Industrial partners:

- akp
- OSC
- OLYMPIC
- EMAS
- VARD
- Statoil
- Rolls-Royce
- DNV-GL
- ULSTEIN
- Cranemaster
- NOI.II
- STATREX
- NTNU
- Statkraft
- FARSTAD

Research partners:

- NTNU
  Norwegian University of Science and Technology
- SINTEF
- MARINTEK
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World leading position within demanding marine operations

Our vision
Our vision

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

Simulation has been used for decades to test the physical aspects of marine operations. Simulators are used to train crew to perform demanding operations. Next generation technology has the potential to provide Virtual Prototyping to pre-test marine operations, including the human component. Cutting-edge interdisciplinary research will provide a bridge between industrial needs, innovation and research.

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

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

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

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

Objectives

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

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

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

The idea is to optimize operations, from planning to execution, by better understanding of the responses. This is a simulation-oriented approach where models are re-used throughout the value chain.

• System development and design
• System integration and configuration
• Ship and ship equipment
• Operation planning
• Crew Competence and Training concepts
• On-board systems
• Operation execution
• Learning

Business areas

The business areas focused on in 2016 are:
• Demanding marine offshore operations as at ultra-deep water, all-year availability, or arctic areas
• Installation and maintenance of offshore wind
• Subsea mining
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, good 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.

SFI MOVE has completed 1.5 years of operation and has become a centrally uniting research effort among four research partners. Aalesund University College has become a part of NTNU and MARINTEK and SINTEF Fisheries and Aquaculture has become SINTEF Ocean. We are very pleased for the restructuring of the research partners in two strong organisations.

The offshore oil and gas industry have been facing huge challenges in 2016. We have seen significant restructuring of the offshore support business and efforts reducing costs have been a top priority. Research in SFI MOVE are trying to balance between activities that can enhance the competitive strength in short-term and long-term strategic research efforts.

Low-cost innovative installation of Wind Power Systems

According to Vattenfall, the development costs of offshore wind power plants were reduced by approximately 50 % in 2016. Bottom-fixed offshore wind projects have reached a cost level where they are profitable even without subsidies.

The EU is likely to reach its target that 20 % of the total energy consumption should come from renewable energy sources within 2020. Their future target is to increase the amount of renewable energy to 50 % within 2030. A report from the global wind power industry organisation GWEC estimates that the investment rate for wind power may be doubled from NOK 910 billion in 2016 to NOK 1800 billion in 2030.

Installation and service of offshore wind power plants is already a massive industry!

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 5 individual lifting operations. SFI MOVE is working with three innovations that can result in major cost cuts:

1. Grip and lift in the lower end of the tower, rather than using a crane which can be as high as 130–140 m.
2. Lift the whole installation onto its new foundation in one single operation.
3. Using a floating installation vessel rather than a jack-up structure. The tower handling is supposed to be taken care of by a manipulator compensating for the ship’s motion.

A ship hull is developed and a crane based on robotic technology is sketched. Simulation models are made and preliminary simulations for wind power assembly on fixed structures are done and presented. Forces between the ship hull and the fixed structure are a challenge and needed damping devices are in the process of development.

Safe – All-year – Effective subsea installation and service

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. This also leads to an increase in the volume of maintenance of subsea facilities and wells in the years to come. 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.

There is a need for new methods, systems and equipment to achieve the defined objective. Our aim is to establish a virtual prototyping (VP) approach for subsea operations. The following topics have been focused on:

- Systematic study of installation vessels leading to indicators for vessel performance. Based on this study the design parameters that contribute to increasing the operational performance for various geographical locations and type of operations will be identified. This is a multi-criteria approach making it possible to optimize the vessel design for unique operations.
- Simulation of dynamic system behaviour during deployment operations (ship, crane, winch, ballast and damping) with systematic parameter variation. Study of system dynamics (statistical distribution of response peaks, estimation of extreme response).

**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 opportunity 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 on value of resources. In Norwegian waters alone, an NTNU study estimates low value USD 75 bn. No upper limit. SFI MOVE has focus on the design of lift systems to allow efficient lift of minerals from the seabed to the ship.

**Simulation Technology and Virtual Prototyping as a Common Approach from Design to Operation**

We are facing a substantial technology shift in digitalising industrial processes. We will see new methods of designing ships, equipment and operations as well as crew training. In other words, virtual ships and virtual operations. Ship designers are at present developing real time energy management systems, vessel health management systems, remote control systems and autonomous ship systems. Numerical real time behaviour models are a precondition to an effective development of such systems. This shift will move simulation from a verification point of view to a design and operation point of view. We can see the following key benefits of this development.

- Transform the industry to a simulation and performance oriented operation approach.
- Increase innovation speed by fast prototyping of ships and operations
- Verification of operations including human factors
- Reduce cost by re-use of models during the process from preliminary investigations to execution of operations

The primary project objective for SFI MOVE is to develop an open, standardized framework and architecture for system simulation and virtual prototyping, which will be a new platform for product development, training and cooperation in the maritime industry. A key to achieving such functionality is an open framework, standardized interface and generic models to be shared in the industry. The purpose is to present methods and demonstrate the cycle from design to virtual prototyping as shown in the figure. Explore shortcomings and suggest improvements.
Research organisation
The following research partners were involved in the beginning of 2016:

- NTNU in Ålesund (former Aalesund University College)
- NTNU
- SINTEF Fisheries and Aquaculture
- Marintek

Aalesund University College has become a part of NTNU and MARINTEK and SINTEF Fisheries and Aquaculture has become SINTEF Ocean. 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.

The Board of the Centre has the following members:

- Torleif Sætrevik, Chairman, (Statkraft)
- Thore Thuestad1 (Statoil)
- Tore Ulstein (Ulstein Group)
- Guro Løken (EMAS AMC)
- Hans Petter Hildre (NTNU in Ålesund)
- Harald Ellingsen2 (NTNU)
- Halvor Lie (Marintek)

Centre Director:
Hans Petter Hildre, Professor, Dean of Faculty of Marine Technology and Operations, NTNU in Ålesund

Administrative key personnel:
Magnhild Kopperstad Wolff, Finance & Administrative Coordinator, SFI Move, Faculty of Marine Technology and Operations, NTNU in Ålesund

Industrial Advisory Board:
- Runar Stave, Olympic
- Harald Stenersen, Havila
- Per Ingeberg, Rolls-Royce Marine
- Bjørnar Vik, Rolls-Royce Marine
- Joel Mills, OSC
- Erling Myhre, Statoil
- Ken Nilsson, Ocean Installer
- Berge Nakken, Farstad
- Ove Bjørneseth, Vard
- Henning Borgen, Vard
- Per Erik Dalen, ÅKP/GCE Blue Maritime

The industrial partners in the project are:

- Farstad Shipping
- Olympic Shipping
- Havila Shipping
- Rolls-Royce Marine
- Ulstein International
- ÅKP/GCE Blue Maritime
- OSC
- Vard
- Cranemaster
- NTNU Ocean Training3
- Statoil Petroleum
- EMAS-AMC
- Ocean Installer
- Statkraft
- DNV-GL

The project leaders are:

<table>
<thead>
<tr>
<th>Project</th>
<th>Project Leader</th>
<th>Deputy project leader</th>
</tr>
</thead>
<tbody>
<tr>
<td>Offshore Wind</td>
<td>Karl Henning Halse, NTNU</td>
<td>Zhen Gao, NTNU</td>
</tr>
<tr>
<td>Subsea</td>
<td>Ole Økland, Marintek</td>
<td>Zhang Houxiang, NTNU</td>
</tr>
<tr>
<td>Virtual Prototyping</td>
<td>Lars Tandle Kyllingstad, SINTEF</td>
<td>Gaspar Henrique, NTNU</td>
</tr>
<tr>
<td>Mining</td>
<td>Svein Savik, NTNU</td>
<td></td>
</tr>
</tbody>
</table>

1Was replaced by Arnt Olufsen during 2016  2Was replaced by Sverre Steen during 2016  3Former Marine Operations
SCIENTIFIC ACTIVITIES AND RESULTS

Project 1

Project Leader:
Karl H. Halse (NTNU Ålesund)

Figure 1. The floating installation vessel includes a gripper mechanism between the fixed foundation and the vessel, as well as a lifting mechanism to transfer the OWT from the vessel to the foundation.

OW 2016 – Low Cost Installation and Maintenance of Fixed Offshore Wind Structures

Figure 2. Illustrations of the gripper design and the lifting mechanism.
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).

Today, Offshore Wind Turbines (OWT) are installed by the use of jack-up platforms (or jack-up ships). This is a costly and time-consuming way of installing the turbines. A critical phase is the positioning of jack-up legs onto the seabed. During this phase, impact forces occur, which are correlated with the barge’s heave, roll, and pitch motions.

Study of the use of flopper stoppers:
One of the activities in this project has been to investigate the effect of a flopper stopper on the motion responses of a jack-up barge. The flopper stopper functions as a passive roll compensation device and is suspended from the side of the barge. A brief summary of the work carried out in this activity is given below:
- Performed basic design of a flopper stopper for leg positioning of a jack-up barge.
- Conducted global dynamic analyses for the barge system with a flopper stopper.
- Established the jack-up operational limits in terms of the significant wave height and peak period by use of characteristic values of leg impact velocities.
- Quantified the effect of the flopper stopper for different wave headings.
- As expected, the roll motion appears to be the response which is most affected by this device, and a 35% increase of the operational wave height in beam sea was found.

Study of a novel installation vessel design:
A floating installation vessel would totally eliminate the challenges involved with setting down the jack-up legs. This will save both time and money in the process of installing an offshore wind power plant. The project includes an activity to study whether it is possible to do the installation of an OWT onto a fixed installation from a floating vessel (see Fig. 1). A brief summary of the work carried out is given below.
- Design of a catamaran vessel to be used for installation of OWTs. The concept was designed to carry 4–5 OWTs each weighing 1000–1500t.
- Stability calculations were carried out and compared with a monohull vessel of similar size. The catamaran proved to have increased stability compared to the monohull.
- Hydrodynamic response analyses were carried out using the vessel response module in SHIPX, to support the response found in the physics engine in the simulator (AGX).
- Design and modeling of a Tank flow control system for the catamaran, both for anti-heeling and roll-reduction purposes.
- Compared the response amplitudes of the Catamaran from WAMIT analysis with those from ShipX analysis, and found a general agreement despite some discrepancies.
- Design of a possible gripper mechanism (see Fig. 2) to control the vessel motions relative to the fixed foundation.
- A preliminary design of a lifting mechanism (see Fig. 2) to lift the OWT and control the motions of the OWT relative to the fixed foundation.
SCIENTIFIC ACTIVITIES AND RESULTS

Project 2

Project Leader:
Ole Økland, Marintek

Subsea: Safe – All-Year – Cost-efficient Subsea Operation
Work on data collection systems and on-board monitoring has also been initiated in 2016 and will be followed up in 2017. Validated simplified models established in the case studies will be used in this work and also lead to improved numerical models for integrated simulator environment (e.g., for training of personnel).

The scale of complex subsea field developments will probably increase. There will be a continuous need for cost improvements for field developments and the cost and ability of maintenance, repair and intervention of such fields.

Subsea installation and services have operational limitations due to environmental conditions such as waves, wind, currents and water depth. In areas with a harsh environment, there will be operational limitations in performing marine operations. For areas with water depth down to 3000m, there will be limitations on weight and dimensions of modules and units. In addition there are challenges with vertical span dynamics. The water depth makes the operations time consuming and puts limitations on the payload capabilities. In addition the landing sequences may be complex due to sensitivity to current.

The objective of the project is to facilitate marine operations taking place in a commercial and cost-efficient manner and thereby contribute to positioning the Norwegian Maritime industry towards the market of such operations worldwide.

- Make operations safer and with required accuracy.
- Improve HSE by making the operations more robust vs. available weather window.
- Reduce total field development costs by more cost-efficient marine operations.
- Increase operational efficiency of subsea fields by all-year vessel operation.

As tools and methods to simulate marine operations vs. weather criteria become more accurate, the Rules & Regulations should be adjusted accordingly.

The operational limitations of marine operations through a moonpool, or from the deck of an installation vessel are influenced by several factors. The specific limitations need to be assessed carefully based on vessel motion characteristics, the deck handling system (including personnel), and shape and size of the object to be installed. Accurate simulation tools are a vital key with respect to planning of operations as well as training for realistic operations with simulators and monitoring systems offering support during operations.

In 2016 an important part of the work in this project has been related to assessment of hydrodynamic coefficients for various complex structures. Marintek have issued a paper and a technical report summarizing results from this study, and hydrodynamic load on complex structures is also the topic of one PhD and one postdoc in the subsea project. A 2D model test to obtain added mass and damping for complex subsea structures has been conducted in May–June, 2016.

A case study based on data from the subsea installation of an integrated template structure (ITS) with mass 285.7 t, on the Johan Sverdrup field (depth 120m) has been defined in 2016, and will be used to explore potential and limitation for different types of installation vessels and operations. These case studies will also serve as a basis for development and validation of new or enhanced simulation models, monitoring systems and implementation of enhanced functionality in simulator systems for training.

In the first part of the case study, a numerical model of lifting vessel and equipment will be defined, and initial simulations of the operation will be performed. The work will consist of the following tasks:

- Model of lifting vessel with simplified positioning system. The model will include diffracted wave points for study of shielding effects.
- Model of ITS with depth dependence coefficients and shielding effects.
- Model and analysis of lift in air.
- Model and analysis of water entry, splash zone crossing.
- Model and analysis of lowering through the wave zone.
- Model and analysis of landing on sea bed.

The numerical modelling of the ITS will include estimation of hydrodynamic coefficients based on data for similar structures and sensitivity to choice of coefficients on the obtained limiting sea state will be assessed. Depth dependency of the coefficients will be included and effect of slamming studied. Modelling of tugger wires and winches will be studied and different set-ups will be tested.
Demonstration of State of the Art Simulation Technologies and Virtual Prototyping as a Common Approach from Design to Operation
The idea of the “Virtual Prototyping” sub-project is to explore the opportunities offered by simulation-based workflows and tools throughout the maritime value chain, from design to operation and, closing the loop, back to design again. The maritime industry is under constant pressure to deliver better solutions and more efficient operations at a lower price and in a shorter time span, and virtual prototyping methods promise great improvements over traditional workflows when it comes to achieving this.

The project has two primary goals:

- To establish common standards and formats for exchange and re-use of digital information and models in the maritime industry.
- To present methods and demonstrate how simulation and virtual prototyping can be used throughout the whole cycle from design to operation.

These are closely linked, as the former is a prerequisite to achieving the latter. Agreed-upon data formats would allow data collected in real operations to be more easily used by different people for a variety of purposes, while common modelling and simulation interfaces would allow exchange and re-use of mathematical models between organisations and throughout the maritime value chain.

Real-world data collected from vessels during actual operations is needed for several purposes:

- As a basis for development and verification of models, methods and software
- As input to performance analyses, decision support systems and simulations.

In 2016, activities were initiated within MOVE to begin systematic collection of data from offshore construction/maintenance vessels. This included developing and preparing software and hardware to be installed on the vessels, and to identify the information needs of other MOVE sub-projects. Unfortunately, it proved difficult to begin the actual installation on the vessels, but the work will continue in 2017 with a goal to have continuous data collection up and running on several vessels by the end of the year.

With a solid data foundation and good mathematical models, it becomes possible to perform highly sophisticated simulations of the complex dynamics of maritime systems and operations. Too often, however, the potential of such simulations is never fully realised, because the models are made for a single purpose or even a specific study, and are difficult to re-use in a different context. A commonly encountered reason is that the models are constructed in a monolithic fashion where it is difficult to extract single components for later re-use. Incompatibilities between programming languages and modelling software are another. Ideally, what we want to enable is:

- The ability to construct full-system models from component models.
- Easy reuse and adaptation of models for different purposes, such as analysis, prototyping, training simulations and onboard decision support systems.
- Efficient knowledge transfer between research, development and industrial use.

There are several obstacles to achieving this, including the large number of incompatible simulation tools used in different engineering disciplines and by different companies, some of which require a high degree of specialist expertise to use.

In 2016, MOVE took the first steps in this direction by starting to adapt the research partners’ in-house modelling and simulation software to support FMI, an open, standardised interface for model exchange and co-simulation. This work will continue in 2017 and will be demonstrated in a series of comprehensive case studies of simulated marine operations. The standardisation work in MOVE is being coordinated with several other R&D projects and research centres, including the other SFIs Smart Maritime and Exposed.
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 study estimates low value USD 75 bn No upper limit. The Marmin 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. AUVs and ROVs were used for surveying selected target areas. Data were collected using different types of imaging equipment to provide means of defining the prospective sites. The mission included water depths down to 3000 m. Selected sites were studied through sampling of rocks and drill cores from the sea floor and inside the upper part of the sea floor. This 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 include a wide range of related topics: Autonomous exploration, detection of sea-floor 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 low) 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 have been allocated in SFI MOVE to work on these issues. The objective includes development of models that enable studying coupled dynamics phenomena related to both two-phase (water and rock) and three-phase flows (water, rock and air). The overall objective of the work is to provide a fully dynamic model that can handle both steady state and transient dynamics of such systems. The concept is illustrated in Figure 5 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.

<table>
<thead>
<tr>
<th>Flow model</th>
<th>Structural model</th>
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<tbody>
<tr>
<td>Method 1</td>
<td>Steady state</td>
</tr>
<tr>
<td>Method 2</td>
<td>Steady state</td>
</tr>
<tr>
<td>Method 3</td>
<td>Transient</td>
</tr>
<tr>
<td>Method 4</td>
<td>Transient</td>
</tr>
</tbody>
</table>

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

Figure 5: The coupled dynamic model concept.
Project 5

Project Leader:
Karl H. Halse (NTNU Ålesund)

Figure 6. Illustrations of simulator environment for marine operations (Both photos over.)

OW 2016 – Installation of Floating Wind Power Systems
The goals for a floating OWT power plant will include:

- Water depths from 40m to approx. 700m
- Heights of the OWTs between 150 and 200m
- Weights of OWTs between 500–2000t

In this project one of the ultimate goals is to develop a simulator, which can be used to test out new ideas, including both new designs and new installation methods. To achieve this, the project has to work along two axes; one is to implement existing numerical models into a real time simulator environment, while another is to continue to develop more advanced numerical models to account for new effects. One of the benefits of a real time simulator is to demonstrate new installation projects as a part of planning the real project (see Fig. 6). This also includes raining of – maritime personnel. This will increase safety and efficiency of the marine operation, thus contributing to reduce the costs involved with these installations.

Statoil installed a 2.3 MW floating wind turbine in 2009 (Hywind Karmøy), and with that they are one of the pioneers of floating wind turbines. During the summer of 2017, they have planned to install 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.

Although the technology development has reduced the installation costs significantly for fixed offshore wind installations, they still have cost challenges. The technology development of floating wind parks has an even longer way to go, but Statoil has already reduced the installation costs with 60–75 % per MW, and claim that they will earn money on the HyWind Scotland project. Furthermore, the pressure on shallow water areas will force offshore wind power plants further from the shore and into deeper water. The challenge is to develop solutions which can be realized at lower costs both for installation and operation.

In 2016, this project was just initiated and should be considered in conjunction with Project 1 Installation of OWTs at fixed installations. Some of the ideas elaborated in that project may be continued for floating foundations.
Seminars and courses

• Technoport “Crack the Code” (02.03.16)
• Entrepreneurship – Perspectives from Silicon Valley with Prof Jack Fuchs (03.03.16)
• From Idea to Market with Innovation Norway (18.10.16)
• “PUBLISH OR PERISH – DEMO OR DIE” Design Thinking with Prof Martin Steinert (postponed to 2017)

Other activities

• Kick off meeting with center leaders at TTO (09.09.16)
• Kick off meeting at AMOS with PhDs (18.08.16)
• Exposed: Seminar for Phd’s in Aquaculture at SeaLab (04.11.16)
• SAMCoT: TechTrans and IP session at Valgrinda (23.11.16)

In general there has been quite a high number of attendees at the events. At the two courses there has been 27 (Jack Fuchs) and 18 (From Idea to Market) the participants. The interest for the last course was low, and this is probably because of the timing in the middle of exams. One full day seminar and one lunch postponed to 2017.

Between 15–45 participants at the Innovation Lunches. Invitations to events has been distributed via e-mail both directly and through administrative personnel in the centers. The center leaders has also been encouraged to motivate the PhD’s to attend Ocean School of Innovation.

Ocean School of Innovation

This group has in cooperation with NTNU-TTO established Ocean School of Innovation. The purpose of this program is to simulate PhD students for innovation.

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

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

Activities 2016
Innovation lunches
• The Story of Telcage with Oddbjørn Rødsten (08.09.16)
• Funding of start-ups with Inge Hovd Gangås, Sintef TTO and Venture (03.10.16)
• The Story of MemBioAct with Arne Lindbråthen and Garil Forbord (postponed to 2017)

International cooperation

The MOVE Centre has a strategic cooperation with the University of Sao Paulo (USP) in Brazil. The key person in contact is professor Kazuo Nishimoto. USP is combining marine research and nautical operations and has a similar approach as we have defined in SFI MOVE.

A cooperation agreement is signed. Student exchange in 2015 and 2016.

The photo shows signing of the co-operation agreement with the Dean, Gunnar Bovim, and the Minister of Education, Torbjørn Røe Isaksen.
Recruitment

Due to late formal start of the SFI MOVE we had a minor delay in hiring PhD students in 2015. We are very pleased with the number and quality of applicants.

<table>
<thead>
<tr>
<th>PhD candidates and Postdocs</th>
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</thead>
<tbody>
<tr>
<td><strong>PhD candidates with funding from AFI MOVE</strong></td>
</tr>
<tr>
<td>Martin Friedwart Gutsch</td>
</tr>
<tr>
<td>Fredrik Mentzoni</td>
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<tr>
<td>Zhengru Ren</td>
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<tr>
<td>Robert Skulstad</td>
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<tr>
<td>Jiafeng Xu</td>
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<tr>
<td><strong>PhD candidates with funding from other sources</strong></td>
</tr>
<tr>
<td>Tor Huse Knudsen</td>
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<td>Svenn Are T. Værnø</td>
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<tr>
<td>Senthuran Ravinthrakumar</td>
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<tr>
<td><strong>Postdocs with funding from SFI MOVE</strong></td>
</tr>
<tr>
<td>Mia Abrahamsen Prsic</td>
</tr>
<tr>
<td>Mats Thorsen</td>
</tr>
<tr>
<td>Niranjan Reddy Challabatla</td>
</tr>
</tbody>
</table>
Scientific questions
- What is a good offshore vessel and why are some vessels performing better than others?
- What are the main factors contributing to operational performance?
- What are the performance indices to measure and quantify operational potential?
- How to validate newly established performance indices?

Innovations
The knowledge of operational performance criteria shall give guidance for vessel design with the goal of increased operability, cost-efficiency, and safety.
- provide knowledge for the assessment of vessel design for a specific operational task and estimated environmental condition with the aim to select the most suitable vessel for an operation
- provide tools to identify task specific weaknesses for a given ship design and/or the planning of an operation and give guidance for improvements
- provide information for further development of on-board support systems

Cooperating companies
Ocean Installer
EMAS CHYODA
Statoil

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

Title
Performance Indicators for vessel performance for challenging marine operations

Research topics
The ongoing exploration of the maritime environment and the increasing effort to use the sea as a source of energy leads to increasing global demands for more 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 operation when a rigid and often conservative weather limitation is reached, often 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 to establish and use vessel and task specific criteria.

The main objective of the PhD work is to address the question what makes an offshore working-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 operation work task and shall deliver tools to estimate ship specific operational limitations.

Industrial goals
The use of rational performance criteria shall provide tools to evaluate operational performance by the use of 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 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.
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 shows 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 exist 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 planning of marine operations.

Cooperating company
DNV GL

Supervisor: Trygve Kristiansen
Co-supervisor: Odd M. Faltinsen
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)
Title
Development of explicit response-based criteria for operability assessment for installation of offshore wind turbines using floating vessels.

Industrial goals
• To reduce costs in the installation of OWTs by using floating installation vessels
• 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 (maximum stress or allowable damage) of the critical components (blades, rotor-nacelle assembly) during installation?

Innovations
• A new way to determine the operational limits for floating installation vessels using response-based criteria

Research topics
In view of the movement of offshore wind industry into deeper waters and the limitation of jack-up vessels, floating crane vessels are now being developed and used for installation of bottom-fixed wind turbines and also floating wind turbines (for example spar wind turbines). However, the big challenge is the motions of floating crane vessels, which may lead to contact/impact between the objects and therefore damages in the critical components (blades, nacelle or pre-assembled rotor-nacelle-tower) in particular in the lift-off and mating operations. In order to obtain an accurate estimate of the operability to reduce the cost for such operations, it is crucial to develop response-based criteria by explicitly assessing the damages in the wind turbine components in case of contact/impact. The purpose of this study is to develop the numerical methods for response and damage assessment of critical wind turbine components during installation and to derive the operational limits in terms of sea state parameters (Hs and Tp) for operability assessment. Case studies for installation of individual blades and integrated rotor-nacelle assembly onto bottom-fixed foundations and floating foundations using floating installation vessels will be considered. Active winch control to reduce or avoid the contact/impact during lifting operations will also be considered.

Cooperating company
Statoil
DNV-GL

Supervisor: Zhen Gao
Co-supervisors: Torgeir Moan, Karl Henning Halse, Nils Petter Vedvik

Cooperating company
Statoil
DNV-GL

Supervisor: Zhen Gao
Co-supervisors: Torgeir Moan, Karl Henning Halse, Nils Petter Vedvik
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)
At later stage, flow model will be extended to investigate the feasibility of the gas lift system for deep sea mining application.

References

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)
Title
Efficient and accurate numerical methods and models for dynamic response analysis for installation of offshore wind turbines using floating vessels.

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.
- 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 reduce the roll motions of a floating installation vessel by passive or active damping devices?

Innovations
- A new numerical method for dynamic response analysis of the coupled installation system using floating vessels

Cooperating company
OSC, DNV-GL, Ocean Installer, Statoil

Supervisor: Zhen Gao
Co-supervisor: Karl Henning Halse

Zhiyu Jiang
Department of Marine Technology • Faculty of Engineering
Title
Real-time Simulation of Marine Operations.

Research topics
My research aims at developing a computer program environment and proper algorithms that can simulate 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 hydrodynamic 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
Communication and dissemination activities

The SFI-MOVE home page is up running, see http://www.ntnu.edu/move

The project has arranged following main conferences/workshops in 2016:

- SFI-MOVE user conference, 7–8 March
- SFI-MOVE workshop in Seabed Mining, 10–11 May
- SFI-MOVE user conference, 18–19 October
Publications

2016

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Gao, Zhen; Moan, Torger; Wan, Ling; Michailidis, Konstantinos
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Li, Lin; Gao, Zhen; Moan, Torger

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Pan, Yushan; Finken, Sisse
Pan, Yushan; Hildre, Hans-Petter
NTNU UID

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Xu, Jiafeng
NTNU

Li, Yue; Halse, Karl Henning; Xu, Jiafeng
NTNU

Simon Helmi Hemstad
M Power and energy optimization for marine operations

Zafer Zerdal
M Investigation of sloshing through experiments and modeling with mechanical equivalent models

Junjie Ding
M Parametric mechanical design for system integration and simulation of virtual crane

Dahai He
M Virtual winch prototyping - Active/passive heave compensation system in 20 Sim

Yu Li
M Component model development and management oriented to both system performance testing and operational behaviour simulation

Bingqiang Wang
F Modelling and simulation of accumulator systems for heave compensated winches in cranes AGX

Zhongkai Wang
F HIL simulation of hydraulic crane control

Kjell Lennart Nygård
M Effect of anchor cable tension on an AHTS vessel at sea.

Petter Svardal Langeland
M Modelling of anchor lines, resulting tension on AHTS (Aquasim)

Zhaonian Zhong
M Smoothed particle hydrodynamics calculations

Stefanos Lango Andrade
M Optimal Structural configuration for Ulstein FX

Greta Levisauskaite
F Implementation of GD framework in ship design for improving exchange and minimizing 3D remodelling

Ruta Mustekaita
F Product lifecycle management applied to offshore support vessels

Brigita Matusiaityte
F Shell product concept applied to ship design

Thiago Gabriel Monteiro
F Framework for product configurator deployment

Tian Xu
M Study of vibration control and analysis on ships

Georgiana Chelmu
M Ship response and manoeuvrability - Main Machinery characteristics, configuration modes, and its resulting effect on thrust response

Framwork for product configurator deployment

Simen Haddal Sæther
M Thruster-assisted position mooring of C/S Inocean Cat I Drillship

Arne Solevåg
M Constrained Optimal Thrust Allocation for C/S Inocean Cat I Drillship

Jon Bjarne
M Torsion Buckling of Dynamic Flexible Risers

Preben Frederich
M Numerical investigation of collapse and ductile fracture in X65 offshore pipelines subject to external pressure, bending and axial loads (cooperation with the Federal University of Rio de Janeiro)

Eugenii Koloshkin
M Assessment of Marine Riser Joints During Offshore Drilling Operation (cooperation with Bureau Veritas Paris)

Jens Mjøen Hafstad
M Oceangraphic modelling of marine riser pressure, bending and axial loads (cooperation with the Federal University of Rio de Janeiro)

Preben Frederich
M Towards data-driven identification and analysis of propeller ventilation

Mariana Maastad
M Numerical and Experimental Study of the Fred Olsen Wind Turbine Concept

Fride Møtødt Birkeland
F Numerical Simulation of Installation of XL Monopile for Offshore Wind Turbines

Shi Deng
M Numerical Simulations for Lift-off Operation of an Offshore Wind Turbine Monopile

Dapeng Xu
M Numerical Modelling and Simulations for Lowering of an Offshore Wind Turbine Tripod

Nishat Al Nahian
M Structural Analysis of the Gripper Connection during Monopile Installation

Martine Gripp Bay
M Dynamic Response Analysis of a Spar Floating Wind Turbine in Level Ice with Varying Thickness

Efstathios Tsigkris
M Smoothed particle hydrodynamics calculations

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Master’s degrees

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## Accounts

The tables show the distribution of funding and costs in SFI MOVE for 2016. The funding plan shows where the funding comes from, and the cost plan shows where the research activity has been carried out.

### Funding

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### Costs

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The Pro-rector for research, Kari Melby, was also present on the first day, and pointed out that the SFI had high ambitions concerning innovation and new thinking for marine resources.

“What will you do better and differently than other SFIs in this area”, was Pro-rector Melby’s question to Hans Petter Hildre, who leads the project.

To this the Pro-rector received the reply that many meetings were planned between those working on the project and industry, to ensure good communication.

“We hold this type of meetings once or twice a year. In addition, we receive frequent visits from our industrial partners, in order to ensure progress in the SFI.

Not surprisingly, there were several interesting discussions when people from various companies and disciplines met, such as when the crane operator from Havila described how he operated the crane in four meter high waves. The person who had developed the crane technology was also in the audience, and wondered why the driver did not follow the instruction book.

“There's a better way of performing the operation”, was the opinion of the developer.

“The instructions are incomprehensible”, replied the driver.

The developer admitted that he was in agreement with this, and said that the person who had written the book had already been dismissed - a statement that drew loud laughs from the audience.

In March there was a meeting for those who wish to revolutionise offshore technology, specifically SFI Marine Operations.

“What we are doing here is huge”, said Finn Gunnar Nilsen from Statoil, referring to the ambitions regarding offshore windmills going further and further out, and into deeper water.

“The opportunity of utilising resources is enormous, because the effect of wind power is greater than nuclear power”, said Mr Nilsen categorically to an attentive audience.

All associated researchers and PhD students were invited to Ålesund, together with both relevant professors and cooperation partners from industry. The researchers received inspirational lectures including from Statoil, Vard, Ulstein, Rolls Royce and Havila.

The developer admitted that he was in agreement with this, and said that the person who had written the book had already been dismissed - a statement that drew loud laughs from the audience.

On Day 2, the PhD students and Postdocs presented their projects. More about the research and the SFI is to be found at: www.ntnu.edu/move
Technip is heavily involved in the Solwara project outside New Guinea, being the first full scale mining development in deep waters, starting up in 2017. One important outcome of the seminar was related to Technip being willing to act as a partner with respect to quality assurance of research within this topic in SFI MOVE by sharing their experiences.

Workshop Agenda
- 09:00–09:10: Welcome by Prof. Svein Sævik, IMT, NTNU
- 09:10–09:30: Technip activities in Deepsea mining, with focus on flow modelling and deepsea mining architecture by Thomas Parenteau and Johann Rongau, Technip Innovation and Technology Centre
- 09:30–09:50: The Architecture of deep Sea Mining Systems by Prof. Meng Tang, Southwest JiaoTong University, China
- 09:50–10:10: Time domain hydrodynamic modeling for riser WV by PhD student Mats J. Thorsen
- 10:30–10:50: Model testing of combined VIV and slug flows by PhD student Tor HKnudsen
- 10:50–12:00: Discussions
- 12:00–13:00: Lunch

Participants:
- Borgundvåg, Stig Ole Rolls-Royce Marine AS
- Brett, Per Olaf Ulstein International AS
- Eiknes, Arnstein DNV GL
- Gjertsen, Egil MARINTEK
- Ingeberg, Per Rolls-Royce Marine AS
- Lie, Halvor MARINTEK
- Nydal, Ole Jørgen NTNU
- Ren, Zhengru NTNU
- Rongau, Johann Technip
- Parenteau, Thomas, Technip (On Skype)
- Sævik, Svein NTNU
- Thorsen, Mats Jørgen NTNU
- Torben, Sverre Rolls-Royce
- Vartdal, Leif Rolls-Royce Marine AS
- Vindstad, Jens Emil Statoil R&T
- Åsøy, Vilmar NTNU Ålesund
- Hildre, Hans Petter, NTNU Ålesund

In addition to this about 10 students and scientific employees at IMT were taking part of the workshop, about 30 in total.

About the workshop
The workshop was arranged as a seminar including presentations both from NTNU and invited speakers representing both industry and academia. The invited speakers were:
- Prof. Meng Tang: Southwest JiaoTong University, China
- Thomas Parenteau and Johann Rongau, Technip Innovation and Technology

Technip is heavily involved in the Solwara project outside New Guinea, being the first full scale mining development in deep waters, starting up in 2017. One important outcome of the seminar was related to Technip being willing to act as a partner with respect to quality assurance of research within this topic in SFI MOVE by sharing their experiences.
During the Autumn of 2016 and the Spring of 2017, the Research Council of Norway will be conducting site visits to the 17 SFI that started up in 2015 (SFI III). On Thursday, 6 October it was the turn of SFI MOVE. The main purpose of the visit was a review and discussion of the stage in the progress of the work of the realization of the Centre, and the challenges that were faced at the start-up of the activity.

The Research Council of Norway has not been present at any of the opening events for SFI MOVE. Department Director Kai Mjøsund therefore introduced the meeting by extending his congratulations on the establishment of SFI MOVE and presenting the Centre with the SFI Plaque as visible proof that the Centre has the status as an SFI (Centre for Research-based Innovation).

The Research Council of Norway had expressed a wish for a dialogue-based and informal setting for the visit. A program was therefore drawn up to reflect this, and the visit was carried out with presentations and dialogue in a good balance.

Halfway through the program a tour took place of the premises of NTNU, Campus Ålesund and the Norwegian Maritime Competence Centre (NMK). The tour was to laboratories, workshops and simulators, including the simulators at the Offshore Simulator Centre (OSC), which is one of SFI MOVE’s corporate partners.

The feedback by the Research Council of Norway regarding the visit was that the main impression of SFI MOVE is that it is well managed, and that overall the Centre is on track both professionally and administratively. The Centre faces some challenges because of the situation the industry finds itself in, and these must be handled in good dialogue with the Research Council of Norway.
In October there was a new meeting of SFI MOVE Marine Operations. The meeting took place at Ålesund, and on the agenda were presentations from all ongoing research projects connected to the SFI. Fellows and scientists presented their most recent work on everything from new details about cranes and offshore wind turbines, to the finances regarding the installation of equipment for wind power. In addition, representatives from industrial partners presented the experiences and challenges they face in their work.

The project is being expanded
Professor Hans Petter Hildre is the leader of SFI MOVE, and welcomed the gathering by saying that he had been requested to adjust the vision for the SFI. The wording was far too modest in relation to what was being accomplished, and the project is constantly being expanded. Five new PhD positions will be advertised next year.

Co-operation partners have high expectations
The presentations took place before an Auditorium filled to capacity, since all SFIs co-operation partners had been invited. The audience continually put questions to the scientists, and it was evident that the investors had high expectations of their investments in the project. At the meeting they were also given the chance to communicate the most important problems to which they wanted answers, and the priorities that should be made, in more explicit terms.

All industrial partners were invited to hear the presentations from fellows and other researchers.

Wind power is greater than nuclear power
This week there has been a meeting for those who wish to revolutionise offshore technology, specifically SFI Marine Operations.

- “What we are doing here is huge”, said Finn Gunnar Nilsen from Statoil, referring to the ambitions regarding offshore windmills going further and further out, and into deeper water.

- “The opportunity of utilising resources is enormous, because the effect of wind power is greater than nuclear power”, said Mr Nilsen categorically to an attentive audience.

All associated researchers and PhD students were invited to Ålesund, together with both relevant professors and co-operation partners from industry. The researchers received inspirational lectures including from Statoil, Vard, Ulstein, Rolls Royce and Havila.

The Pro-rector for research, Kari Melby, was also present on the first day, and pointed out that the SFI had high ambitions concerning innovation and new thinking for marine resources.

- “What will you do better and differently than other SFIs in this area”, was Pro-rector Melby’s question to Hans Petter Hildre, who leads the project.

To this the Pro-rector received the reply that many meetings were planned between those working on the project and industry, to ensure good communication.

- We hold this type of meetings once or twice a year. In addition, we receive frequent visits from our industrial partners, in order to ensure progress in the SFI.

Not surprisingly, there were several interesting discussions when people from various companies and disciplines met, such as when the crane operator from Havila described how he operated the crane in four meter high waves. The person who had developed the crane technology was also in the audience, and wondered why the driver did not follow the instruction book.

- “There’s a better way of performing the operation”, was the opinion of the developer.

- “The instructions are incomprehensible”, replied the driver. The developer admitted that he was in agreement with this, and said that the person who had written the book had already been dismissed – a statement that drew loud laughs from the audience.

On Day 2, the PhD students and Postdocs presented their projects.

Working to revolutionise wind power
NTNU in Ålesund
Else Britt Ervik