Hans Petter Hildre is the leader for SFI MOVE

Norway has a long coastline and a continental shelf that is six times larger than the mainland and constitutes a third of the European continental shelf. It has major oil and gas resources, rich areas for fishing, excellent conditions for fish farming, as well as offshore wind and a leading position in the ocean industries. 70 % of Norwegian export is from ocean-based industries. Marine operation is a core of development of this industry.

The oil and gas industry and related maritime activity had a tremendous 15 years of growth until 2015. Then a drop in oil prices created a fundamental shift, 80 % of the order book for Norwegian shipyards was related to oil and gas activity in January 2015 and has dropped to less than 8 % in 2018. The offshore oil and gas industry have therefore paid a lot of attention to cost reduction during the last 3–4 years. In spite of the tough economic situation, the industry is in recovery and we can see increased activity and optimism. SFI MOVE is trying to balance between activities that can enhance the competitive strength in short-term and long-term strategic research efforts.

SFI MOVE will have a mid-term evaluation by an international committee the following spring. Results achieved so far are summarised.

- The Industrial Advisory Group has been active generating new ideas for innovation. 11 ideas in 2017 and 13 new ideas in 2018.
- The researchers have contributed with more than 22 potential ideas for innovations.
- The research team has contributed with 128 publications
- 55 student theses

The project portfolio is gradually changing from exploration and solving fundamental problems to using results to solve industrial problems and create new tools and methods.

Innovative installation of floating wind power systems
Technology advances, a maturing supply chain and policy support are making offshore wind an increasingly viable option for renewables-based electricity generation. After a record year in 2017 in Europe, a steady growth is expected in the next years. Wind energy is expected to become Europe's largest renewable source with a supply of 200 GW by 2020- contributing to about 16.5 % of Europe's electricity needs - and surpassing hydro power.

Fewer restrictions on size and height than their onshore counterparts, offshore wind turbines are becoming giants. The height of commercially available turbines has increased from just over 100 metres in 2010 capable of producing 3 megawatts (MW) to more than 200 metres in 2016 (8 MW), and a 12 MW turbine design is now under development is 260 metres high. Installations are also moving further from shore, tapping better quality wind resources and pushing up capacity factors.

We are all proud of Equinor's installation of Hywind Scotland, the first floating wind farm in the world. The turbines have successfully been delivering electricity to the Scottish grid for more than a year. Floating wind sectors are expected to follow a similar downward cost trajectory over the next decade, making them cost competitive with other renewable energy sources.

Next generation giant turbines demands 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 caused by waves, wind and current. Several new concepts are sketched and simulated. It is a clearly defined goal to find new innovative methods to do installation at low cost and on a global scale.

Installations are normally carried out with a jack-up ship and with high-lift cranes lifting the individual parts of the offshore wind turbine in place one by one. In total, this is five individual lifting operations. SFI MOVE is working with a concept for installing the subsea part of the installation (the spar) first and then assemble the tower, turbine and blades in one unit. Several new concepts have been worked out in 2017 and 2018. A new promising concept is sketched and will be simulated and evaluated in 2019.

On-board decision support tool, All-Year-Round cost effective subsea installation

In the development of offshore oil and gas fields, more and more of the fields are utilising subsea technologies. An increasing number of subsea wells and trees in operation both at the Norwegian Continental Shelf as well as in other regions for offshore activities can be seen. Today a number of fields are also being assessed for life extension, which also contributes to an increased number of systems in operation as the average years in service increases.

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

Hydrodynamic forces during deployment of complex seabed structures are uncertain due to lack of hydrodynamic data. SFI MOVE has collected hydrodynamic data of various structures and geometries by systematisation of data in literature and results from existing experiments. Additional hydrodynamic experiments are being performed to cover a wide range of structures. A guideline for experimental and numerical modelling of the structures is made.

Historically, the operational limits for various marine operations have typically been limited by a wave height level (Hs). The goal for this project is to develop tools calculating real responses. The idea is to add the possibility to perform on-board simulation where the theoretical hydrodynamic models are corrected/replaced by real-time measurements of vessel motions and response. Combined with information about development of the environmental conditions through weather reports and the development over time of the actual measured responses of 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 responses and lifting equipment forces. Combined with limiting criteria for operation, 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 predictive simulation and predictive analytics tools.

The idea is also to reuse models from engineering to briefing, at position, in operations and finally in de-brief. The tool will also support the variety of crew members as DP officer, the bridge, crane and winch operator, deck and offshore manager with a common real time information about the operation.

Exploration of Technologies to Develop Seabed Mining as a New Business Area

The mining industry has a large growing resource potential if moving from onshore to offshore. Present challenges also creating offshore opportunities include: Future lack of onshore resources, rare earth material challenge, geopolitical positioning, conflicting societal interests (environmental damage vs business). Large volume of resources most likely available both inside/outside national waters, very high uncertainty regarding value of resources. In Norwegian waters alone, an NTNU study estimates low value USD 75 bn. SFI MOVE has focused on the design of lift systems to allow efficient lift of minerals from the seabed to the ship.

A 1D time domain riser flow model that includes the water, stone and gas phases is developed. A time-domain Vortex Induced Vibration (VIV) model being is developed and implemented in the riser dynamics program Riflex (SIMA). This was followed by implementing the internal flow model into the same structural dynamics framework, thus enabling coupled time domain dynamic analysis of mining riser systems to be carried out taking both internal and external flows into account.

Design for workability

The focus in hydrodynamic optimisation of 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 optimisation of efficiency and workability in other operational modes is required especially in marine operations. Design for workability focus on the development of tools providing guidelines for design optimisation and vessel selection based on the requirements to be satisfied aiming an improvement of operational performance over a wider range of criteria.

The determination of ship performance requirements is strongly dependent on their intended purpose and operational area. In 2018, the Vessel Response Tool has been developed and implemented in a web application. The web application utilises the database with motion transfer functions for providing design guidelines regarding vessel motion performance information for Design for workability. An important step in 2019 will be to implement the tool for the shareholders stakeholders in SFI MOVE.

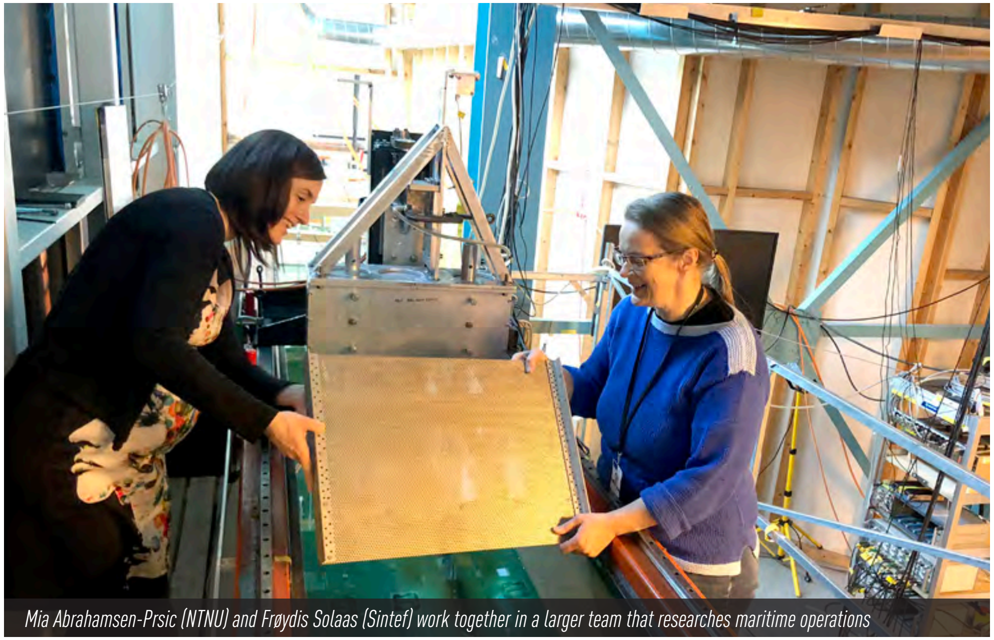
Dispersed team, – a new project in SFI MOVE

We are facing a wave of digitalisation in the industry. The introduction of technologies such as IIoT, 4G, satellite commutation and cloud computing open new possibilities for dispersed ship crews. Increased use of advanced tools for designing and evaluating system performance and safety are generating a range of digital models of a vessel and its equipment. In the operational phase, cheaper sensors and increased connectivity together with increasing data storage and computational power are enablers for new ways of managing a vessel's safety and performance.

The idea is to have a ship's crew that is partly onboard and partly in a support centre (for example in the ship owner's office). We can see the following benefits:

1. Improved quality in operations
    - Access to a broad variety of types of competence
    - Access to specialised competence, particularly for tasks that are not done frequently
    - Simplified access to suppliers.
2. Reduced costs due to reduced crew on board

In 2019 we will install needed sensors and technology in NTNU's research vessel Gunnerus and set up a ship owner control centre in Ålesund. By this approach we will run experiments; design new solutions, implement, test and observe the effect of new solutions. The goal is to test solutions in cooperation with one of the ship owner partners in 2020.



Mia Abrahamsen-Prsic (NTNU) and Frøydis Solaas (Sintef) work together in a larger team that researches maritime operations

Mia in the NTNU lab at Tyholt in Trondheim

– I have been interested in everything regarding water and the sea since I was very young!

Text and photo: Kjersti Lunden Nilsen

Mia and Frøydis at the lab they have spent many hours in together. «Having several women in research is incredibly important, and at this lab we have had modifications done to accommodate pregnant researchers», emphasises Frøydis, and points to the new stair installation in the background

In close partnership in a small laboratory in Tyholt, Mia Abrahamsen-Prsic from NTNU and Frøydis Solaas from SINTEF work with calculating how maritime operations can be implemented in a safe and defensible manner.

Main profile:
Mia Abrahamsen-Prsic (35)

– Master in physical oceanography, PhD from Maritime Technical Centre at NTNU
– Post.Doc with NTNU, SFI MOVE

Theme: Numerical calculations of hydrodynamic forces in maritime operations

Mia Abrahamsen-Prsic, who is originally from Croatia, holds a Master in physical oceanography and at the moment is employed as Post Doc at NTNU.

Since 2016 she has been affiliated with SFI MOVE where she works as a researcher in a team researching on maritime operations.

Since she took her Doctor's degree at NTNU she has worked with heavy numerical calculations on large abstract constructions.

«My job now is to be more practical and understand more about what the requirements of industry are, but also to generalise the models and experiments enough so that we can use our conclusions for general modules», she explains.

Hydrodynamic forces

We meet her at her place of work at Tyholt in Trondheim, together with Frøydis Solaas from Sintef Ocean.

Frøydis and Mia have worked closely in several different contexts, and complement each other well. Frøydis with her solid knowledge about the requirements industry has – and what research they ask for. Mia with her theoretical competence in numerical calculation.

– I have been interested in everything regarding water and the sea since I was very young!

According to her, the job is mainly about understanding hydrodynamic forces on modules for subsea production of oil and gas.

This is academic research in close co-operation with industry.

«This was completely new and very exciting for me, and something I did not experience in the Doctor degree, because that was very theoretical and scientific», says Mia.

It is about large installations at sea, and calculations of hydrodynamic forces.
It is about waves, sea states and various types of weather.
It is about mathematics and logistics.
And it is about boats, cranes and vessel – and how they will come alongside with equipment that is to be lowered – for example, when parts of the subsea production systems are to be installed.

«Correct calculations must have been done for how this must be carried, for example, when a gigantic crane shall lower heavy equipment through the waves» says Mia.

Various sea states

«There are a few challenges if something is to be installed on the bottom of the North Sea. Large, heavy pieces of equipment which have different shapes and sizes, must be lowered down through the waves in a defensible way», say Mia and Frøydis.

One of the main objectives for the calculations which must be done before an installation can take place, is to find out in what type of weather conditions the installation job can be done.

«If we underestimate the hydrodynamic forces on the modules, we can risk that we find out that the installation can be carried out in worse weather than it actually can, and we can risk damage and injury to equipment and people. If we overestimate the forces, the result can be that we must wait for better weather than necessary to get the job done», explains Frøydis.

There is a broad spectrum of different sea states, and when they work offshore it is a must that they avoid that the equipment snaps or break up during the operations.

«Good weather is the best, but it is seldom that we can work under such conditions and then we must take all precautions», says Mia.

Costly processes

Waiting for good weather costs money since the installation vessels cost a lot in operation for each 24 hours .

«The margins must be so wide that all possible aspects are covered, both for equipment and installations», explains Mia.

They also follow DNV GL's rules, which lay down principles for how one shall operate at sea.

How does the ship move?
How great are the forces acting on each wire?

In the project they have also studied how they can calculate and gain knowledge of which forces can act on the various structures that are to be installed. Two questions are particularly central in their research:

What happens in different sea states?
What forces act on the various parts of the modules, and what simplifications can be done to generalise the modules and calculate the forces?

«The data and knowledge we gain from our research will be able to be used by the project engineers when they shall make calculations to find out in which sea states (i.e. how high waves) an installation can be carried out. It does not make it easier to do the job itself, but will make the calculations more precise so the correct weather limitations can be found», explains Frøydis.


Frøydis and Mia in the NTNU lab at Tyholt in Trondheim


Trygve Kristiansen is Mia's mentor and an important supporter in several research projects in which they are both involved

Close-knit team, different strengths

We move to one of the labs at Tyholt, and here are both Mia and Frøydis in their elements when they show me around.

«Our group started as a project interested in methods and numerical tools for simulation of offshore operations, but with time has developed into being a part of the research around the on-board support systems», explains Mia.

She boasts about the interdisciplinary research environments both at Sintef and NTNU, where she herself belongs and has been for many years.

«We are many curious people who work together, and that does something with the environment, all of us have different backgrounds, and we have a lot of freedom to develop research themes according to our own interests and needs», she emphasises.

She would mention in particular those with whom she has worked in a team on this project.

In addition to Frøydis Solaas, Fredrik Mentzoni and Trygve Kristiansen have also played important roles in the project. Fredrik Mentzoni is a Ph.D candidate, while Trygve Kristiansen is a professor employed at the Institute for Marine Technology at NTNU. He has had an important role regarding asking the right questions that have brought the project further.

She is also grateful for being given the opportunity to contribute with her background in various research projects.

«This environment is very research focused, and then gender is not the most important. Here I can use my time as a researcher first and foremost. I do not experience being perceived as a woman researcher», she says.

Trygve Kristiansen, who is also Mia's mentor, has also been an important supporter in several different ways.

«As a professionally interested and involved professor, he forms the basis and sets the direction of our research, and makes us into a close-knit team», emphasises Mia.

A woman in a large research environment

Despite the fact that there are male-dominated environments where it can be a challenge to be a woman, she boasts of her own working environment.

«I have been so lucky that I have not needed to fight as a woman in research, I have been able to concentrate on being a Post.Doc in research, independent of gender», says Mia.

After eight years in Norway she nevertheless experiences some differences from her own homeland Croatia.

«In Croatia, maternity leave is mainly reserved for women, but I myself have experienced having two parents with scientific careers, and who managed to combine this in a very good way», she says.

At the time this interview was done, Mia was expecting her third child.

She boasts about the welfare schemes in Norway, which have given her – and her husband – the opportunity of having research careers at the same time as they have established a family.

«We have both been able to be at home, at the same time as we have taken our part of the maternity leave. It is quite simply a gift», says Mia.

Innovation

Hans Petter Hildre

New ideas generated in 2017	New ideas generated in 2018
1. Access system from ship to floating and fixed structures	1. Optimum routing with respect to energy consumption
2. Remote control of operations	2. Hybrid machinery with respect to minimum energy consumption
3. Subsea operations from submersible vessels	3. Station keeping risk
4. Giga-moon-pool	4. Lifting from deck/barge/HTV/to splash zone
5. Active subsea lifting frame (fibre ropes)	5. Technology to increase operation window and reach
6. Crane structure to force modules through the splash zone	6. Semisubmersible vessel for offshore wind installation
7. On-board tool for subsea lifting	7. Access system from ship to fixed structures
8. Design for workability	8. Use of 3D and animations to illustrate procedures
9. Floating dock for offshore wind assembly and installation	9. Methods for effective briefing on-board and de-briefing.
10. Wave and tide energy	10. Remote operations and dispersed teams
11. The "Digital Ocean Space" at Breisundet	11. Traffic control in close range to critical installations
	12. Innovative method for installation of offshore wind
	13. Innovative link between tower and floating SPAR

The idea of the SFI scheme is to promote innovation by supporting long-term research through close co-operation between R&D intensive companies and prominent research institutions. It is a challenge to achieve both good research and stimulate corporate innovations. The method is to facilitate alliances between enterprises and research groups. Researchers are training in the field to gain insight into the business community and are encouraged to transfer research-based knowledge and technology.

The PhD candidates, the Post Docs, and the associated MSc-/BSc students are working on tasks that are discussed with the partners through user meetings, reports and publications. It is important for the partners to engage in a proper manner in order to be able to assimilate the results coming out of MOVE.

SFI MOVE has an Industrial Advisory Group with participation from each industrial partner. The group is setting up an Innovation Plan annually with the purpose of initiating and defining ideas and challenges as direction for the research. The idea is that the Innovation Plan shall give common goals and direction for the research (voice of the user). The plan describes prioritised projects as business cases. 11 ideas were described in 2017 and 13 ideas in 2018.

The table illustrates ideas generated in 2017 and 2018 by the Advisory Group. For example, ideas 7, 8 and 9 were prioritised as separate projects for 2018 by the Centre Board. Business cases were defined and discussed in January 2018. Ideas 10 and 12 were prioritised by the Centre Board in November 2018 and will be projects in 2019.

SFI MOVE, SFI Exposed, SFI Smart Maritime and SFF AMOS have cooperated with NTNU TTO and established the Ocean School1 of Innovation. The objective is to create a culture for innovation, strengthen the awareness and competence of innovation and contribute to increased commercialisation of research results. Its success will be shown when some of the PhD students wish to start a new business. Our priority has been to innovate in close cooperation with the companies and not as an internal research effort. It is a huge challenge fulfilling the scientific merits and contributing to innovation in the participating companies. This has been a tremendous learning process and new methods of how to organise SFI MOVE have been needed.

The professors, researchers and PhD are also continuously reminded about generating innovations. 22 ideas have been described so far.

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

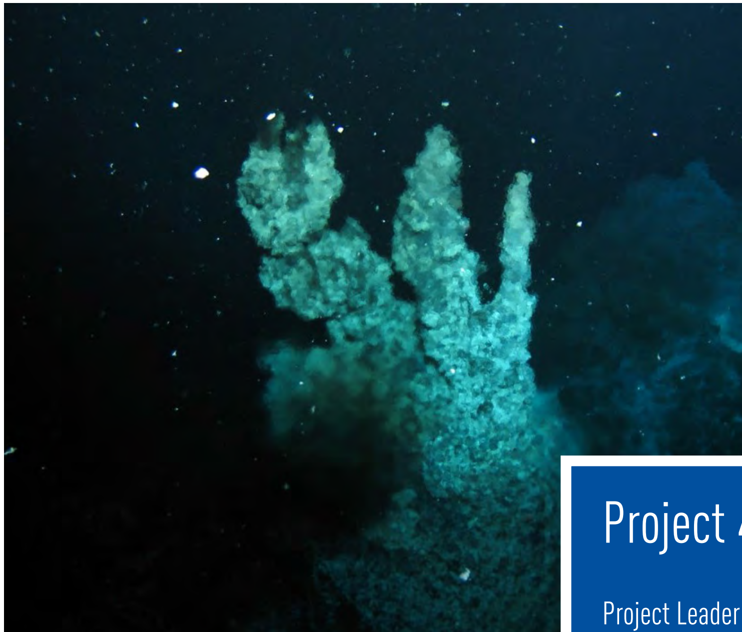
Active projects in 2018:

Project 4: Seabed Mining: Exploration of Technologies to Develop Seabed Mining as a New Business Area

Project 5: OW: Innovative Installation of Offshore Wind Power Systems

Project 6: On-Board Decision Tool

Project 7: Design for Workability



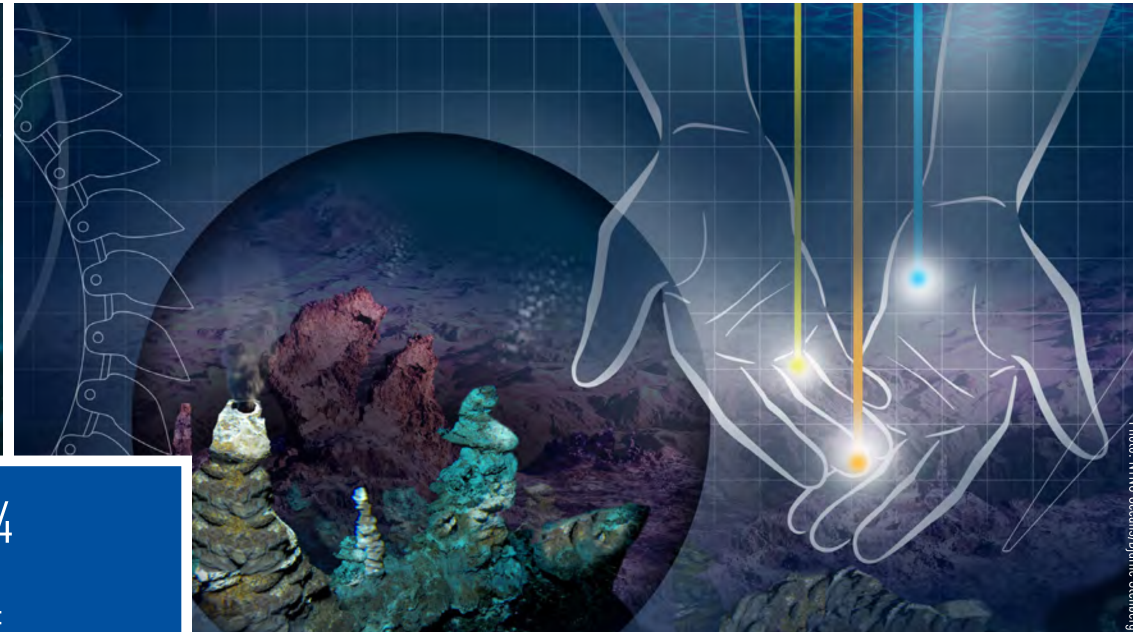
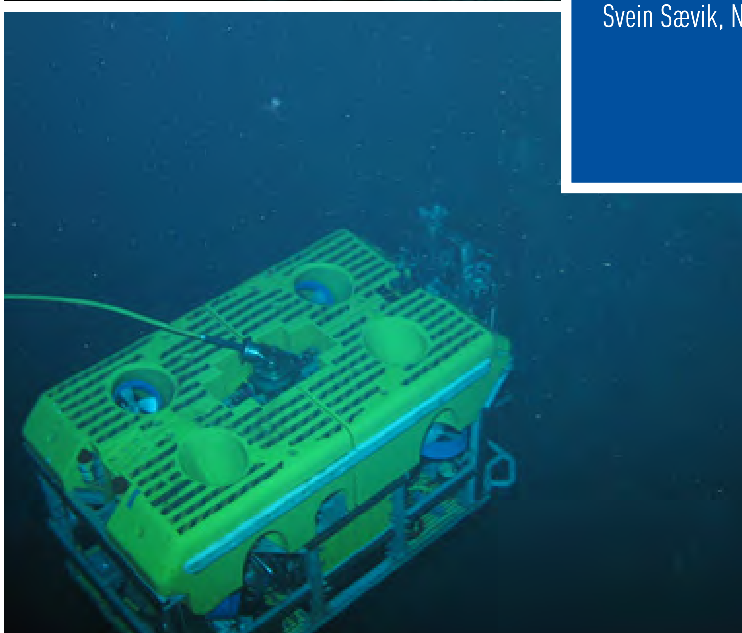


Photo: NTNU Oceans/Bjarne Stenberg



Project 4

Project Leader:
Svein Sævik, NTNU

Seabed Mining:
Exploration of Technologies to Develop Seabed Mining as a New Business Area

The interest for subsea mining is growing. Norway controls one of the world's largest sea areas - six times the land area of Norway, including the northern expanse of the Mid-Atlantic Ridge. In Norwegian waters alone, NTNU studies estimate low value USD 75 bn. No upper limit. The Marmine NFR project (https://www.forskningsradet.no/prosjektbanken/#!/project/247626/no) started with a research cruise to the Arctic Mid-Ocean Ridge (AMOR) in 2016, covering the extended Norwegian Continental Shelf. NTNU and NIVA, together with several research partners, surveyed and sampled potential mineral deposits on the ridge. The mission included water depths up to 3000 m and the sample material will be used for characterization of the ores.

Parallel to this, NTNU Oceans, Pilot Deep sea mining, is an ongoing project being part of NTNU Oceans, which is one out of four strategic research areas at NTNU. This program coordinates all activities related to sustainable Ocean Space utilization (https://www.ntnu.edu/oceans). With respect to Ocean Mining the current activities includes a wide range of related topics: Autonomous exploration, detection of seafloor minerals based on spectral signatures, energy supply, environmental aspects of deep sea mining, ethics and social responsibility, exploration – geophysics, history of subsea mining – legal aspects, platform development, resource assessment, resource geology and vertical transportation.

With respect to SFI MOVE, the marine operation aspects of ocean mining, including the structural behaviour of the riser system, needed to transport the deposit from the seabed to the vessel is focused on. The material transport may be provided by pumping water and rock particles (slurry flow) possibly combined with compressed air through the riser. The structural behaviour of the riser system when exposed to both external current and internal flow at large water depths is identified as a critical topic. Therefore, two PostDocs, Niranjan Reddy Challabotla and Mats Jørgen Thorsen were allocated in SFI MOVE to work on these issues. The objective included development of models that enable studying coupled transient riser dynamics phenomena related to both multiphase flows (water, rock and air) and hydrodynamic loads. The concept is illustrated in Figure 1 and its performance as compared to the state of the art is illustrated in red in the Table 1 where it is noted that the state of the art of today only includes Methods 1–3. It is additionally noted that the hydrodynamics model allows for both stationary and oscillatory flows from current, wave and floater motions combining the forces from 1st order and higher order VIV effects. This represents a significant step forward as compared to existing models applied by industry today.

The work was completed in September 2018 and has resulted in the following:

- A 1D dynamic vertical transport model based on the in-house multiphase flow code SLUGGIT that included slurry transport and air lift features
- Implementation of a VIV hydrodynamic load model in RIFLEX
- A framework for coupled RIFLEX-SLUGGIT simulation (riser dynamics and internal multiphase flow)

The following papers have been published as a result of the work:

- Thorsen MJ, Sævik S: Vortex-induced vibrations of a vertical riser with time-varying tension. Procedia Engineering 2017, Volume 199, pp. 1326–1331.
- Thorsen MJ, Sævik S: Simulating Riser VIV in Current and Waves Using an Empirical Time Domain Model. OMAE2017-61217, ASME 2017 36th International. Conference on Ocean, Offshore and Arctic Engineering, June 25–30, 2017, Trondheim, Norway.
- Thorsen MJ, Sævik S: An Analytical Model of the Effect of Internal Density Waves in Risers Subjected to Vortex Shedding. ISOPE-I-18-701, The 28th International Ocean and Polar Engineering Conference, 10–15 June, 2018, Sapporo, Japan.
- Thorsen MJ, Challabotla NR, Smith IE, Nydal OJ, Sævik S: numerical study on vortex-induced vibrations and the effect of slurry density variations on fatigue of ocean mining risers. Ocean Engineering, Volume 174, 15 February 2019, Pages 1–13.

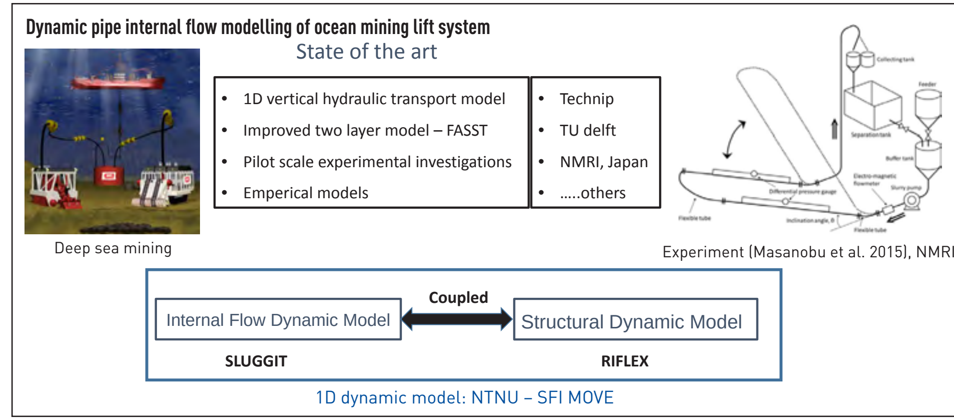


Figure 1: The coupled dynamic model concept

	Flow model	Structural model
Method 1	Steady state	Static
Method 2	Steady state	Dynamic
Method 3	Transient	Static
Method 4	Transient	Dynamic

Table 1: Illustration of the research objective (red) as compared to the state of the art.

Figure 2: Snapshot of mass distribution in riser due to internal flow

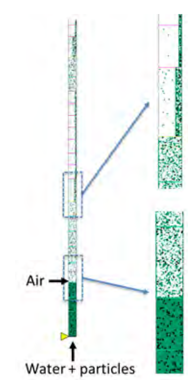


Figure 3: 1D flow model considering airlift and slurry flow

Then the following conference presentations have been made:

- Challabotla NR, Smith IE, Nydal OJ, Sævik S: Simulation of two-phase flow in airlift pump using 1D two-fluid model. Underwater Mining Conference 2018; 2018-09-10 – 2018-09-14.
- Thorsen MJ: A Coupled Riser Dynamics Model for Deep Sea Mining risers. Ocean Week 2018; 2018-05-06 – 2018-05-09, NTNU.
- Challabotla NR: Dynamic pipe flow modelling for Ocean Mining Lift System. OCEAN WEEK, 2018-05-06 – 2018-05-09, NTNU.
- Thorsen MJ: Riser Dynamics in Deep Sea Mining. Ocean Week 2017; 2017-05-03 – 2017-05-05, NTNU.
- Challabotla NR: Model development for ocean mining lift system. OCEAN WEEK, 2017-05-03 – 2017-05-05, NTNU.

Project 5

Project Leader:
Karl H. Halse (NTNU Ålesund)

OW: Innovative Installation of Offshore Wind Power Systems

The installation costs of a typical offshore wind power plant, is 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, Equinor installed the world's first floating wind power park, known as Hywind Scotland. The wind park consists of five floating wind turbines of 6 MW each and is estimated to cost approx. NOK 2 billion. The installation cost of Hywind Scotland was greatly reduced compared to the single Hywind Demo unit installed in 2009. However, the installation costs were still substantial, 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 simulate marine operations for demonstration and design, and not only for training purposes.

Installation of floating Offshore Wind Turbine from catamaran

During 2018, we continued to develop an alternative lifting mechanism to transfer the OWT tower from the catamaran deck to the floating SPAR. We used the same catamaran vessel as studied earlier in the project, but the lifting mechanism is modified. In the present version, we have placed the lifting mechanism with the OWT on a motion compensated platform. The platform follows the SPAR motions.

The design has been studied in AGX, where we have modelled the control model to minimise the relative motion between the lifting mechanism and the SPAR substructure. The hydraulic system that provides the necessary motion compensation is simplified in the present model.

Since the AGX model has very simplified hydrodynamic capabilities a verification study was started in SIMO. However, this is put on hold due to limitations in the modelling capabilities in SIMO.

Installation of floating Offshore Wind Turbine from a floating dock

In 2018, a large floating dock concept was introduced by SFI MOVE. Offshore installation of floating wind turbines is a challenging task, and the floating dock concept is intended to shield a spar floating wind turbine during installation of tower, nacelle, and rotor onto a spar foundation. First, design optimisation of the dock was performed to minimise the material cost. During the optimisation, multiple design variables and nonlinear constraints imposed by operational and transit conditions were addressed, see Figure 1. Then, hydrodynamic analysis and dynamic response analysis of the coupled system of the dock and the spar were conducted. The present design of the dock reduces the platform-pitch responses of the spars and potentially facilitates the blade mating, but may deteriorate the heave velocity of the spars in swell conditions.

Installation of fixed Offshore Wind Turbines from a jack-up vessel

Comparative study for single wind turbine blade installation using jack-up and floating installation vessels (the work by Yuna Zhao)

The feasibility of floating installation vessels for single blade installation is studied by comparing the motions of the blade root relative to the monopile top for jack-up, mono-hull and semi-submersible floating installation vessels, as shown in Figure 2. The Morison's formula for hydrodynamic loads, the flexibility of the legs and the soil-pile interaction are considered for the jack-up vessel model, while the first and second-order wave loads and a dynamic positioning system were considered for the mono-hull and the semi-submersible floating installation vessels. The comparison indicates that the large-displacement semi-submersible has slightly higher motions of the blade root as compared to the jack-up vessel, while the mono-hull installation vessel has too large blade root motions. It is more feasible to use the semi-submersible than the mono-hull vessel for blade installation.

Wind turbine blade installation considering structural response-based criteria (the work by Amrit Verma)

Single blade installation by a lifting operation using jack-up and floating crane vessels are investigated with the focus on blade leading edge impact and blade root impact. The blade leading edge impact analysis shows more damage for the case using floating installation vessels. Further, a high fidelity finite element model based on solid elements along with experimentally validated subroutine is developed for damage assessment. These structural results are also used with global responses to assess the feasibility of blade installation using floating crane vessels. The sideways blade root impact gives the worst scenario, as shown in Figure 3, and the failure modes include severe bending of the guide pin bolt and the failure of adjacent root laminate. A mitigation measure by placing a passive tuned mass damper on top of the monopile is investigated and is found to reduce the impact velocity between root and hub by 40 %, which can substantially increases operability of the blade mating operation.

Automated wind turbine blade installation (the work by Zhengru Ren)

Research on automated wind turbine blade installation is continued. Both single blade installation for a bottom-fixed offshore wind turbine and preassembly installation for a floating offshore wind turbine are investigated. First, the blade lifting operation is optimised by a nonlinear model predictive controller. The controller for the active single blade installation is improved to achieve a successful mating operation by reducing the relative motion between the blade root and the hub at the monopile top. Novel three-tugger-line configuration is discussed and controlled with optimal control allocation. GPS and IMU are integrated to provide high-fidelity hub motion estimation which overcomes several significant issues, such as, GPS noise, GPS time delay, GPS low sampling rate, accelerometer noise, and accelerometer bias. Sensitivity studies are conducted to evaluate the performance of the proposed algorithms. Furthermore, the novel preassembly installation concept using a catamaran is studied. Control laws are designed for the roll reduction system and active heave compensator.

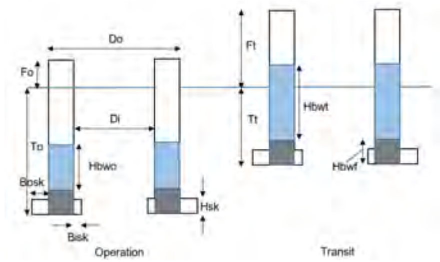


Figure 1: Illustration of the design variables of the floating dock

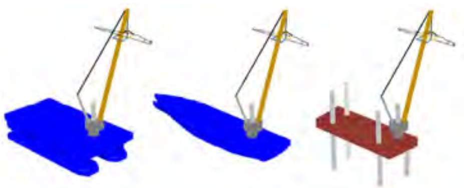


Figure 2: Illustration of single blade installation using semi-submersible, mono-hull and jack-up installation vessels

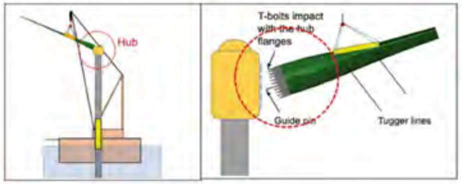
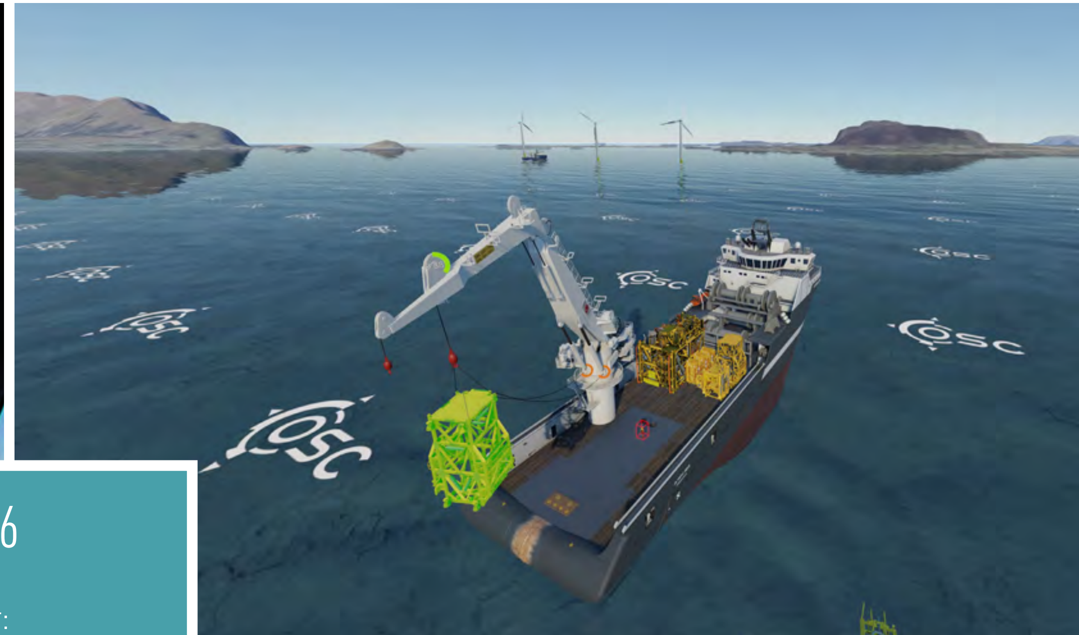


Figure 3: Blade root sideways impact and damage in guide pin and root laminate



Project 6

Project Leader:
Henning Borgen,
SINTEF Ålesund/SINTEF Ocean

On-board Decision Tool

New emerging technologies offer the possibility of establishing digital twins of ships and their equipment based on fundamental physical models and/or real time live sensor data from operating ships. The On-Board decision tool project is developing technology on how this can be used to monitor and predict the response of the vessel and its lifting equipment, and based on this information, give advice to the crew performing a marine operation on how to operate safely and efficiently. The technology developed will give an important contribution towards response-based decision making in marine operations.

The project has two main tracks for development

1. Decision support system infrastructure (framework, system architecture)

2. Decision support system applications (e.g. subsea crane lifting)

In 2018 the project has focused on the development of a flexible architecture for real-time onboard decision support software. The goal was to create a framework that can be adapted to a variety of applications. The backbone of the framework is therefore an efficient data exchange mechanism to which any number of data sources, data processing algorithms, storage mechanisms, analysis modules and user interfaces can be connected. This data exchange mechanism is based on the *Data Distribution Service for real-time systems* (DDS), an open middleware standard that ensures high performance, scalability and interoperability.

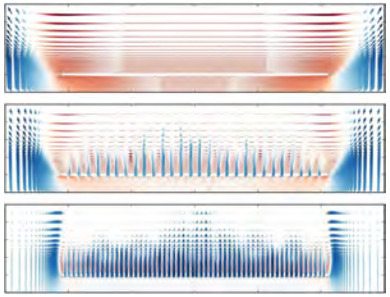
To demonstrate the framework, we have also started development of a decision support system (DSS) for offshore crane lifts. The goal is to create a system that can advise the crew on how – and whether – an operation can be performed in the most safe and efficient manner possible given the current and predicted environmental conditions, taking into account the actual, measured, responses of the vessel. In 2018, the work has focused on the first phase of a lifting operation, after the payload has been lifted off deck but before it has been lowered into the water.

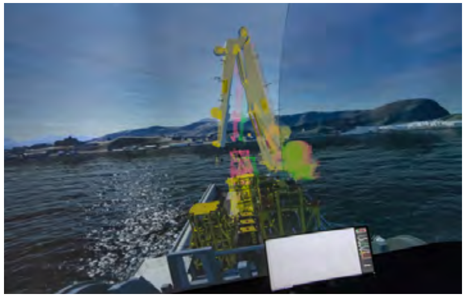
The behaviour of the ship and payload are predicted using simulation, and to that end we have developed numerical models for the payload, crane wires and constant-tension tugger winches. In addition, we have done further work on implementing support for the *Functional Mock-up Interface* (FMI) standard in the SIMO simulation software, enabling it to be more easily connected with the DSS and other simulation tools. To demonstrate this, we have connected a SIMO vessel model to the crane payload model through the FMI.

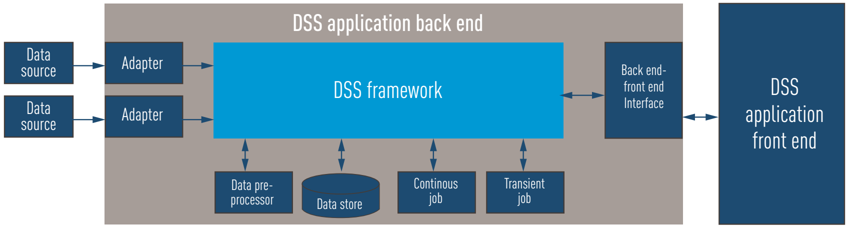
The *Olympic Challenger,* a light construction/ROV support vessel owned by Olympic Subsea, has been selected to serve as a case study for the project. We have made plans for instrumentation and installation of logging equipment which will be carried out at the earliest possible time. This equipment will continuously record the position, heading and motions of the vessel. Initially, we will use this information for development and testing of the DSS. Eventually, the plan is to demonstrate the system in actual operation onboard the Olympic Challenger.

Before performing an installation operation an assessment of the necessary vessel and crane capacity and the limiting sea state for the installation has to be performed. This may be done by use of numerical time domain simulations of the operation or the so-called «Simplified Method», which is described in DNVGL RP N103 and gives conservative estimations of the hydrodynamic forces on the structure to be installed. A good hydrodynamic model of the structure is also essential for a reliable onboard decision tool. In all cases, hydrodynamic coefficients for the structure to be installed has 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. Therefore, more accurate methods to estimate the coefficients together with the use of time domain simulations may be cost saving when it comes to time spent on waiting for acceptable weather conditions for the installation operation.

When estimating coefficients, it will always be a question of how much we can simplify. Is it necessary to model every part of the structure in detail, or is it sufficient for example to model the protection roof and the mudmat? In which cases can we estimate the coefficients as the sum of the coefficients for the different parts or when does interaction effects and shielding has to be taken into account? How proximity to the free surface will influence on the coefficients must also be considered. To help answering these questions, SINTEF and NTNU performed a comprehensive model tests series of conventionalized structure parts and combinations of structure parts. In total, 30 different structures parts and combinations were tested in a fully submerged condition. In addition, some of them were tested close to and at the surface and in waves.

Project 7

Project Leader:
Martin Gutsch, SINTEF Ocean/
NTNU

Design for Workability

The offshore industry in northern Europe is operating increasingly large installations in exposed areas, requiring high reliability and availability. Downtime of those large and complex offshore systems leads to significant financial losses. Attention is on vessel designs for installation and maintenance, which are insensitive to weather, as a requirement to operate safely in high sea states. Here, a key aspect is the optimization of hull geometry, aiming for a reduction of vessel motions in waves.

The objective of this project is the development of a tool providing guidelines for design optimization and vessel selection based on the specific requirements of a marine offshore operation. Here, the project is utilizing former SFI MOVE research for the evaluation of vessel performance to make the results useable for industrial partners.

Main deliverables of Project 7:

- Vessel Response Tool (VRT)
- 2nd Marine Operations Forum

The Vessel Response Tool

The Vessel Response Tool (VRT) is designed to support decision-making processes where a quick analysis of motion response behavior of various ship designs for benchmarking or vessel selection is needed. Hence, the Vessel Response Tool can be used for design optimization at the early design stage, where the optimal hull size for a specified work task and sea area is needed, or for the selection of the best suitable vessel for an intended offshore operation. The tool enables the user to evaluate and compare mission dependent ship motion behavior based on the vessel's main characteristics, motion limitations, and environmental data.

In contrast to other available tools on the market, the Vessel Response Tool is openly accessible on vrt.sintef.no. Further, it does not require any advanced hydrodynamic expertise nor exact geometrical hull descriptions.

Based on the vessel, operational, and limitation input data, the tool delivers an approximation of selected performance parameters, such as:

- Limiting sea states for non-exceedance of the specified operational criteria
- Percentage operability (operational time) based on environmental data of the specified sea area and motion characteristics (RAOs)
- Operability Robustness Index (ORI, formerly nominated Integrated Operability Factor, IOF)

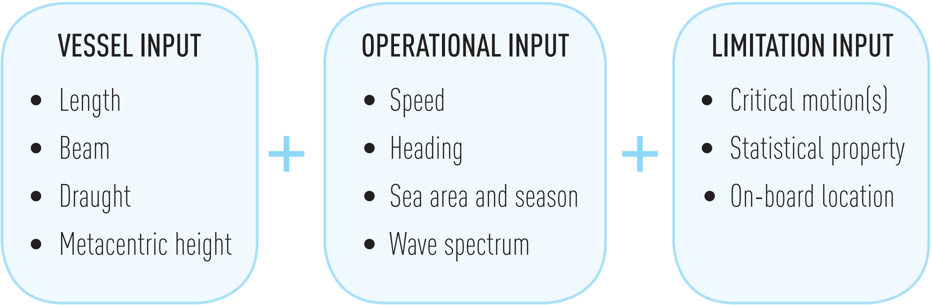
The latter parameter was newly introduced as performance indicator for vessel response motion behavior showing the level of operational performance for limitations lower than the specified input. Mathematically described, the ORI indicates how quickly the percentage operability curve converges (steepness of the curve).

The results are established based on motion transfer functions (RAOs) for 2835 ship geometries of different size and loading conditions, all calculated based on a generic hull geometry of an offshore construction vessel in operation since 2014. For a practical estimation of the dependency of motion responses in waves the accuracy is sufficiently high. A comparison against a variation of other hull geometries leads to an accuracy level (standard deviation) for the ORI of 7.7 % for roll, 3.3 % for pitch and 1.8 % for heave at COG. For further information please refer to OMAE2017-62307 proceedings: *Design Parameters for Increased Operability of Offshore Crane Vessels.*

2nd Marine Operations Forum

Another activity in the project was the organization of the 2nd Marine Operations Forum. The yearly organized forum shall provide an arena for knowledge exchange between researchers in SFI MOVE and stakeholders of the marine and offshore industry.

The focus of the 2nd Marine Operations Forum was the development of a valid weighting of individual Performance Indicators according to their significance for the successful execution of offshore lifting operations. The forum was held in a workshop arrangement on April 21, 2018 at the Norwegian University of Science and Technology (NTNU) in Ålesund. About 40 participants from 14 different companies were actively participating in the forum. The general program was divided into two parts: A first part addressing weighting factors for vessel performance assessment and a second part discussing and collecting the industry's prime requirements on on-board decision tool development activities in SFI MOVE. Further information is available for SFI MOVE partners in Report No. OC2018 I-118: *Weighting of Performance Indicators for Offshore Lifting Operations.*



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, Rolls Royce Marine, 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.

Program cooperation

SFI MOVE is increasing the cooperation with NTNU AMOS (Centre for Autonomous Marine Operations and Systems). Researchers at NTNU AMOS work between the disciplines to create a world-leading centre for autonomous marine operations and control systems. NTNU AMOS contributes with fundamental and interdisciplinary knowledge in marine hydrodynamics, ocean constructions and control theory. The research results are being used to develop intelligent ships and ocean structures, autonomous unmanned vehicles (under water, on the surface and in air) and robots for high-precision and safety-critical operations in extreme environments.

The projects On-board decision support system and Dispersed team/Remote operations in SFI-MOVE have a common interest with NTNU AMOS and further cooperation will be a driving force.

Research cooperation

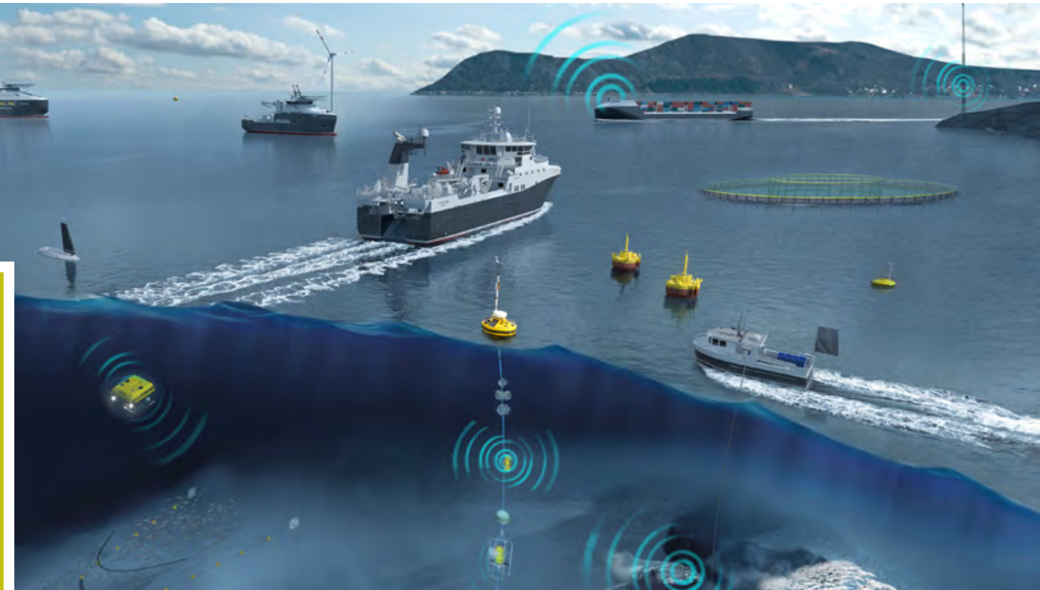


Illustration of Fjordlab Ålesund

Ocean Space Centre

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 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. Sensors and instruments that measure water, electricity and equipment are to be placed in the fjord in a full-scale laboratory. 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.

Ocean School of innovation

Ocean School of Innovation was established in cooperation with NTNU-TTO. This is a joint initiative between several centers to increase awareness and competence on innovation among PhDs and researchers.

Main goals:

1. Create a culture for innovation
2. Strengthen the awareness and competence on innovation
3. Contribute to increased commercialization of research results

Ocean School of Innovation provides:

Courses and Training

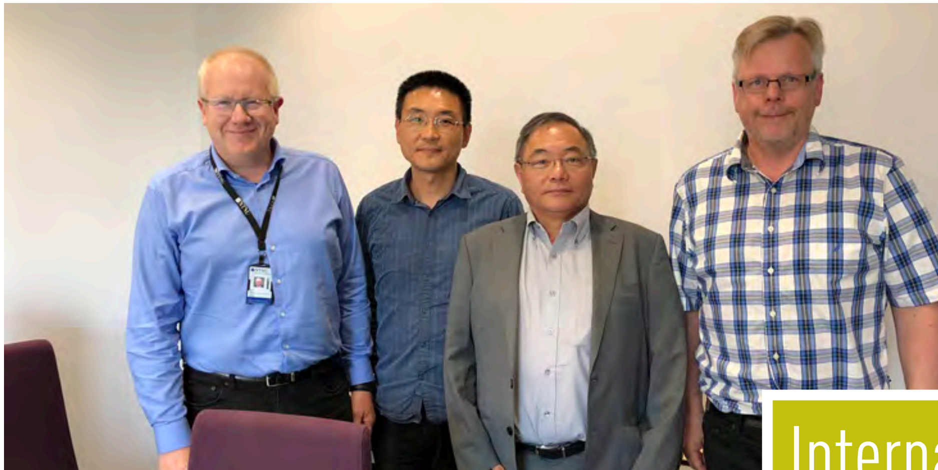
- Entrepreneurship
- Innovation in start-ups and large companies
- IPR and Asset Management
- Design Thinking

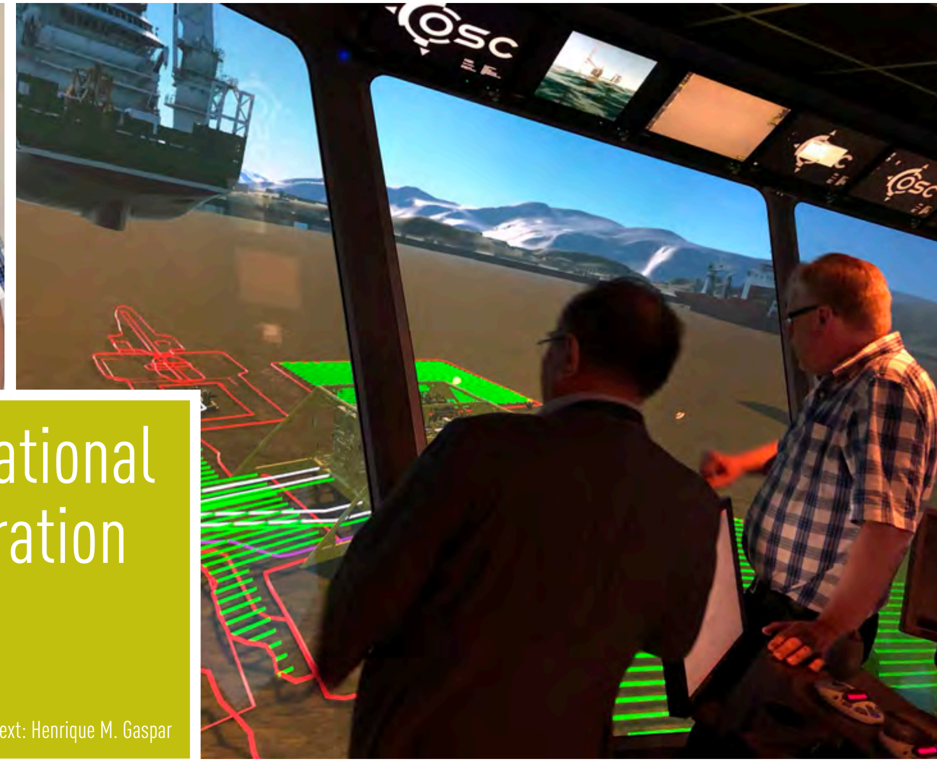
Culture for Innovation

- Innovation Lunches
- Teambuilding and Networking
- Pitching
- Tech Transfer Speed-dating
- Funding Opportunities

Activities 2018

Workshop: Communication skills & negotiation (07.02.2018)
Innovation Crash Course (27.02.2018)
Improve your presentation skills (04.04.2018)
Ocean Week, Oceans in Change (07.-09.05.2018)
Networking Skills for researchers (14.05.2018)



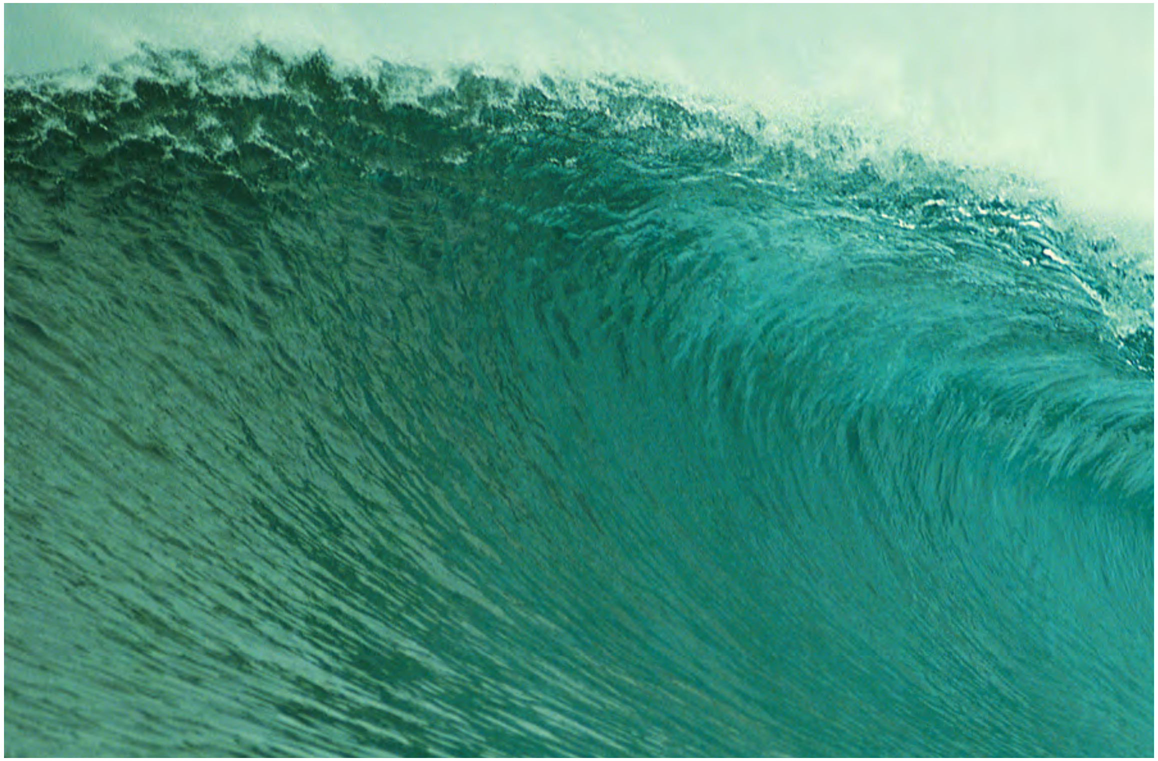


International cooperation

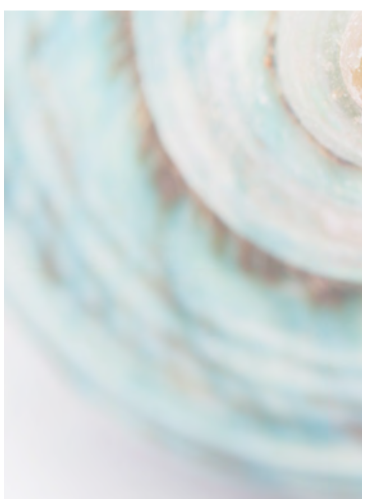
Text: Henrique M. Gaspar

Recently, SFI MOVE has been active in strengthening the existing international cooperation. 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.

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.




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**	**Planned exam**	**Project**	**Nationality**	**Gender M/F**
Martin Friedwart Gutsch	2015	2019	Vessel performance	German	M
Fredrik Mentzoni	2015	2018	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	2019	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
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
Postdocs with funding from SFI MOVE					
Mia Abrahamsen-Prsic	2016	2018	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

Martin Gutsch

Photo: Thor Nielsen

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 HS-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

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

Department of Marine Technology • Faculty of Engineering

Photo: Thor Nielsen

Title

Control and Online Decision Support of Crane Operations for Fixed and Floating Offshore Wind Turbines.

Research topics

- Build control plant models for marine lifting operation.
- Design controllers to precisely locate the payloads (lumped-mass, tower, and blade) and verify it through experiments.
- Consider fixed-to-floating, floating-to-fixed, and floating-to-floating installation operations, as well as an integration with DP system.

Industrial goal

- Design real-time robust controllers for the mating and positioning operations during wind turbine installation.
- Improve the weather limits during lifting and mating operations.

Scientific questions

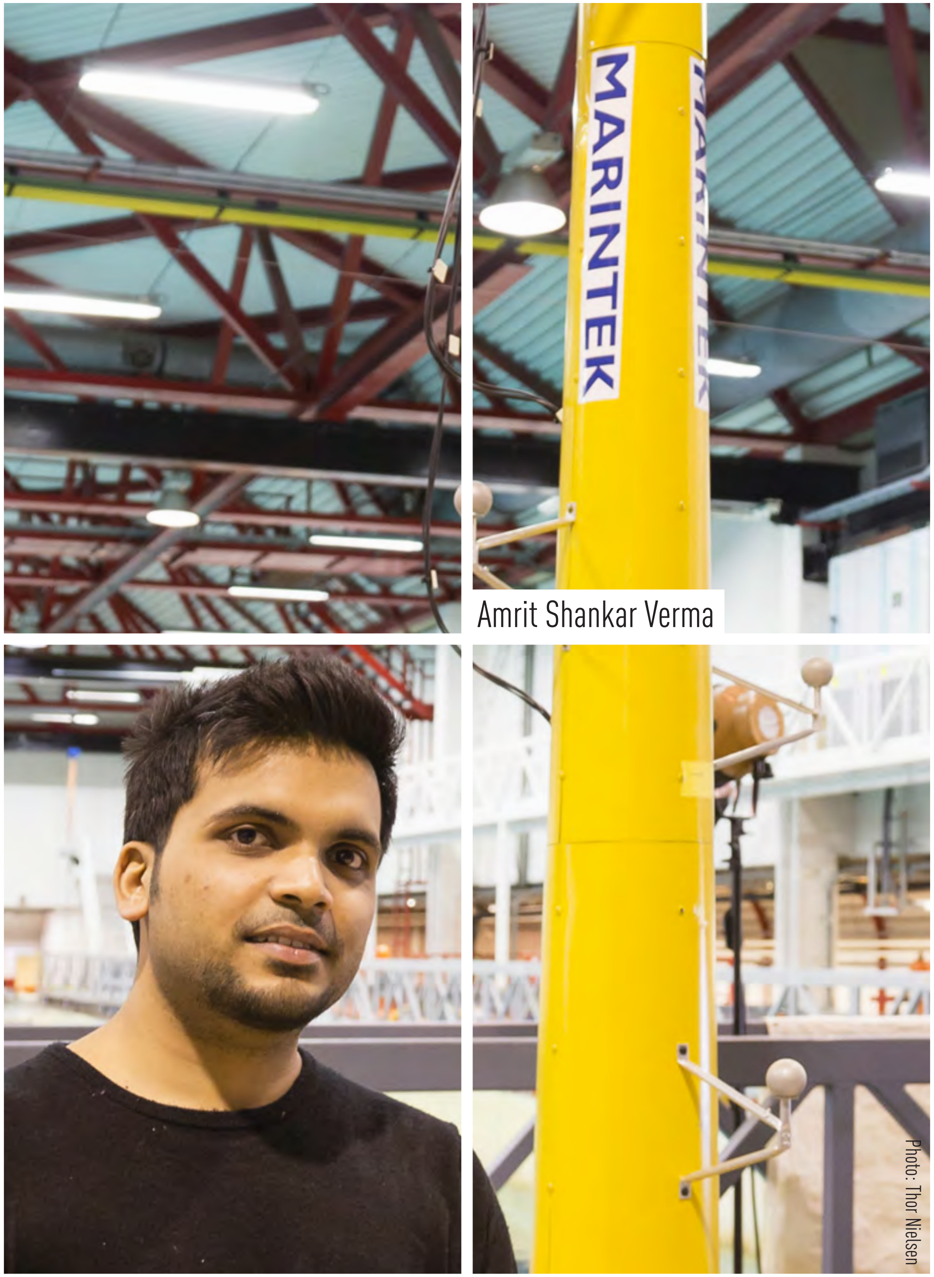
- Influence of wave-induced motion to the crane operation; Underactuated system; High lifting; Robust control; Model-free control.

Innovations

- Attempt to study vessel-based installations, not commonly jackup-based.

Supervisor: Roger Skjetne (IMT, NTNU)
Co-Supervisors: Zhen Gao (IMT, NTNU)

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 company

Equinor
DNV-GL

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

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-Supervisor: Thor I. Fossen (ITK, NTNU)
and Bjørnar Vik (Rolls-Royce)

PHD-STUDENT

Department of Marine Technology • Faculty of Engineering

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

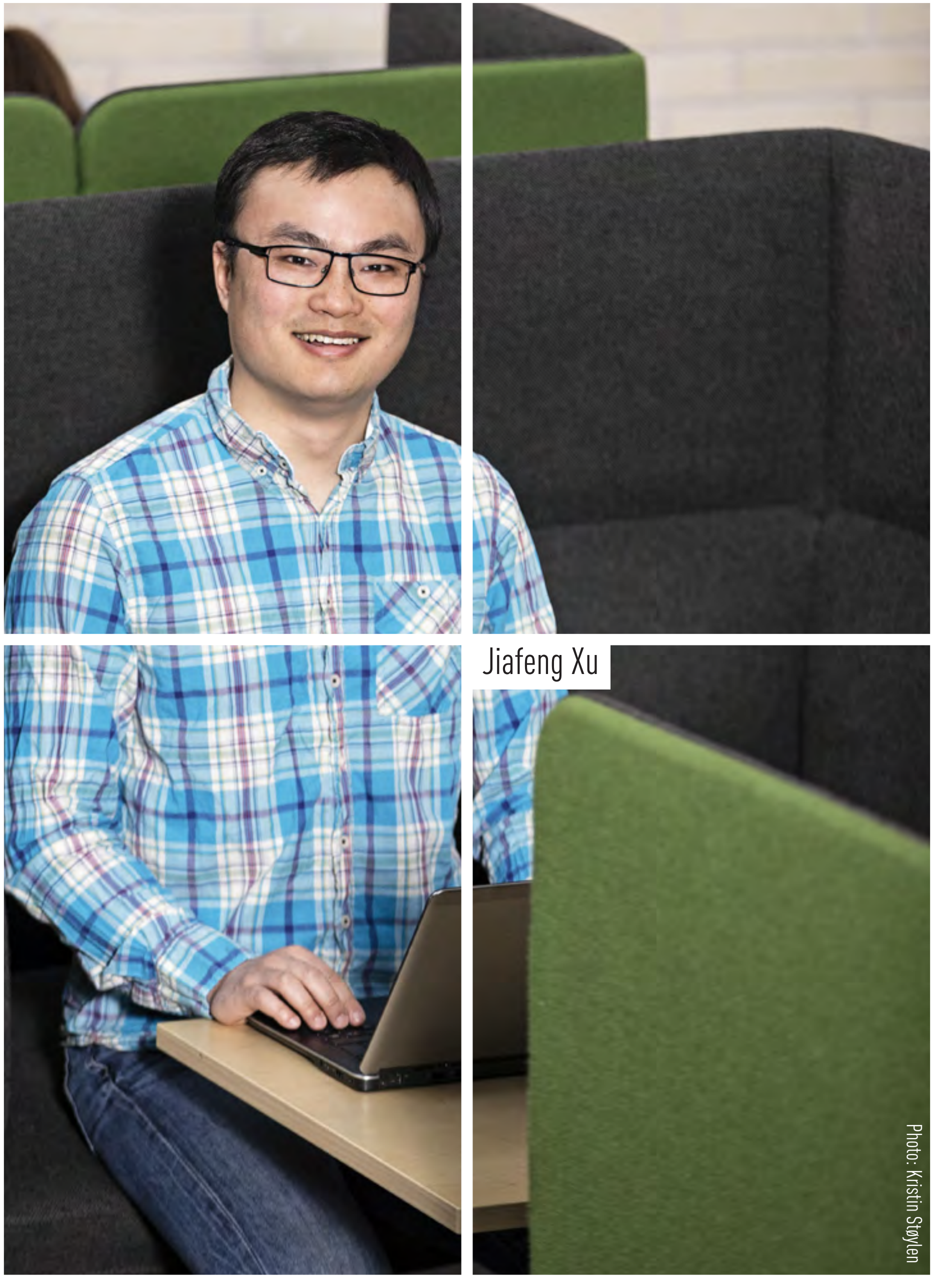
Scientific questions

- 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



Title
Real-time Simulation of Marine Operations.

Research topics
My research aims at developing a computer program environment and proper algorithms that can simulation marine operation in real-time with good reliability and flexibility. The focus will be on the result accuracy and calculation speed. Such simulation can serve as a powerful tool for both personnel training and product development.

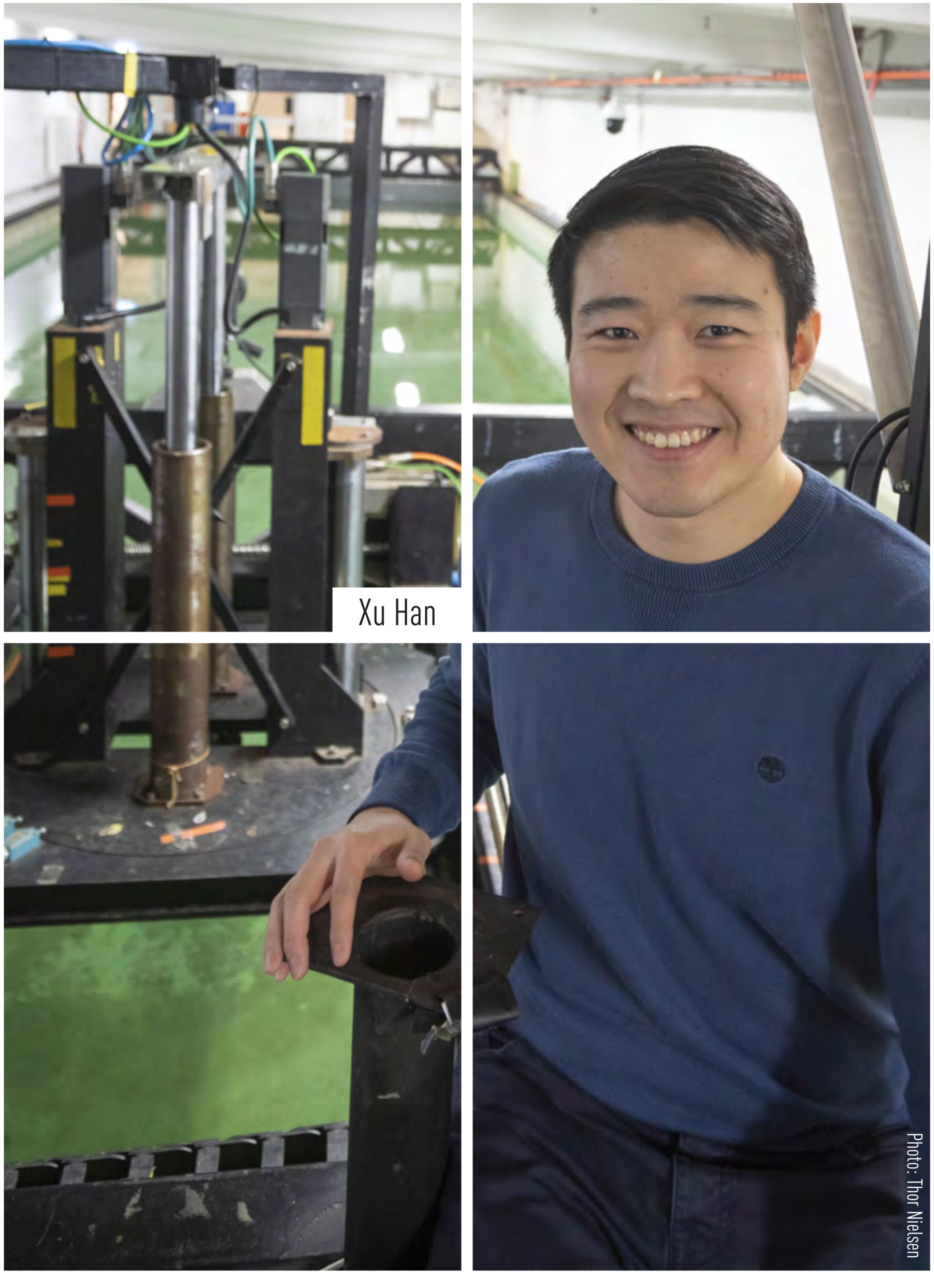
Industrial goals
Ongoing projects include development of multibody dynamics simulation environment and development of real-time hydro-dynamic simulation with mesh or meshless method. A more integrated simulation framework with higher interaction level between different systems can better predict different kinds of marine operation scenarios. With better knowledge from the simulation, operators can make faster and more rational decisions in real operations and engineers can adjust the products more efficiently with lower cost.

Scientific questions
- How to define a generic and robust simulation framework?
- How to implement modular concept into simulation?
- How to democratize simulation methods to the industry?

Innovations
Traditional methods need to be modified and adapted to the real-time world. Isolated simulation perspectives need to be integrated for a higher interaction level.

Cooperating company
Offshore Simulation Center (OSC)

Supervisor: Karl Henning Halse
Co-supervisor: Eilif Pederson



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

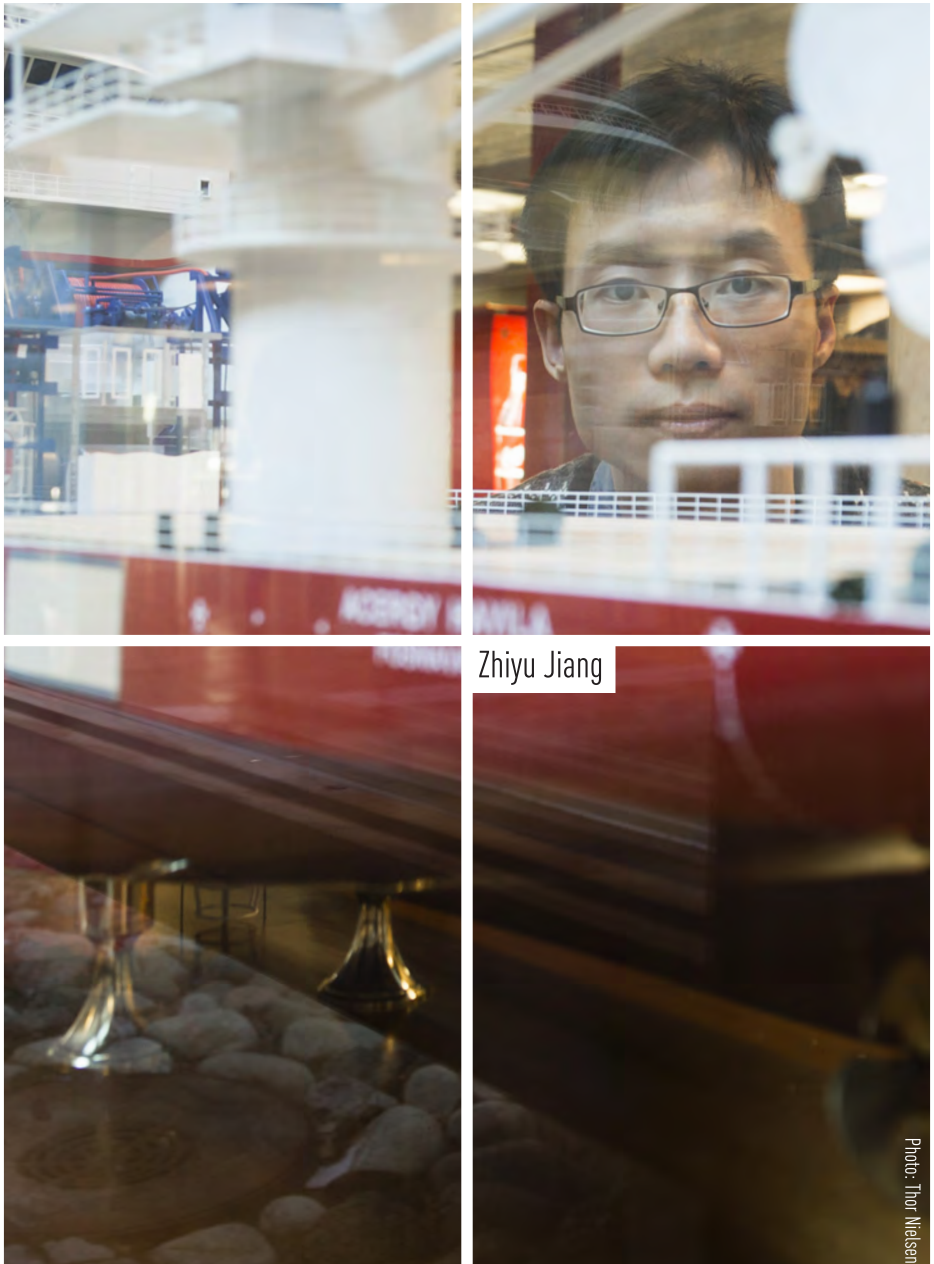
Methods for vessel motion prediction leading to improved safety and operability for marine operations

Cooperating company

SINTEF, Ocean Installer

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

Department of Marine Technology • Faculty of Engineering



Zhiyu Jiang

Photo: Thor Nielsen

Title

Efficient and accurate numerical methods and models for dynamic response analysis for installation of offshore wind turbines

Research topics

When using a floating vessel to install wind turbine blades or rotor-nacelle assembly, dynamic behaviour of the coupled system under simultaneous wind and wave loads are complicated. It is challenging to accurately model such floating system and predict the dynamic responses for design of the installation mechanism and system. The purpose of this study is to develop accurate numerical methods and models to analyse the actual installation procedure and to obtain the system responses for design check. The following case studies will be considered.

- Advanced modelling and analysis of the installation system for a pre-assembled rotor-nacelle-tower using the novel catamaran developed by NTNU Ålesund for design check and for validation of the numerical models used in the real-time simulation. The focus will be on modelling of the coupled system of the catamaran vessel, rotor-nacelle-tower and lifting mechanism.
- Conceptual design and optimisation of the very large floating dock concept for installing pre-assembled rotor-nacelle-tower system.
- Modelling of floating installation vessels to study the effectiveness on roll motion reduction using various damping devices (such as flopper-stopper, anti-roll tank).

Industrial goals

- To assess the feasibility of novel installation methods for a pre-assembled rotor-nacelle-tower system
- To reduce the roll motions of floating vessels to increase the weather window for installation

Scientific questions

- How to accurately model the coupled system of a floating installation vessel, blades or rotor-nacelle-tower assembly and a bottom-fixed or floating foundation and predict the dynamic responses under stochastic wind and wave loads?
- How to address the hydrodynamic and structural design aspects of a very large floating dock?
- How to reduce the roll motions of a floating installation vessel by passive or active damping devices?

Innovations

- New numerical methods and models for dynamic response analysis of installation systems

Cooperating company

OSC, DNV-GL, Ocean Installer, Statoil

Supervisor: Zhen Gao
Co-supervisor: Karl Henning Halse

POSTDOC

Department of Marine Technology • Faculty of Engineering

Mats Jørgen Thorsen

Title

Coupled dynamic analysis of subsea mining riser systems.

Research topics

- Build a numerical model that allows coupled dynamic analysis of long riser systems applied in subsea mining operations
- Integration of time domain VIV model in SIMA
- Integration of 1D flow model in SIMA

Industrial goal

To contribute towards positioning the Norwegian Maritime industry in the forefront wrt. commercial harvesting of subsea minerals

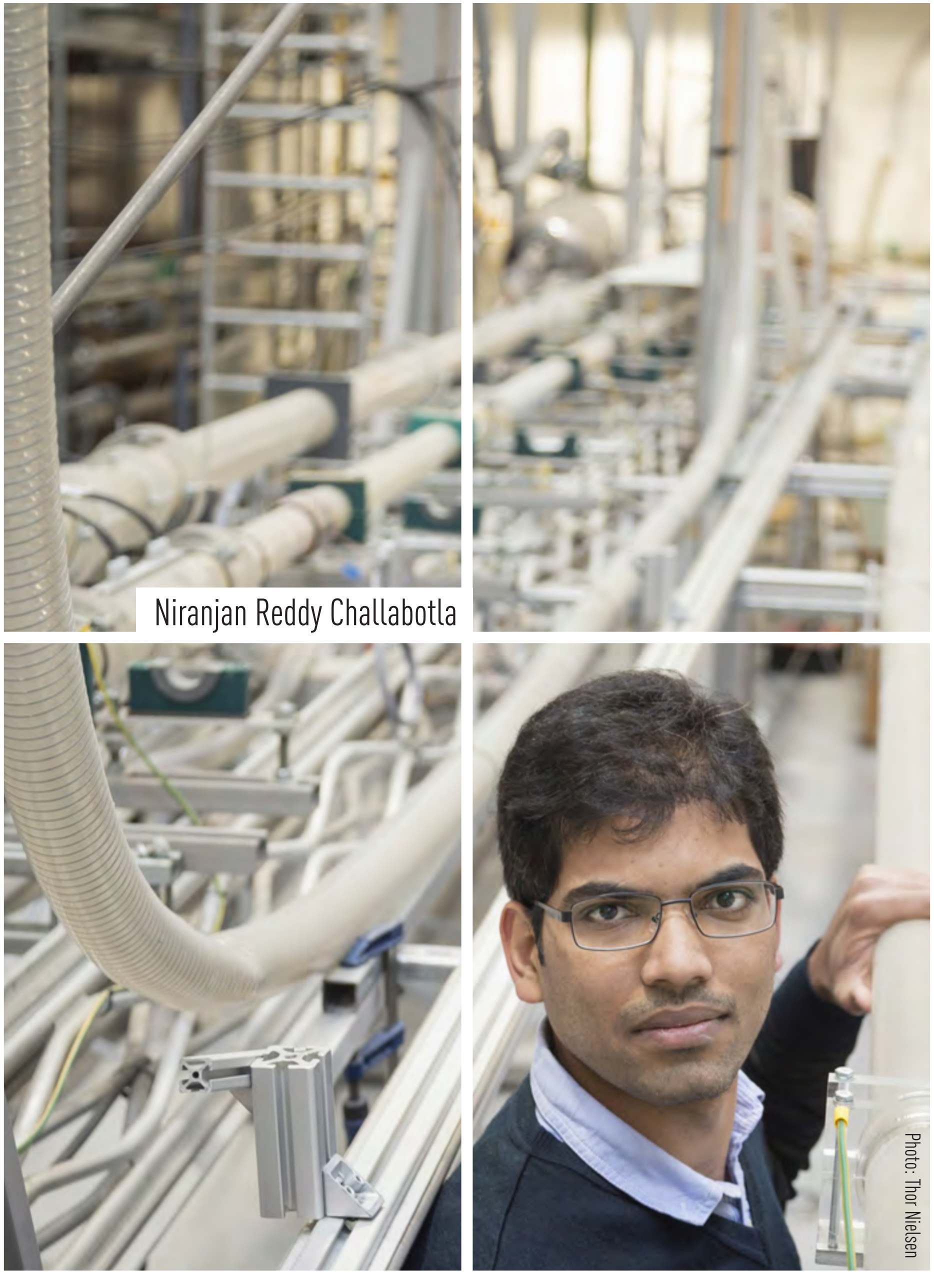
Scientific questions

How will transients related to start-up and operation of mining riser system contribute to riser response?

Innovations

A framework for performing dynamic response analysis of long riser systems with internal and external flow.

Supervisor: Svein Sævik (IMT, NTNU)
Co-Supervisor: Ole J. Nydal(IPT, NTNU)



Niranjan Reddy Challabotla

Photo: Thor Nielsen

Title

Coupled dynamic analysis of subsea mining riser systems.

Research topics

- Tflow model to include particles and three phase flow with compressible gas (gas-lift scenarios).
- Integration of 1D flow o extend the 1D model in SIMA

Dynamic pipe flow modelling for Ocean Mining Lift System

Lifting of particles in long pipes from the sea bed to the surface is a challenging problem in deep sea mining. Many correlations were proposed in the literature for prediction of the pressure drop in horizontal and inclined pipes. Most of these correlations were semi-empirical and valid for steady state liquid-solid two-phase flows and particular range of particle parameters. The validity of these correlations is not well established in the application of deep-sea mining, where the particle size is larger and the fluid flow in pipe is highly transient. Recently, there is an increased interest towards better understanding of the particle transport in deep-se mining application. TECHNIP has developed transient flow assurance model FASST (Flow Assurance Simulation for Slurry Transportation) for design and monitoring of large particles transportation in liquid-solid riser systems (Beauchesne et al., 2015). Different mechanisms leading to riser blockage during the transport of particles in vertical hydraulic lift were reported by experimental and 1D models (van Wijk, 2016).

Dynamic flow conditions may occur during operations, and the structural pipe dynamics may also be influenced by the internal flow dynamics. The current postdoctoral candidate is focusing on extension of a 1D dynamic flow model (Sluggit) to include particles (Kjeldby, 2013). The proposed flow model will be based on a bubble tracking method which has been developed for analysis of flow transients in multiphase pipelines (based on C++, semi-implicit, moving grid). The developed dynamic flow model will be coupled with the structural pipe model. At later stage, flow model will be extended to investigate the feasibility of the gas lift system for deep sea mining application.

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Industrial goal

To contribute towards positioning the Norwegian Maritime industry in the forefront wrt. commercial harvesting of sub-sea minerals.

Scientific questions

How will transients related to start-up and operation of mining riser system contribute to riser response?

Innovations

A framework for performing dynamic response analysis of long riser systems with internal and external flow.

Supervisor: Ole J. Nydal (IPT, NTNU)
Co-Supervisor: Svein Sævik (IMT, NTNU)

POSTDOC

Department of Marine Technology • Faculty of Engineering

Photo: Thor Nielsen

Mia Abrahamsen Prsic

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


Photo: Karl Otto Kristiansen

The SFI MOVE-team at the autumn conference 27.11.2018

Photo: Karl Otto Kristiansen

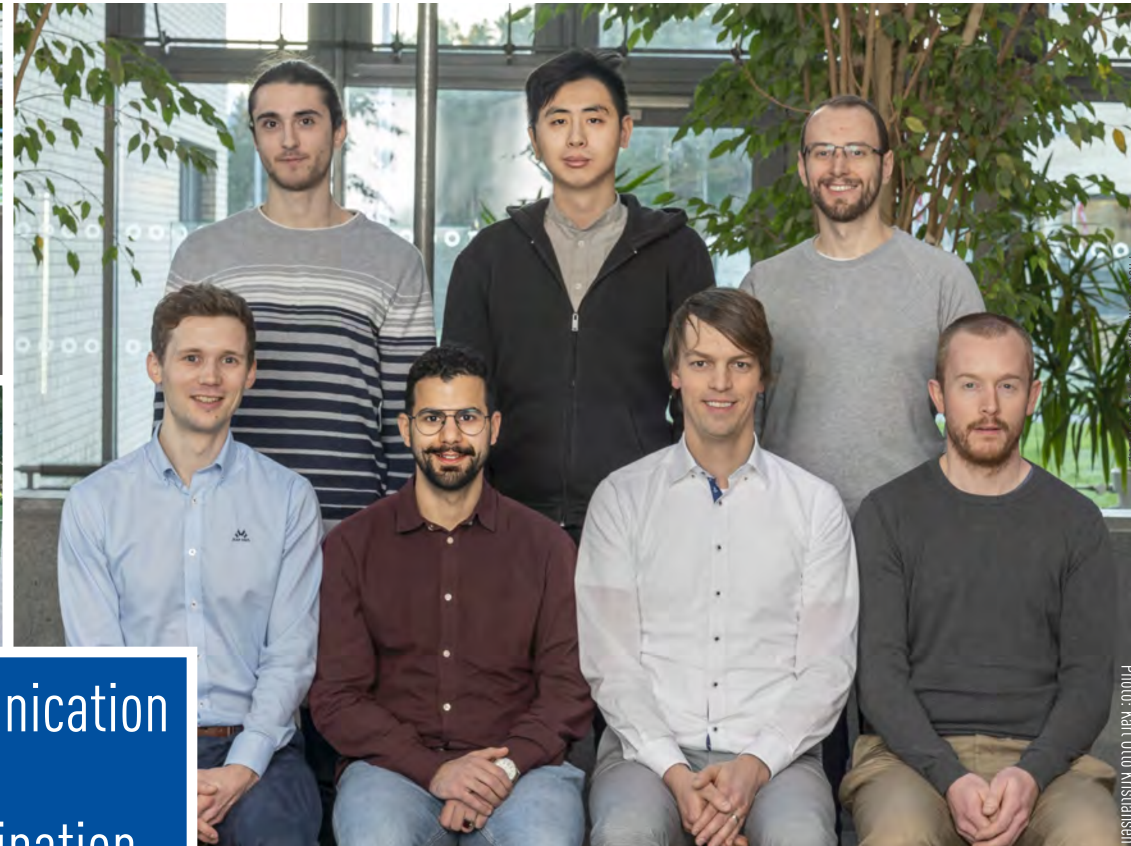

Photo: Karl Otto Kristiansen

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 2018:

- Spring conference, 19.04.18
- Marine Operations Forum, 20.04.18
- Workshop – PhD and Postdocs, 31.05.18
- Autumn conference, 27.11.18

Subsea Lifting Operations, Norwegian Society of Lifting Technology, November 2018,
Stavanger:
Hans Petter Hildre and Joel Alexander Mills 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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NTNU

Master's degrees

Name	Sex M/F	Topic
Ingrid Mehn-Andersen	F	Time-domain Roll Motion Analysis of a Barge for Transportation of an Offshore Jacket Structure
Anders Juul Weiby	M	Frequency-domain Roll Motion Analysis of a Transportation Barge Using Stochastic Linearization of Viscous Roll amping
Jorge Luis Rangel Valdes	M	Dynamic Response Analysis of a Catamaran Wind Turbine Installation Vessel with focus on the Transportation Stage
Guodong Liang	M	Frequency-domain Method for Global Dynamic Response Analysis of a Semi-submersible Floating Wind Turbine
Tesse Marianne Balkema	F	Hydrodynamic Loads on an Inclined Monopile in the Splash Zone
Brandon Thomas Pereyra	M	Design of a Counter Weight Suspension System for the TetraSpar Floating Offshore Wind Turbine
Prateek Gupta	M	Subsea Installation, splash zone hydrodynamics
Frid Grøtterud Birkeland	F	Accidental drop of pipes
Helene Salte Håland	F	Accidental drop of pipes
Amund Helvik	M	Radical installation methods
Sebastian Eriksson	M	Large moonpools with recesses
Morten Ravnås	M	Unstable two phase flow in long vertical pipes
André Humlestøl Rongsøy	M	Development nd verification of CFD methods for simulation of forces on ventilated structures
Xiaoxuan Wan	F	Numerical time domain simulation of fully submerged object in subsea lifting
Qian Yu	F	Estimate Dynamic Factors for Subsea Lifting operation by Using Experimental Method - Rapid Prototyping
Odne Øyen Hovde	M	Comparing the vessel response by measuring the operability for fishing trawlers
Silje Aarvik Johannessen	F	Autonomous heading control in position mooring with thruster assist
Alexander Mykland	M	Low-Cost Observer and Path-Following Adaptive Autopilot for Ships
Guttorm Udjus	M	Force Field Identification and Positioning Control of an Autonomous Vessel using Inertial Measurement Units
Mats Håkon Follestad	M	Autonomous Path-Planning and -Following for a Marine Surface Robot

Accounts

Project 1: Low Cost Offshore Wind Installation and Maintenance – was completeted in 2016
Project 2: Subsea: Safe – All Year – Cost-efficient Subsea Operation – was completed in 2017
Project 3: Simulation Technology and Virtual Prototyping as a Common Approach from Design to Operation – was completed in 2017

All figures in 1000 NOK

Funding		Project 4	Project 5	Project 6	Project 7	Lab/Dissemination	Management	Total
The Research Council		2033	3636	2 996	1 509	-	1 326	11 500
The Host Institution, NTNU in Ålesund		-	170	2 190	-	-	-	2 360
Research partners:		53	264	2 403	1 726	-	-	4 446
	NTNU	53	160	1 295	1 513	-	-	3 021
	SINTEF	-	104	1 108	213	-	-	1 425
Enterprise partners:		141	1 316	2 422	606	491	-	4 976
Total		2 227	5 386	10 011	3 841	491	1 326	23 282

Costs		Project 4	Project 5	Project 6	Project 7	Lab/Dissemination	Management	Total
The Host Institution, NTNU in Ålesund		-	679	2 196	-	491	1 241	4 607
Research partners:		2 186	4 291	6 902	3 335	-	85	16 799
	NTNU	2 186	3 876	2 471	2 482	-	85	11 100
	SINTEF	-	415	4 431	853	-	-	5 699
Enterprise partners:		41	416	913	506	-	-	1 876
Public partners		-	-	-	-	-	-	-
Equipment		-	-	-	-	-	-	-
Total		2 227	5 386	10 011	3 841	491	1 326	23 282

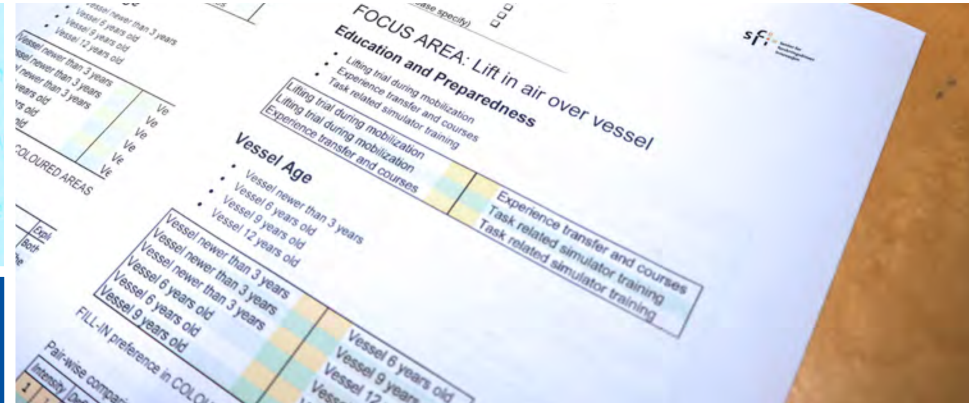
Name of active projects in 2018:

Project 4: Exploration of Technoligies to Develop Seabed Mining as a New Business Area
Project 5: Innovative Installation of Offshore Wind Power Systems
Project 6: On-Board Decision Tool
Project 7: Design for Workability
RA 5: Lab/Dissemination
RA 6: Management

Marine Operations Forum

Ålesund, April 20

Text: Martin Gutsch



The establishment and organization of the annual Marine Operations Forum is part of the ongoing work in research area Vessel Performance. The forum serves as an arena for discussion and information exchange between the stakeholders of the marine and offshore industry and researchers in SFI MOVE.

The second forum was held on April 20th at NTNU Ålesund, focussing on two objectives. In a first part, more than 40 experts from the complete value chain of marine operations were contributing to the finalization of the weighting of performance indicators as a measurement tool for mission oriented performance measurement of offshore crane vessels. In a second part, a dialogue gathering the needs and expectations of the offshore industry on future activities developing on-board systems and decision support tools has been established.

The Marine Operations Forum creates a unique opportunity for direct aim oriented discussions with experts from the offshore industry and will contribute to more industry oriented results and applications as the outcome of research activities in SFI MOVE.

Wind power in deep water is possible

SFI Marine Operations (SFI MOVE)'s big Spring conference was launched on 19 April, with the theme of offshore wind installations. A total of 65 researchers, Ph.D students, Post Doc students and representatives from partner companies and other representatives from the business world attended NTNU in Ålesund to discuss windpower and offshore installations.

> «We hold two such conferences a year», says Hans Petter Hildre, who is the Centre Director of SFI MOVE, Professor and Head of the Department of Ocean Operations and Civil Engineering.

The gatherings are important for giving our partners an arena where they can meet, exchange experiences and discuss various problems in their areas of speciality.

Statoil impressed with the Ph.D students

Among the participants was Trine Ingebjørg Ulla from Statoil, who gave a speech on concentration of efforts on offshore wind power. She made the trip to Ålesund on the way home from business meetings in Berlin and London.

> «Such a lot of exciting things are happening in Ålesund» Ms Ulla said.

> «I am impressed with the work the Ph.D students are doing, and it was especially interesting to hear their speeches. They gave me an insight into how complex the work really is, when it is combining both design and technical details in the maritime installations».

The only negative thing Ms Ulla had to say about the environment at Ålesund was that more women could well be recruited to the project. During the Conference she observed only one woman besides herself.

It is possible to expand construction of wind power in Norway

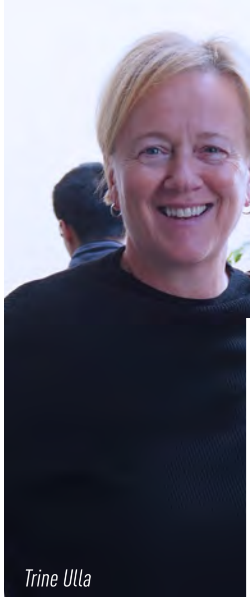
Vegard Nedrevåg from Technip FMC gave a speech on the world's first floating wind farm. Mr Nedrevåg is the project engineering manager for the world's first and only floating wind farm.

> «The farm is small and consists of only 5 wind turbines, but they provide electricity to 20 000 households in Scotland», says Mr Nedrevåg.

Technip FMC is the company that has been responsible for the work with the project, where the parts for the wind turbines were assembled in Norway, then towed over the sea to the ocean off Scotland. Previously wind power has had some limitations when the water was too deep, because the wind turbines have been standing on the sea bed. The floating installations make it possible to have wind farms in deeper water, since the installation is fixed to the sea bed using anchor technology.

> «It should also be possible to expand construction of wind power in Norway, and it is Statoil that is the furthest advanced in the world regarding floating wind power».

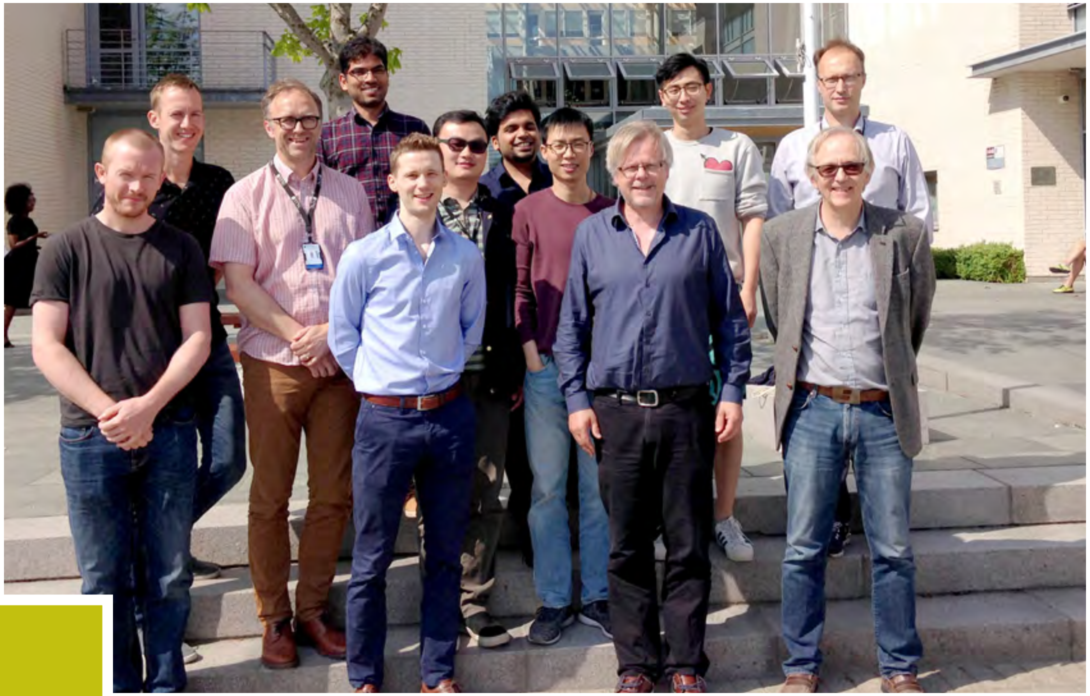
Mr Nedrevåg is in agreement with Trine Ulla that the Conference has been very exciting, and he thinks it was especially good to see that there is the focus on wind power in the work with SFI.



Trine Ulla

Vegard Nedrevåg

Spring Conference
Ålesund, April 19



Workshop

PhD and Postdocs

Ålesund, May 31

09.00 Opening: Hans Petter Hildre

09.15 Offshore Wind, status and future outlook, innovations? Karl Henning Halse
Status and idea for innovation, presented by:

- Zhengru Ren
- Amrit Shankar Verma
- Zhiyu Jiang

10.15 Seabed mining, status and future outlook, innovations? Svein Sævik
Status and idea for innovation, presented by:

- Tor Huse Knudsen/Svein Sævik
- Mats Jørgen Thorsen
- Niranjan Reddy Challabatla

11.30 Lunch

12.30 On-board systems/subsea/simulation technology, status and future outlook, innovations?
Henning Borgen
Status and idea for innovation, presented by:

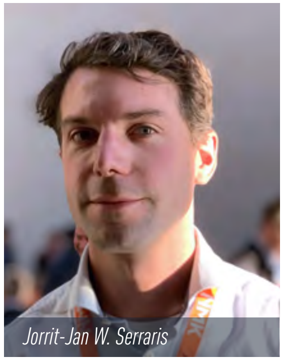
- Fredrik Mentzoni
- Robert Skulstad
- Mäel Moreau
- Jiafeng Xu
- Svenn Are Værnø
- Senthuran Ravinthrakumar
- Øyvind Rabliås
- Tore Relling
- Rami Zghyer
- Mia Abrahamsen Prsic

The competitive edge of the Norwegian maritime industry is constantly being strengthened

Autumn Conference

Ålesund, November 27

Text: Else Britt Ervik



Jorrit-Jan W. Serraris

Henning Borgen

«Previously wind power has had some limitations when the water is too deep, but floating installations make it possible to have wind farms in deeper water. In this lies enormous possibilities within wind power», says Hans Petter Hilde, leader of SFI MOVE.

The Autumn Conference held by SFI MOVE

The latest news regarding revolutionary technology at sea could be heard on Tuesday 27 November during the Autumn Conference held by SFI Marine Operations (MOVE). An update was given by the parties involved in the 8-year programme for research-based innovation, which is led by NTNU in Ålesund.

«Some of the purpose of SFI MOVE is to increase the weather window for when maritime operations can be carried out», says Henning Borgen, leader of SINTEF Ocean.

Simulation increases safety and profitability

Mr Borgen is referring to that one of the objectives of SFI MOVE is to find new and cost-effective methods of installation and maintenance of floating offshore wind turbines. During today's conference he presented SINTEF's project «Onboard Decision Support».

«The weather in the North Sea is often bad, and not having to wait for good weather can save the maritime industry huge costs. We have developed a PC-based simulator that can be taken on board the vessel when, for example, a crane lift on an offshore installation shall be done in high waves. The weather and conditions are analysed, so that one can quickly simulate the operation one has thought to do at the same place, just before it is done physically, in the same weather and with all the steps of the operation fresh in one's mind.»

According to Mr Borgen it will mean greater safety when one has all the information regarding weather and conditions and can simulate the operation.

Ensures progress in the research

«Gatherings of this type take place twice a year, in addition to regular meetings for the industrial partners», says the leader of SFI MOVE and Head of Department of Ocean Operations and Civil Engineering at NTNU, Hans Petter Hildre.

Mr Hildre opened the Conference, which consists of 60 participants who are persons who work in SFI with Doctoral Degree projects, persons from co-operation partners in industry, in addition to some external participants.

The Netherlands and Norway learn from each other

«We can learn a lot from one another, even though we work on two different research projects», says Jorrit-Jan Serraris from the Dutch company MARIN.

Mr Serraris is on his first visit to Ålesund, and says that MARIN researches many of the same things, namely, wind power and offshore installations in oceans. Mr Serraris is clear about there being far more to gain by co-operation on research in preference to competing. The research that MARIN carries out is about simulation and testing of almost everything that can sail or float.

«It was very useful being invited to this gathering as an external actor», says Mr Serraris.

He has spoken on the theme installation of wind turbines, and the challenges when the vessel moves and there are large, heavy installations that are to be put in place.

Through its projects, MARIN has experience largely from waters further south in Europe, where wind turbines and other installations are anchored to the sea bed. He is impressed with seeing how this is done in Norway where the waters are far deeper, and where construction of floating installations has come far.

The future lies in wind power

«SFI MOVE can show great progress regarding research on floating installations. It is complicated work when simulation shall be combined with technical details in the maritime installations», says Hans Petter Hildre.

Facts: SFI Marine Operations is an «SFI» (Centre for research-based innovation) and is supported by 50 % from The Research Council of Norway. Remaining financing is covered by industry (Equinor, DNV-GL, the maritime cluster at Møre) in addition to an individual share from the participants in the programme.

List of partners:
https://www.ntnu.edu/web/move/partners

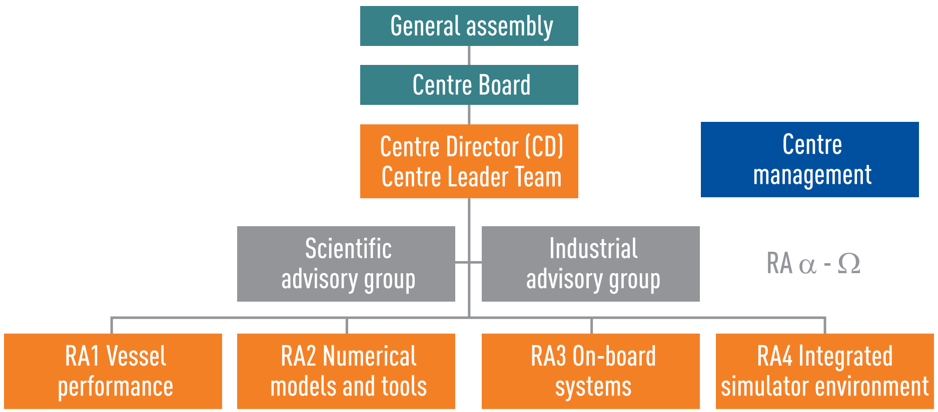
Research organisation

The following research partners were involved in 2018:

- 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
Seabed Mining – Exploration of Technologies to Develop Seabed Mining as a New Business Area	Svein Sævik, NTNU
Offshore Wind – Innovative Installation of Offshore Wind Power Systems	Karl Henning Halse, NTNU in Ålesund
On-board Decision Tool	Henning Borgen, SINTEF Ocean
Design for Workability	Martin Gutsch, SINTEF Ocean/NTNU

The Board of the Centre has the following members:

- Arnt Olufsen, Chairman (Equinor)
- Tore Ulstein (Ulstein Group)
- Svein Kleven (Rolls Royce Marine)
- Hans Petter Hildre (NTNU in Ålesund)
- Sverre Steen (NTNU)
- Harald Stenersen (Havila)
- Halvor Lie (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 Advisory Board:

- Runar Stave, Olympic
- Harald Stenersen, Havila
- Per Ingeberg, Rolls-Royce Marine
- Bjornar Vik, Rolls-Royce Marine
- Joel Mills, OSC
- Erling Myhre, Equinor
- Ken Nilsson, Ocean Installer
- Ove Bjorneseth, Vard
- Henning Borgen, SINTEF Ocean/SINTEF Ålesund
- Per Erik Dalen, ÅKP/GCE Blue Maritime

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 has decided to withdraw from the project from January 2019.

The industrial partners in the project in 2018 were:

- Farstad Shipping
- Olympic Shipping
- Havila Shipping
- Rolls-Royce Marine
- Ulstein International
- ÅKP/GCE Blue Maritime
- OSC
- Vard
- NTNU Ocean Training
- Equinor
- Ocean Installer
- DNV-GL

Campus Ålesund