Centre for Research-based Innovation

The Research Council of Norway

SMART MARITIME

Annual Report 2016

Host: MARINTEK, Otto Nielsens veg 10, 7052 Trondheim • PO.Box 4125 Valentinlyst, NO-7450 Trondheim
Web: www.smartmaritime.no

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NORWEGIAN CENTRE FOR IMPROVED ENERGY EFFICIENCY AND REDUCED HARMFUL EMISSIONS

Summary

The SFI Smart Maritime is dedicated to improving energy efficiency and reducing harmful emissions from ships. With particular focus on the Norwegian Maritime Industry, our mission is to provide our partners with technologies, tools and capabilities for effective identification, assessment and verification of performance optimization solutions. The research focus is on technological solutions within hydrodynamics (hull and propellers) and machinery system (energy optimization, exhaust emissions and fuels). To test the effect of these technologies and measures on the ship performance, a ship-as-a-system approach is adopted, enabling the virtual design and optimization of a ship by help of numerical simulation models. To complete the ship performance analysis, life-cycle analysis is applied to assess the full economic viability and environmental impact of the new design. Since its take-off in the summer 2015, the Centre has focused its activity on exploring potential, state-of-the-art of technologies, building first versions of simulation tools.

Research activity from all five Work packages (WP) is in good progress, with 24 additional publications in 2016. The joint activity between the research team and industry partners has flourished during 2016. First of all, five technical sub-projects (SPs), complementary in terms of discipline as well as partner involvement, have been conducted, leading to the main scientific achievements presented in this annual report. These are *Main dimensions and hull form*, *Marine hybrid power systems*, *Fuel and abatement technologies*, *Energy saving devices and technology*, *Analysis of full-scale data*, *Simulation of long-term ship performance*, and *Ship transport environmental assessment model*.

Furthermore, two large network meetings were held in Mars and October, gathering around 40 participants. These 2-day meetings are central to the communication among Smart Maritime participants, to the involvement of our industry partners, and therefore to the overall success of the Centre.

The web page www.smartmaritime.no has been populated with general information, publications and status reports. An e-mail newsletter was launched and is now released regularly.

The Centre has a very active Board, who gathered four times in 2016, including a strategy workshop when a thorough evaluation of the Centre resulted in adjustment in organization and communication strategy.

We also had the pleasure to welcome the Norwegian Research Council for a Site Visit in November. This opportunity was used to present the strategy and structure of the Centre, and offer a tour of our research facilities and laboratories.

In 2017, Smart Maritime will concentrate the activity around few cases integrating the totality of the Centre's disciplines. At least two case studies will be used to demonstrate the potential of new concepts by help of simulation, as well as providing feedback on the models and tools under development. The Centre will also increase in flexibility, setting up thematic workshops in order to respond to the needs of our industry partners. To keep up with technological evolution, Smart Maritime will explore the possibility of expending its focus towards the new paradigms emerging from digitalization as well as automation. We expect an increased number of publications, including from Smart Maritime PhD students arriving at mid-term.

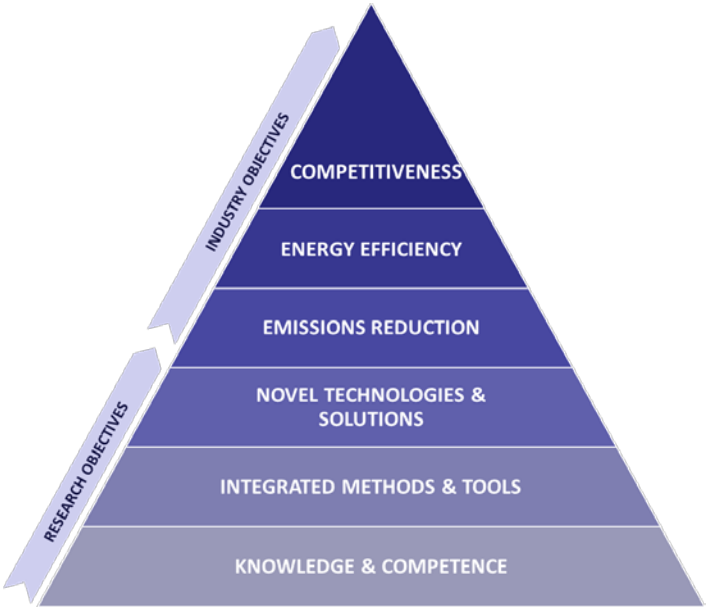
Centre for Research-based Innovation

The Research Council of Norway

Vision and objectives

Smart Maritime is a Centre for Research-based Innovation (SFI) for higher energy-efficiency and lower harmful emissions from ships.
Our vision is greening maritime transport, and by that enabling the Norwegian maritime cluster to be world leading in environmentally friendly shipping by 2025. This position will be gained through innovative use, improvement and combination of technologies, which are not only cost, energy and emission efficient, but also could improve the competitiveness of the maritime industry.

Our mission is to create innovations securing sustainability and competitiveness of the maritime transport sector. By developing new knowledge, methods and technologies and educating students (PhD, MSc), Smart Maritime will also contribute to strengthen the Norwegian maritime industry's international competitiveness. The Centre collaborates closely with global industry players, national and international research communities and maritime networks.



After the eight-year period of the SFI, the Centre will become a permanent part of the planned Ocean Space Centre in Trondheim.

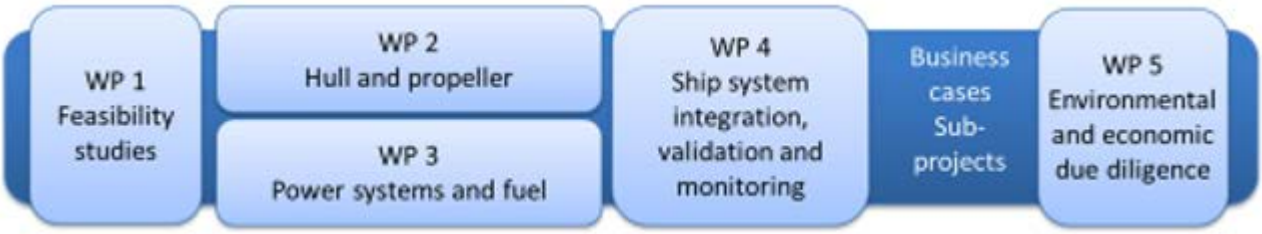
Research strategy and plan

Our research strategy and methodology is to fulfil our vision of greening maritime transport, maintain or improve competitiveness of the Norwegian Maritime industry. The research strategy is the foundation for the structuring of the work packages. Improvements in full-scale measurements are fundamental to learn to utilize the growing access to real-time operational data to be used in ship and ship technology design, as well as ship operation. The underlying hypothesis is that this will become the 'big-data' parallel in the maritime industry – which in this SFI will be applied to enable improved energy efficiency and reduced emission in the design and operation of ships and ship technology. The framework for simulation-based design will enable fast, effective and reliable assessment of design in early-phase feasibility studies. This will enable designers to assess a larger set of designs in a feasibility phase (WP1), before entering a detailed design phase with the most promising design alternatives with respect to energy and competitive performance (WP5). This is a game-changer compared to the contemporary practice of reusing or alternate old designs.

In summary, the Centre will develop a holistic system-centered ship design method using a modular simulation and analysis framework for accurate performance assessment for ship and ship systems under realistic full-scale operation-al conditions (WP4), to assess the effect of energy efficiency improving measures developed for hull and propeller (WP2) and power systems and fuels (WP3). Hybrid LCA methods will be used in combination with profit and opportunity cost models to verify environmental and economic benefits (WP5).

The proposed Centre partners comprise research institutes, academic institutions and key industry players in the Norwegian ship and ship equipment value chain. These partners are involved in scientific activity through business cases and sub-project activity across the WPs.

During its 8-year period, the SFI Smart Maritime will finance 9 PhDs and 8 Postdocs.



Copyright Havyard

Long-term research - Work Packages

Research activity is divided into five work packages, each with 3-year rolling plan These WP follow a concept development process: WP1 produces feasibility studies to screen the most promising options for energy and emissions reductions. These are further explored and tested in WP2 and WP3. Thereafter WP4 offers a ship system integration platform based on models developed in WP2 and WP3, and used to validate solutions and technologies through simulation of ship performance. Finally, WP5 completes the concept development process by providing environmental and economic due diligence of concepts and solutions at ship and fleet level.

Feasibility Studies (WP1)

Feasibility studies enable investigation of alternative concepts early in the project to identify the most promising options.

Objective:

Develop assessment models that enable ship designers and innovators to investigate a number of alternative designs at an early stage and produces series of feasibilities studies.

Background:

There is a lack of assessment methods and tools to enable comparison of alternative designs at the feasibility stage of the design process. Current studies and state-of-the-art design practice regarding concept, speed and capability tends to be based on marginal improvements of existing designs and solutions instead of challenging todays practice. One explanation is that most vessels for the merchant fleet have been built by shipyards according to quite standardized designs to minimize building cost while more specialized vessels generally have been improvements and amendments of existing designs.

Hull and propeller optimization (WP2)

Currently, most merchant vessels are designed for optimum performance in calm water. There is an increasing understanding of the importance of including sea-keeping and manoeuvring-related aspects, but it has not found its way into practical design work yet.

Objective:

Identify potential for energy savings by means of hull and propulsion optimization, and introducing novel approaches to improve efficiency.

Background:

The tools currently used in design of offshore vessels have a potential for being applied in the design of merchant vessels. Despite this, design for a balanced set of operational conditions is still at the development stage even for offshore vessels. Hydrodynamic performance of ships and propulsion systems, with special emphasis on operation in waves, are specially addressed in WP 2.

Power systems and fuel (WP3)

Exploring options for integration of novel technologies into current and new designs, such as advanced combustion control, waste heat heat recovery, power system optimization and energy management, as well as alternative fuels and hybrid power systems.

Objective:

Improve current designs and explore novel technologies, systems and solutions for power generation that are energy and emission efficient.

Background:

Reducing fuel consumption and harmful emissions for different vessel types at different operation profiles and modes to comply with current and future IMO legislations is currently the main challenge for maritime transport. Traditionally the power solutions for seagoing vessels have been designed to ensure that the vessels have the required power to be seaworthy in rough weather and to achieve its desired design speed utilizing 85 % of its installed power resources on calm water.

Ship system integration and validation (WP4)

The research activity in WP 4 will consider how to technically integrate the components and sub-system developed in WP 2 and 3 in one simulation framework where the full complexity of the future operational profile of the vessels is considered.

Objective:

Enable performance evaluation and benchmarking of designs on a ship system level by combining monitoring data and simulations in a framework where component and subsystem models can be combined in a full ship system, and validate the results through laboratory and full-scale tests.

Background:

The research activity in WP 4 will consider how to technically integrate the components and sub-system developed in WP 2 and 3 in one simulation framework where the full complexity of the future operational profile of the vessels is considered. This holistic system-centered ship design process will enable accurate performance assessment of full ship systems in realistic operational conditions, and assessment of effects of energy efficiency improving measures. In addition, continuous optimization of these systems can be achieved by the combination of real-time monitoring and appropriate system simulations.

Environmental and economic due diligence (WP5)

This work package will integrate state of the art methods for detailed environmental and economic analyses, to systematically assess, compare, and benchmark ships and shipping system designs

Objective:

Systematically assess the environmental and economic performance parameters of different ship and shipping system designs

Background:

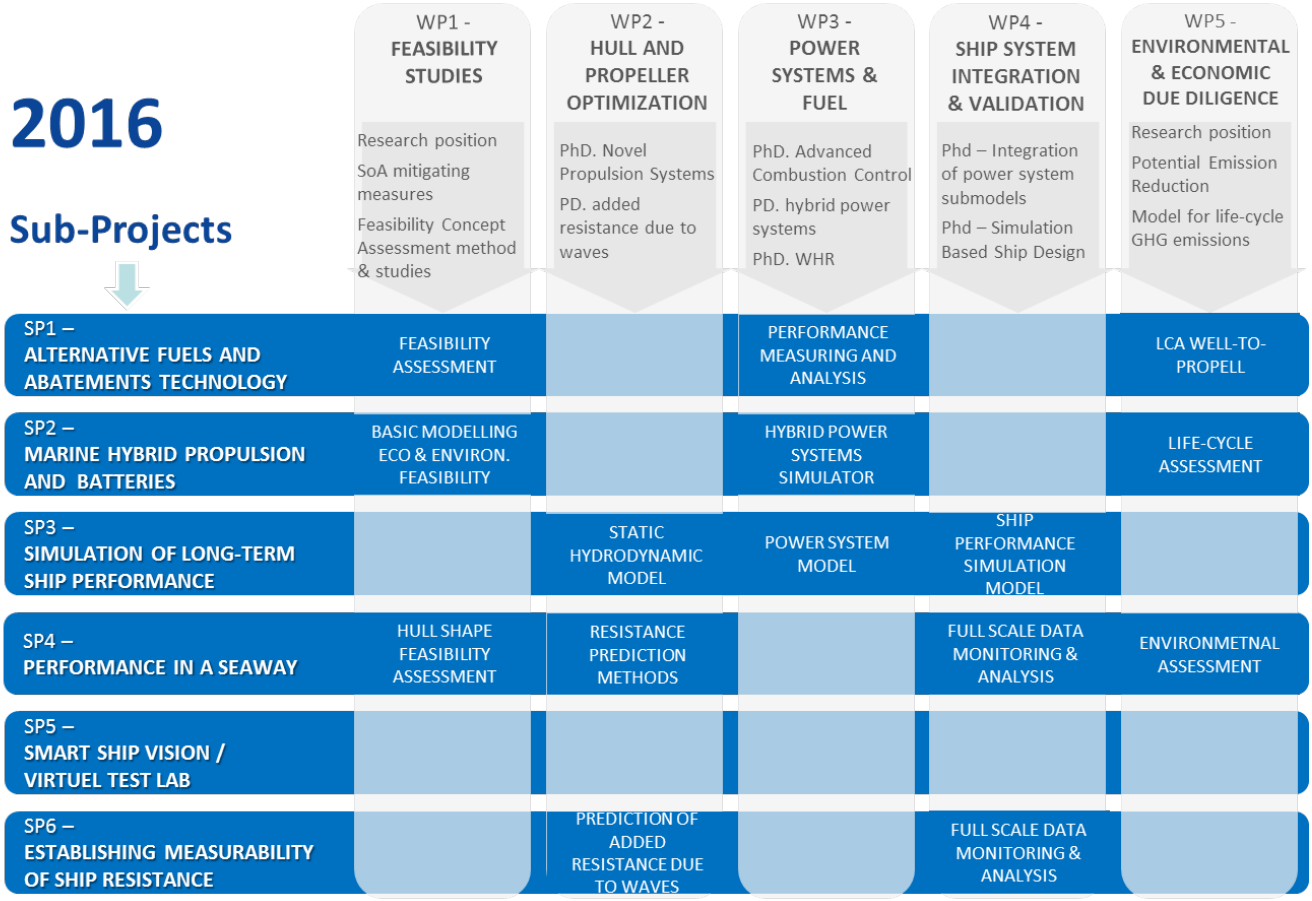
Both maritime trade and international transport have increased at tremendous rates in the past decades. Maritime transport is estimated to contribute 3.3% to the global anthropogenic CO2 emissions, and the environmental consequences of increased trade are an important factor in the current climate debate. There is a need for detailed harmonized environmental and economic costs assessment of current and novel ship designs. In addition, there is a lack of good approaches for integration of such assessments with ship design and engineering workflows.

Copyright Kristian Gerhard Jebsen Skipsrederi A/S

Short-term research - Sub-Projects

In addition to the long-term work-packages (WP), R&DI activity at the Centre is organised through sub-projects (SP). These consist of shorter research activities involving several work-packages, and are defined and carried out in collaboration with industry partners.

In 2016, six SP launched in 2015, were carried out. The matrix below presents an overview of these SP and the main contribution from WPs in each of them.



Each project is described briefly in the next pages. At the core of this SP activity was the interaction between research team and industry partners, which, throughout the year, resulted in a common understanding of the Smart Maritime strategy, challenges and opportunities.

At the end of year 2016, a review of these ongoing projects lead to the joint decision between the Centre Board, Management team and Technical Advisory Board (industry partners) to restructure the panel of sub-projects into fewer and more integrated activities. The motivation behind this decision is to further exploit synergies across work packages and sub-projects and to maintain the balance between long-term publishable research and shorter-term projects with practical value for industry partners.

Sub Project 1 - Fuels and abatement technologies

Meeting IMO Tier III emissions restrictions with focus on Heavy Fuel Oil (HFO), Marin Gas Oil (MGO) and Natural Gas in form of LNG.

The known emission limits may be met by alternative fuels like LNG, low sulphur fuel oil with SCR or by HFO applying scrubbing technology and means to reduce NOx, like EGR (Exhaust Gas Recirculation). There is today a focus on GHG emission from ships but no stated limits for the shipping industry. There is therefore a need for an objective comparison between different fuel options and machinery systems, The purpose of the sub-project is to perform a full economic, technical and environmental due diligence of the different alternative fuels and abatements technologies, as well as an assessment of technology trends and future legislation development. The study is to be supported with data and experience from ships in operation.

Deliverables 2016:

- Report: Clipper Harald HFO operation with scrubber - Wash water analysis at berth
- Two reports on full-scale exhaust gas measurement

Expected impact

Reduced harmful emissions:

- SOx, NOx, PM
- Reduced GHG

Competitiveness of Norwegian maritime cluster:

- Scrubber + EGR

Project team

Project Leader: *Per Magne Einang, MARINTEK*
Project industry partners: *Solvang, Wilh. Wilhelmsen, KGJS, Grieg Star, Wärtsilä Moss, DNV GL, Bergen Engines, Kystrederiene, Sjøfartsdirektoratet*

Sub Project 2 - Marine Hybrid propulsion and batteries

Identify and quantify the potential from hybrid propulsion and batteries for reduction of cost and emissions in a maritime setting.

The interest in using batteries in maritime applications has grown rapidly the latest years, mainly due to the success in road transport (private cars). We believe there is a need for a study determine the applicability for maritime applications of batteries, and to perform a full economic and environmental due diligence. Hybrid technologies will include; battery storage of energy to take peak power requirements, engine power arrangements, cold ironing in port by vessel batteries, propulsion at sea by electricity from batteries only, and power management systems.

Deliverables 2016:

- Report on Marine hybrid power systems and components
- Simulator of the hybrid power lab, used to estimate efficiency of the equipment for different operational points

Expected impact

- Impact on emission reduction
- Impact on fuel saving, emission reduction and increased competitiveness

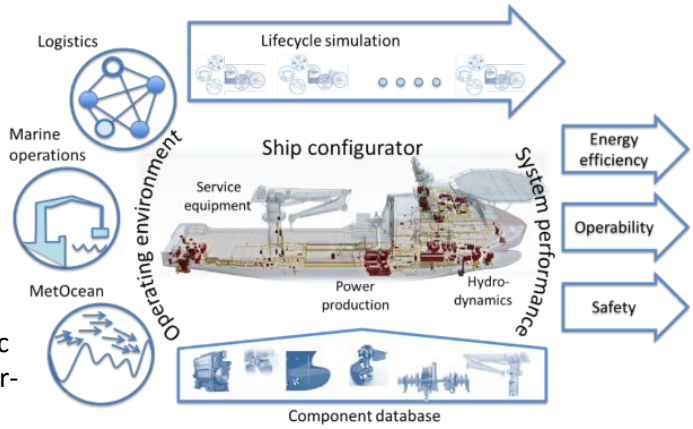
Project team

Project leader: *Dag Stenersen, MARINTEK*
Industry partners: *ABB, SIEMENS, Rolls-Royce Marine, Grieg Star, NES, DNV GL*

Sub Project 3 - Simulation of long-term ship performance (Virtual testing phase 1)

Improving early stage design decisions by enabling simulation of long-term performance of new ship technology and design solutions, and validate simulations against full-scale performance.

Virtual testing can be done at different levels of detail, from the dynamic time-domain simulations with full physical models and milliseconds time-steps to the static discrete-event simulations with average value calculations and hour-long time steps. In this virtual testing phase 1 project we will focus on the static simulations, which allows us to evaluate the ship performance over years of operation. (Figure: VISTA project)



Deliverables 2016:

A tool (GYMIR) for early-stage design assessment, simulating the long-term performance of a ship in realistic operational profiles. The tool enables the integration of ship sub-systems models (WP2, WP3).

Expected impact

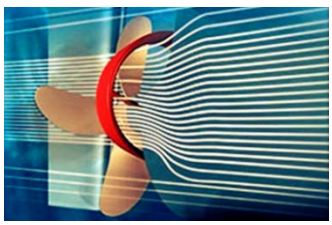
- Improved competiveness of ship designers using the GYMIR application
- Use of the application results in more energy-efficient ship designs

Project team

Project leader: *Trond Johnsen, MARINTEK*
Industry partners: *Vard, Havyard, Rolls-Royce, DNV GL*

Sub Project 4 - Performance in a Seaway

Methods for reliable prediction of the performance in a seaway, i.e. added resistance due to wind and waves, and the change of propulsive efficiency.



Ships are traditionally optimized for operation in calm water, at design draught. Wind and waves are important for the operation of the ships, and might mean that the ships should be designed differently to be optimal in their actual operation. In addition comes the need to design for safety and operability in harsh weather conditions.

Deliverables 2016

- Method and tool for full scale data monitoring of speed loss and power increase
- Computational methods for speed loss and power increase
- Effect of waves on Energy Saving Devices.

Expected impact

- competitiveness through increased knowledge and guidelines wrt hull design, weather routing and application of Energy Saving Devices
- Potential fuel savings 10-15%

Project team

Project leader: *Sverre Anders Alterskjær, MARINTEK*
Industry partners: *Wilh. Wilhelmsen, KGJS, Grieg Star, Vard Design, Havyard, DNV GL, Jotun, Rolls-Royce Marine*

Sub Project 5 - Smart Ship Vision

Describe and illustrate one or more far future ship concept introducing new technology in a wide-ranging way, representing a vision for the Smart Maritime activities.

Characteristics of the Smart Ship concept:
- Long-term horizon
- Introduces new technology to a large extent
- Solves critical challenges (special focus on environmental issues)
- Technically qualified to a level that ensures realism

Deliverables 2016

- Review of state-of-the-art technologies, measures, and potential for reducing GHG emissions (WP1,WP5)
- Feasibility studies: slender hull, batteries in OSV, alternative fuels and abatements technologies (WP1)
- Advanced test & further exploration of potential: energy saving devices, LNG, abatement technologies (scrubbers, EGR), hydrofoils (WP2, WP3)

Expected impact

- Energy efficiency
- Reduction of harmfull emissions
- Competitiveness of maritime cluster

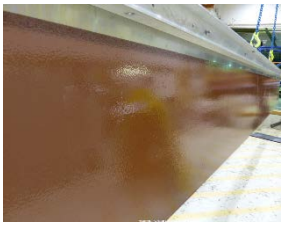
Project team

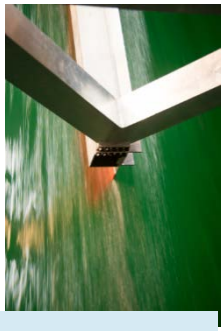
All WPs

Sub Project 6 - Establishing Measurability of Ship Resistance

Measurability of hull performance in full scale

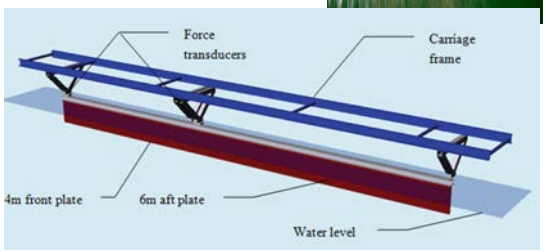
- Prediction methods for increase of resistance and fuel consumption due to hull roughness and fouling
- Prediction method for of full scale frictional resistance based on model scale tests.





Deliverables 2016

Report on frictional resistance and flow characteristics of different surfaces, based on hydrodynamic testing of plates with different roughness at different speed (plates covered with painting from Jotun)



Expected impact

- Increased resistance by 10% between painting intervals
- Reduced fuel consumption and emissions by 10% based on air lubrication

Project team

Project leader: *Kourosh Koushan, MARINTEK*
Industry partners: *Jotun, Grieg Star, KGJS, Wilh. Wilhelmsen, DNV GL*

Copyright Wilh. Wilhelmsen

Organization

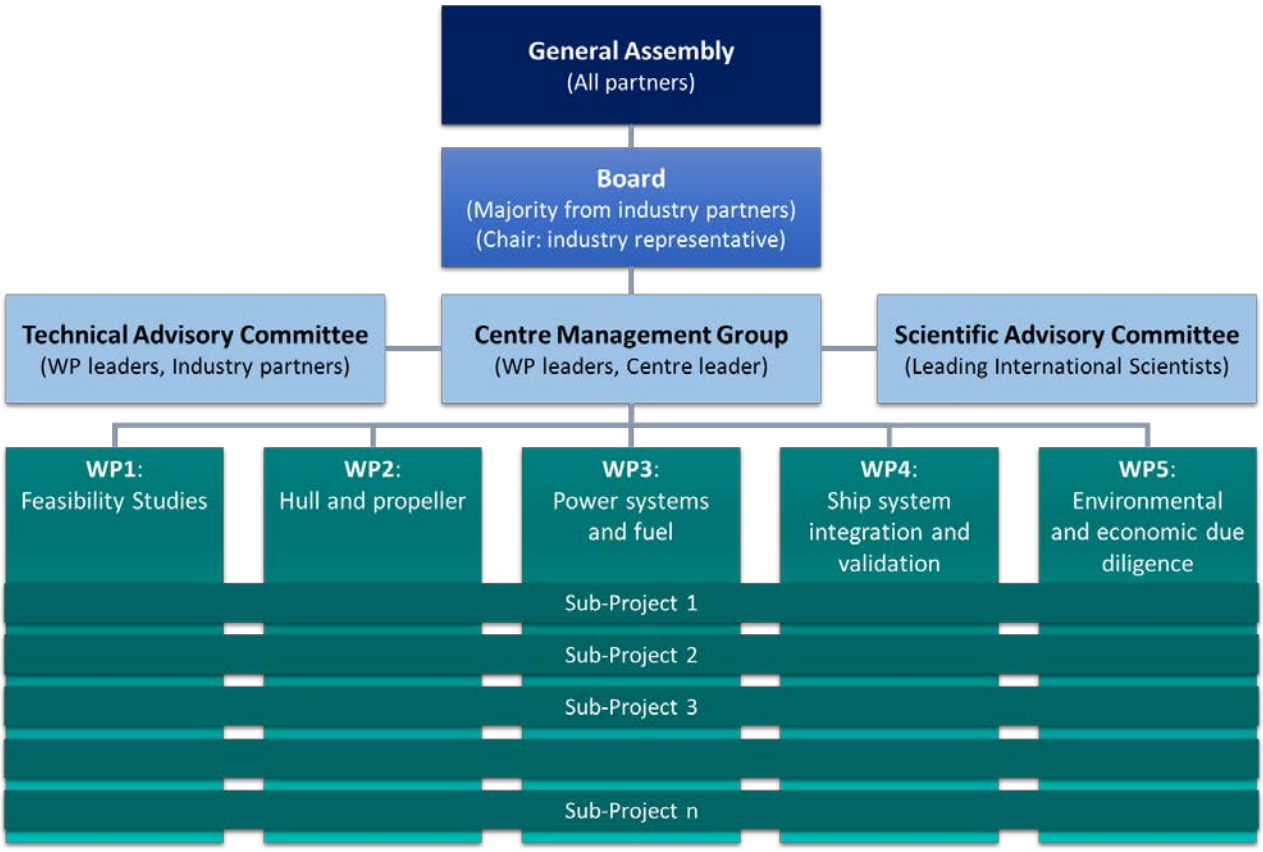
The Centre is using a matrix organization where the long-term research with the PhD programs performed in Work Packages (WP). Across of the WP's are Sub-Projects (SP) involving two WP's as a minimum. The SP's are relevant to actual topics for the industrial partners and are short-term activities, typically 2 years.

General assembly consist of all partners and a Centre Board with seven members, industry partners in majority. The Centre management team consist of the WP leaders, Centre Director and a Deputy Centre Director.

The Technical Advisory Committee (TAC) is formed to create a meeting place for all partners in the Centre to discuss and suggest activities in the WP's and SP's. Its role is to advise the Centre Management on prioritization of RDI activities to be conducted within Smart Maritime. The TAC is gathered together twice a year at the bi-annual Network Meetings.

The Scientific Advisory Committee consists of leading international capacities auditing and advising the research activities in the Centre.

Organization Structure



Board Members	Affiliation
Jan Øyvind Svardal (Chairman)	Grieg Star
Per Brinchmann	Wilh. Wilhelmsen
Per Ingeberg	Rolls-Royce Marine
Henning Borgen	VARD Design
Jan Fredrik Hansen	ABB
Ingrid Schjølberg	NTNU
Beate Kvamstad-Lervold	MARINTEK
Sigurd Falch (observer)	Norwegian Research Council

General Assembly Chairman	Affiliation
Stig-Olav Settemsdal	Siemens

Industry Coordinator	Affiliation
Gunnar Malm Gamlem	Wilh. Wilhelmsen


Jan Øyvind Svardal


Per Brinchmann


Bjørn Egil Asbjørnslett


Per Ingeberg


Henning Borgen


Jan Fredrik Hansen


Ingrid Schjølberg


Beate Kvamstad-Lervold


Sigurd Falch


Stig-Olav Settemsdal


Gunnar Malm Gamlem

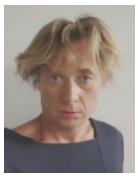
Board meetings 2016
June: review of ongoing activities
Sept.: Strategic planning
Nov.: planning and budget 2017
Dec.: preparation of General Assembly meeting

Centre Management Group	Affiliation	Role and responsibility
Per Magne Einang	MARINTEK	Centre Director
Anders Valland	MARINTEK	Deputy Centre Director
Haakon-Elizabeth Lindstad	MARINTEK	WP1 Feasibility studies
Sverre Steen & Sverre Anders Alterskjær	NTNU MARINTEK	WP2 Hull and Propeller
Eilif Pedersen	NTNU	WP3 Power systems and Fuel
Trond Johnsen	MARINTEK	WP4 Ship system Integration
Anders Strømman & Evert Bouman	NTNU NTNU	WP5 Environment and economy

Centre administration	Affiliation	Role and responsibility
Jan Andre Almåsbakk	MARINTEK	Controller
Inger Gudmundsen	MARINTEK	Document control and Web
Agathe Rialland	MARINTEK	Adm. Coordinator


Per Magne Einang


Anders Valland


Haakon-Elizabeth Lindstad


Sverre Steen


Sverre Anders Alterskjæ


Eilif Pedersen


Trond Johnsen


Anders Strømman


Evert Bouman


Jan Andre Almåsbakk

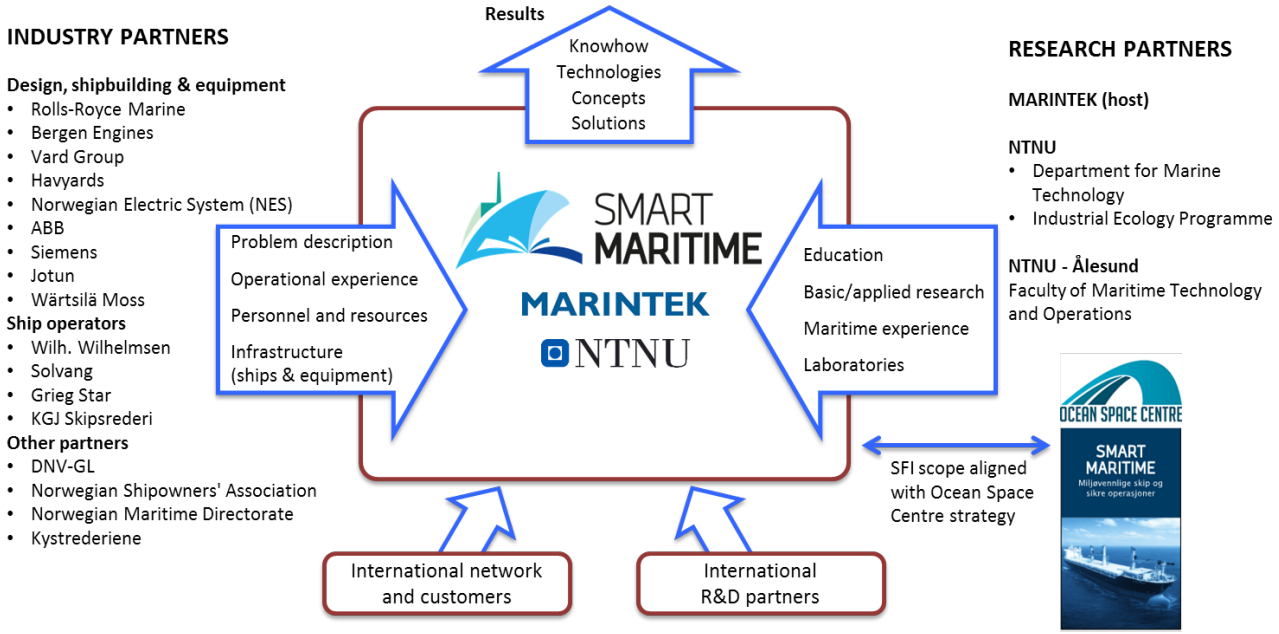

Inger Gudmundsen


Agathe Rialland

Scientific Advisory Committee	Affiliation	Focus area
Professor Osman Turan	Strathclyde University	WP 1
Professor Harilaos Psaraftis	DTU - Technical University of Denmark	WP 4
Professor Rickard Benzow	Chalmers University of Technology, Gothenburg	WP 2
Professor Karin Anderson	Chalmers University of Technology	WP 5
Professor Friedrich Wirz	TU Hamburg	WP 3

Partners

MARINTEK[1] hosts the Centre in collaboration with the research partners NTNU and NTNU Aalesund. The industry partners, together forming the Technical Advisory Committee, cover major parts of the maritime value chain: ship system suppliers, ship designers, ship owners and stakeholder groups.



NTNU and MARINTEK have developed a joint strategy (MARINTEK & NTNU, 2013) for Ocean Space Centre where "Smart Maritime" is one out of five strategic areas for research and education. In 2012 MARINTEK, SINTEF, NTNU and Aalesund University College formalized an inter-regional collaboration project with the objective to strengthen the interaction between the Møre maritime cluster and the research and education communities in Trondheim and Ålesund. This work has led to several KPN, IPN and offspring projects that will support the activities in SFI Smart Maritime and Ocean Space Centre.

[1] Host institution to become **SINTEF Ocean** by January 1st 2017

Research partners

MARINTEK (Host institution)
Performs research, development and verification of technological solutions, business and operating concepts for the shipping, marine equipment, ocean energy and petroleum industries.

NTNU - Department of Marine Technology
Educates MSc, PhD and postdoc, and conducts research on marine systems and marine structures.

NTNU - Industrial Ecology Programme
Internationally leading institution within its field and has five authors contributing to the forthcoming WG III assessment report of the IPCC.

NTNU - Ålesund Faculty of Maritime Technology and Operations
Educates candidates on BSc and MSc level. The Faculty conducts research in the fields of maritime systems and operations.

Industrial Partners

SHIP OWNERS

Wilh. Wilhelmsen ASA	Offers shipping and integrated logistics services for cars and rolling cargo, controlling 150 vessels worldwide
Solvang ASA	One of the world leading transporters of LPG and petrochemical gases. The fleet consist of 23 vessels – semi-refrigerated/ethylene carriers, LPG ships and VLGC.
Grieg Star AS	Fully integrated shipping company and owner of one of the world's largest open hatch fleets.
Kristian Gerhard Jebsen Skipsrederi AS	KGJS) is a fully integrated shipping company involved in tankers, dry cargo and specialized cement vessels.

DESIGN & SHIPBUILDING

Havyard Group ASA	Fully integrated Ship Technology company and deliver products and services within the complete value chain from vessel design to support of vessels in operation.
Vard Design AS	Major global shipbuilder of offshore and specialized vessels for offshore oil and gas exploration, production and service.
Rolls-Royce Marine AS	Leading provider of innovative ship designs and systems, and a manufacturer of power and propulsion systems to oil & gas, merchant and naval sectors.

EQUIPMENT AND SYSTEM SUPPLIERS

ABB AS	Leading manufacturer of electric power and propulsion systems for ships. The product range also includes advisory systems for monitoring operational parameters
Bergen Engines AS	A subsidiary of Rolls-Royce Power Systems within the Land & Sea Division of Rolls-Royce. Our medium speed gas and liquid fuel engines are supplied for a broad range of power generation applications.
Jotun AS	world's leading provider of paint systems and marine coatings to ship-owners and managers active in the newbuilding and dry-dock and maintenance markets
Norwegian Electric System AS	NES is an innovative, high-tech electrical company with a focus on diesel electric and hybrid electric systems for the global marine market.
SIEMENS AS avd corporate centre & real estate	Siemens is among the world's leading suppliers of diesel-electric propulsion systems
Wärtsilä Moss AS	Manufactures advanced inert gas and nitrogen solutions for marine and offshore oil and gas applications. Wärtsilä Norway (parent) delivers solutions for ship machinery, propulsion, automation, ship design, automation systems and liquid cargo solutions

SERVICE AND STAKEHOLDER ORGANIZATIONS

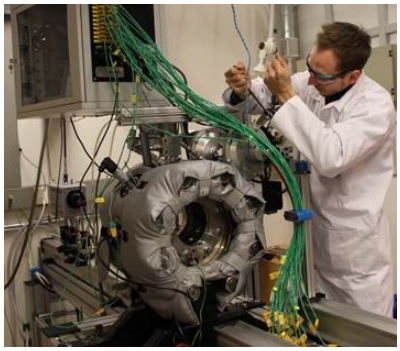
DNV GL AS	world's largest ship and offshore classification society and a leading technical advisor to the maritime, energy and oil & gas industries
Norges Rederiforbund	Norwegian Shipowners' Association is a non-government organization serving more than 160 companies in the field of Norwegian shipping and offshore activities
Kystrederiene	The Coastal Shipowners Association works for promoting sea transport and marine services with focus on innovation and environmental-friendly solutions.
Sjøfartsdirektoratet	The Norwegian Maritime Authority has jurisdiction over ships registered in Norway and foreign ships arriving Norwegian ports.

Research facilities

The SFI make use of own research facilities[2] (MARINTEK and NTNU) as well as on-site laboratories from its industry partners.

ENERGY AND MACHINERY LABORATORY

Amongst the best equipped independent engine laboratories in Scandinavia. Well-developed installations with highly specialized experimental equipment, instrumentation and data-acquisition systems. Full scale medium speed piston engines, complete hybrid propulsion system with batteries for energy storage and combustion rig for ignition and combustion studies.



TOWING TANKS

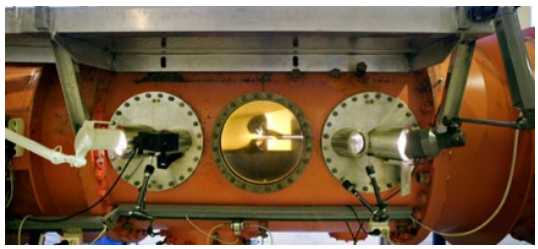
Used for investigation of hydrodynamic performance of ships: resistance, propulsion, seakeeping in head and following seas, and directional stability tests with free running models. The tanks are equipped with two carriages: One for towing up to 10 m/s for traditional calm water tests and a second carriage for seakeeping tests and other tests performed with fixed or free-running models.

OCEAN BASIN

Used for basic as well as applied research on marine structures and operations. A total environmental simulation including wind, waves and current offers a unique possibility for testing of models in realistic conditions. With a depth of 10 metres and a water surface of 50x80m, the Ocean Basin Laboratory is an excellent tool for investigation or existing of future challenges within marine technology.

CAVITATION TUNNEL

The cavitation tunnel is used to investigate the hydrodynamic performance of different type of ship hulls, propulsors and other hydrodynamic objects. Propeller induced pressure fluctuations and noise as well as cavitation are investigated by means of measurements and high speed video observation. Propeller shaft and single propeller blade forces and moments can be measured using advanced in-house developed miniaturized instrumentation, in addition to standard thrust and torque measurements.



[2] Pictures: MARINTEK

CIRCULATING WATER TUNNEL

Test facility dedicated to optical measurement techniques and flow visualization. The tank's measurement section is completely transparent and can be operated either with a free surface or the lid closed.

R/V GUNNERUS

The NTNU research vessel R/V Gunnerus is a platform for ocean research, both with respect to technology and life sciences. It has a full diesel-electric propulsion plant, and has recently been upgraded with two novel Rolls-Royce rim-drive permanent magnet azimuthing thrusters. It has the latest Kongsberg DP and motion measurement systems, and it is equipped with Rolls-Royce HeMOS remote monitoring system. *(Photo: Fredrik Skoglund)*

CLIPPER HARALD

Clipper Harald (Solvang) A LPG tanker operating at coast of Norway on HFO equipped with Exhaust Gas Scrubber with open loop and wash water cleaning system. EGR (Exhaust Gas Recirculation system) for reduction of NOx emissions.

BERGEN ENGINES LABOARATORY

Bergen Engines Laboratory for Gas engine development operating on LNG and equipped with complete exhaust gas emission analysis including PM (Particulate Matter)

Cooperation between partners

Smart Maritime organize a network meeting twice a year when the research team and the industry partners (functioning as the Technical Advisory Committee of the Centre) gather for two days. The purpose is to make a meeting place for the partners to receive updates and scientific lectures from the research team, to discuss and express interest in the ongoing WP and SP activities, as well as new research focus areas.

In 2016, the first network meeting took place Lysaker, hosted by Wilh. Wilhelmsen, and served as workshop for ongoing sub-projects.

The second network meeting, in Værnes, aimed at presenting the achievement from 2016 and prepare for 2017.

In addition to the network meeting, Smart Maritime management team has launched individual partner visits in order to keep a close dialog between the Centre and each of its members.

Furthermore, a representative of the Technical Advisory Committee has been appointed as industry coordinator, serving as single point of contact and ensuring that all industry partners' interests are respected.

Network meeting, 15-16 March 2016

Host: Wilh. Wilhelmsen
Place: Lysaker
No participants: 31

Network meeting, 24-25 October 2016

Host: MARINTEK
Place: Værnes
No participants: 47

Dialog with the Norwegian Research Council

On November 3rd 2016, the Norwegian Research Council, represented by Liv Jorunn Jenssen, Sigurd Falch and Kai Mjøsund, conducted a **Site Visit** of Smart Maritime at MARINTEK. They expressed their satisfaction regarding the progress of the Centre and the cooperation between the research team and the Technical Advisory Committee. They noted particularly the engagement from industry partners, and your high expectations and requirements playing a key role for ensuring innovation.

Kai Mjøsund (NRC), Henning Borgen (VARD Design, Smart Maritime Board member) and SFI Coordinator Liv Jorunn Jenssen (RCN)

Presentation of the Towing Tank by Sverre Anders Alterskjaer (MARINTEK)

Scientific activities and results

2016 can be summarised as a period of exploration, both in terms of scientific activity and working methods. With six sub-projects running in parallel and with contribution between the research team (5 work packages) and industry partners, this year has laid the foundation for solid cooperation in the years to come. At this stage, dialog and mutual learning is important to ensure that Smart Maritime catches interests from its industry partners and prioritise activities that are both relevant for long-term and publishable research and at the same time provide value and potential for innovation to the participating companies. To ensure valuable results that can be adopted by Smart Maritime's industry partners, the SFI has attached importance the active participation of our participating companies in the development of solutions, methods, models, as well as measurement and test activities.

The main achievements from 2016 R&DI activities are presented in the following pages. All these results have been made possible by the constellation of competence available at the Centre.

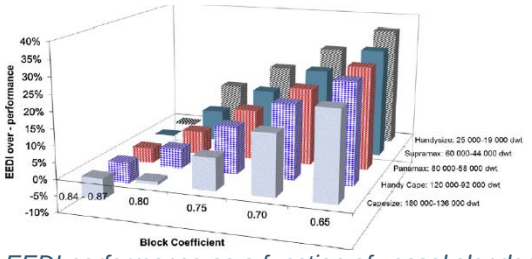
MAIN DIMENSIONS AND HULL FORM (WP1)

Contact: Dr Haakon-Elizabeth Lindstad, MARINTEK

Exploiting energy saving opportunities from slender hull design.

Feasibility study of slender bulk vessel designs, with assessment of profit, cost and emissions

Building more slender vessels can reduce fuel consumption per ton nm, emissions, costs and improves the EEDI performance. (Lindstad 2015)



EEDI performance as a function of vessel slenderness

How speed, size and slenderness amounts to Substantial Capital Energy Substitution

Relationship between the fuel price and the ballast versus loaded speed (Lindstad & Eskeland, 2016)

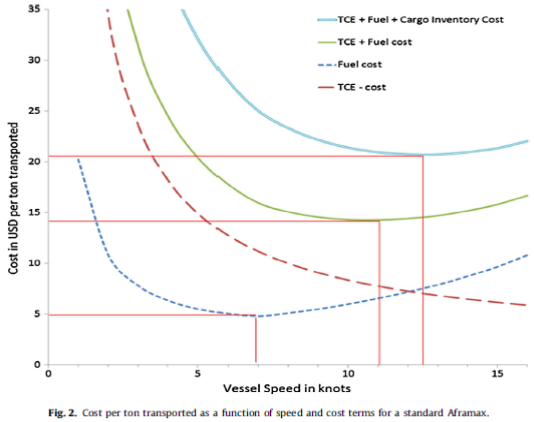


Fig. 2. Cost per ton transported as a function of speed and cost terms for a standard Aframax.

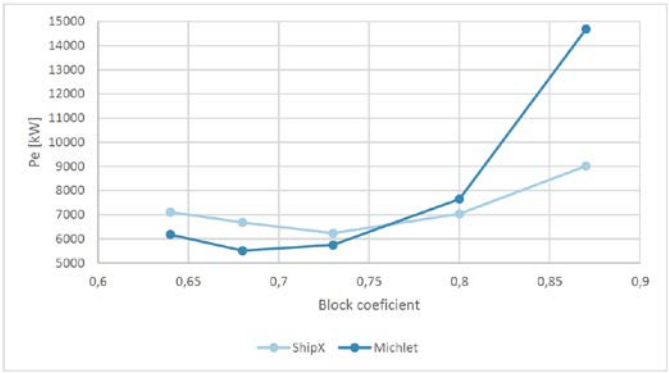
Roundtrip cost curves for an Aframax 110 000 dwt and a fuel cost of 600 USD per ton

Impact of Panama Canal expansion on the global merchant shipping fleet.

The expansion of the Panama locks in 2016 will enable vessels with larger capacity (economies of scale), more slender designs (energy-efficient designs) or a combination (Lindstad, 2016)

Hydrodynamic optimization of bulk and tank ship hulls

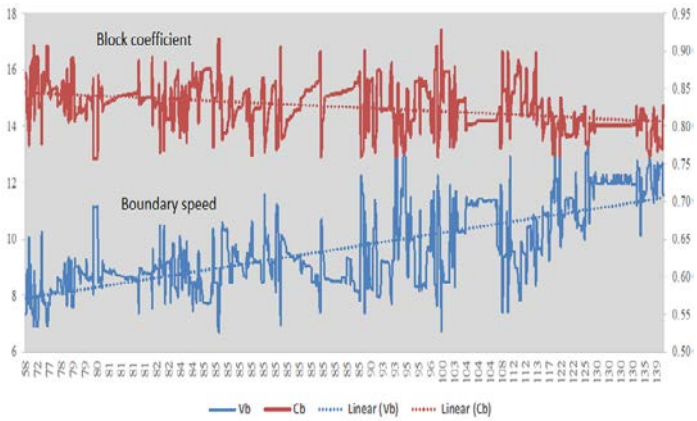
Taking into account also added resistance due to waves and relieving the typical restrictions on main dimensions, the thesis shows significant savings by making the hulls more slender by increasing the beam. (MSc thesis, H. Utby, 2016)



Effective power for CBC series at 13 knots calculated by ShipX and Michlet

Revitalization of short sea shipping through slender, simplified and standardized designs

Study concluding on fuel and cost savings in the same range as what is achievable by doubling the vessel size. (Lindstad et al., SNAME 2016)



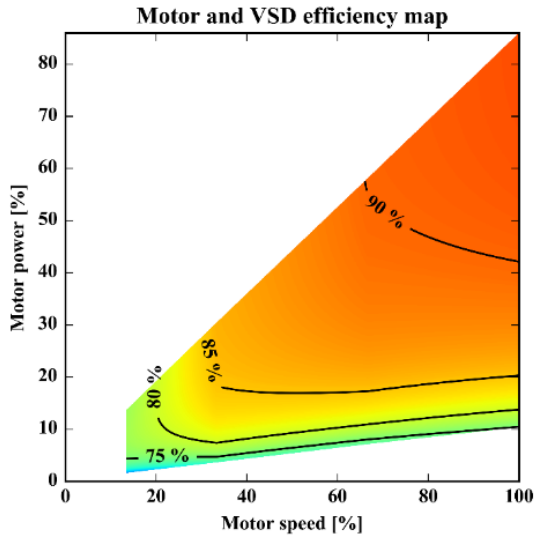
Boundary Speed and Block coefficient as a function of vessel length.

MARINE HYBRID POWER SYSTEMS (SP2, WP3)

Contact: Dr Torstein Ingebrigtsen Bø, NTNU;
Kevin Koosup Yum, MARINTEK

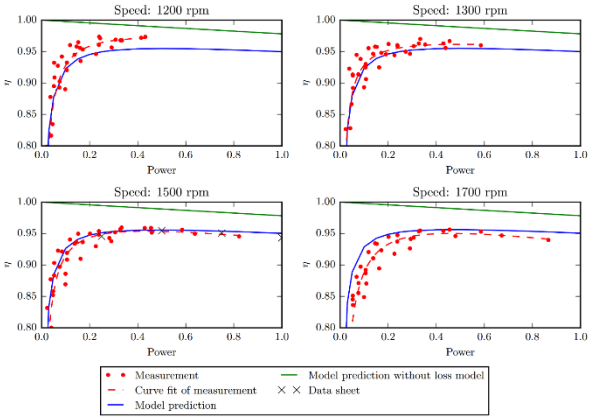
Loss investigation of marine electric propulsion systems

An investigation of losses in marine electric propulsion systems is conducted. To investigate where the losses are and to find the relevant operations.



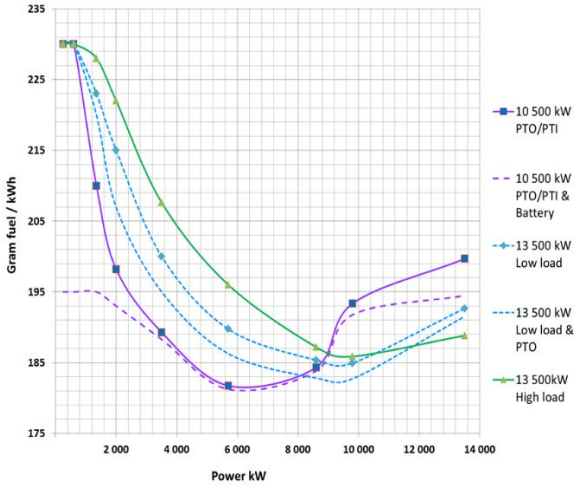
Combined loss and dynamic models of electric machines

For system designers, loss models of electric machines are needed to evaluate the performance of the drive train. These models must be in a level of details that is available for the system designer. Multiple loss models are developed for synchronous machines.



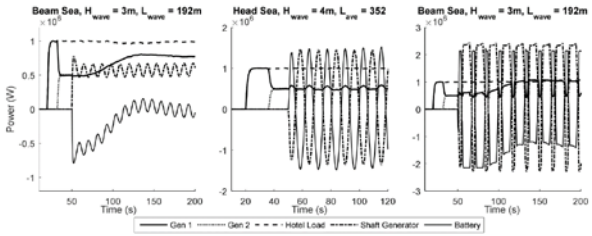
Power take in/out and batteries

For some vessels, the diesel engine is over dimensioned. Shaft generator and motors can be used to downsize the main engine while keeping the propeller shaft power capacity. The economic potential of this solution is studied in Lindstad et al. (2016).



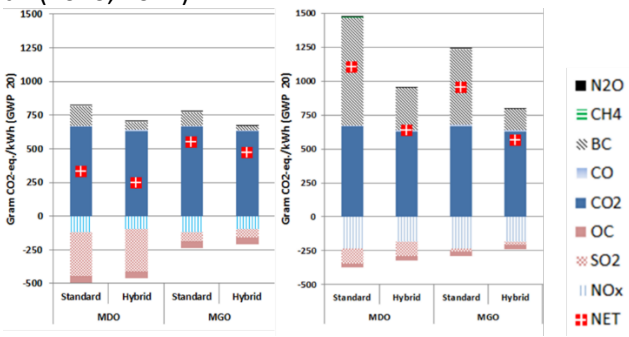
Power smoothing in waves

Power taken in/out and batteries can be used to smooth out power variations of the propeller, such that the main engine produces a constant load and batteries smooth out the variations. This method is evaluated in Yum et. al (2016).



Batteries in Offshore Support vessels

Batteries may be used in offshore support vessels to reduce environmental emissions. The greenhouse warming potential is evaluated for different locations, fuels, and configurations in Lindstad et al. (2016; 2017)



FUEL AND ABATEMENT TECHNOLOGIES (SP1, WP3)

Contact: Per Magne Einang, MARINTEK

LNG as Fuel: GHG emissions

LNG – Shortsea case: test on several ships on Pure gas operation. A test program has been performed on two different ships operating on LNG with complete exhaust gas analysis. The results show very low level on NOx resulting in high level of methane slip. A laboratory test at Bergen Engines on a full-scale gas engine showed simple adjustments reducing methane slip significantly keeping NOx within tier III limit.

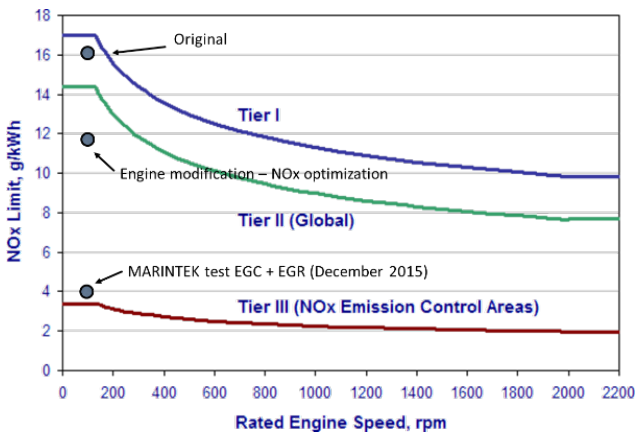
Load	NOx	THC	Methane
[%]	[g/kWh]	[g/kWh]	[g/kWh]
25	0,3	13,9	13,3
50	0,6	7,8	7,2
75	0,8	6,0	5,2
100	0,9	4,8	4,2
Weighted E3 cycle	**0,75**	**6,4**	**5,6**

Load	Nox	Methane
[%]	[g/kWh]	[g/kWh]
25	1,7	2,5
50	1,2	3
75	1,1	2,8
100	1,1	2,3
Weighted E3 cycle	1,2	2,7

HFO operation in ECA: Exhaust Scrubbing and EGR

Clipper Harald, a LPG carrier operating between Kårstø and Reftnes or Stenungsund in Sweden. Operating on HFO both main engine and axillary engines, employing exhaust gas scrubbers on main engine and axillary engines, to meet sulphur emission limitation of 0,1%. The ship is addition using Exhaust Gas Recirculation (EGR) to control NOx emission. The initial tests show it is possible meet the emission requirements ECA and Tier III.

A test on improved EGR quality showed a reduced need for turbine and heat-exchanger washing. New measurements and analysis of washing-water quality were also performed showing very low levels of harmful components, due to the washing-water cleaning system.



ADDED RESISTANCE AND LOSSES DUE TO WIND AND WAVES (SP4, WP2)

Contact: Sverre Anders Alterskjaer, MARINTEK; Sverre Steen, NTNU

Effect of waves on Energy Saving Devices

In August 2016, model tests were carried out in MARINTEK's long towing tank in cooperation with Vard Design and Rolls-Royce Marine.
The purpose of the model tests was to investigate the effect of waves, steering actions and off-design operation on the power savings obtained by using the PROMAS system over a conventional propeller/rudder.
The results of the test show that the power saving from applying the PROMAS rudder and hubcap is maintained at the same levels as for idealized calm water conditions both in the tested waves and steering actions.

Prediction of Added Resistance in Waves

As part of WP2, a review on **state-of-the-art methods for prediction of the added resistance of ships in a seaway** was carried out by R. Skejic and S.A. Alterskjaer and F. Sprenger.
This report summarizes various methods that are currently capable to investigate added resistance in waves. In particular, the presented methods are discussed from the perspective of their characteristics, level of accuracy of the estimated added resistance and the practical applicability for displacement monohull ships which operate at Froude numbers up to 0.3.
The report lays the foundation for development of an improved practical and fast calculation method for added resistance due to waves, under development by R. Skejic in his post doctoral research project.

MSc theses

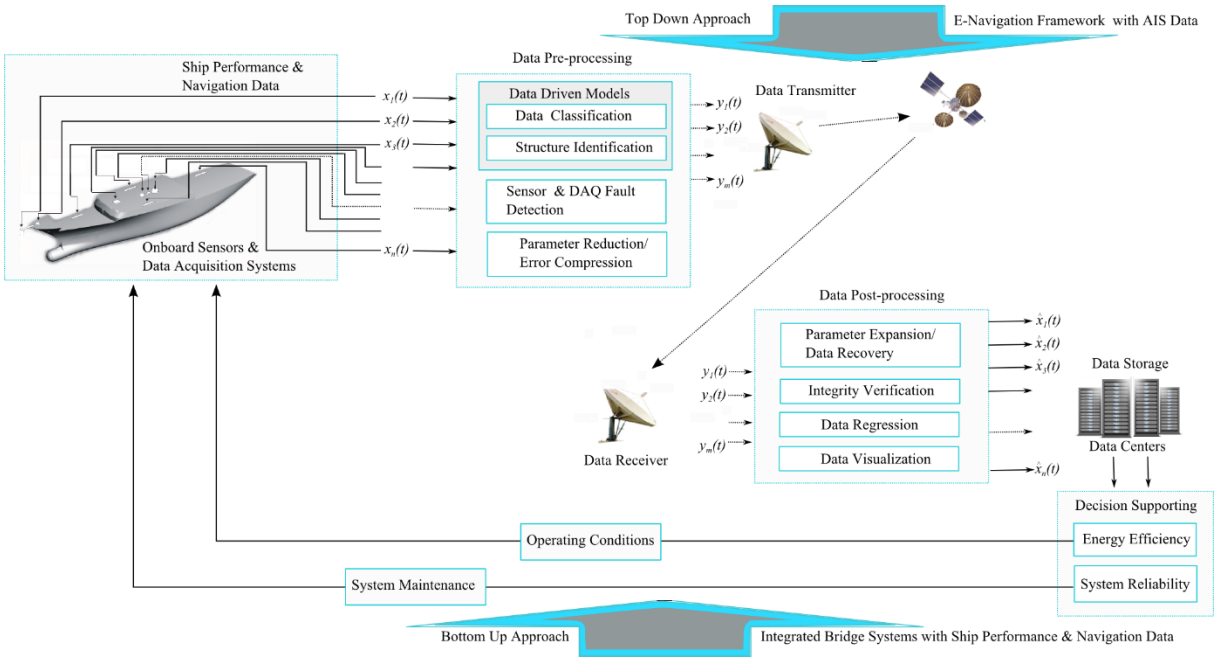
Jørgen Rørvik did a Msc thesis on the **use of non-viscous CFD to compute added resistance due to waves**, and found that the computational time could be halved by omitting the effect of viscosity.
Haakon Utby did a Msc thesis on the **optimization of hull shape of bulk and tank ships**, taking into account also added resistance due to waves, and relieving the typical restrictions on main dimensions. The study shows significant savings by making the hulls more slender by increasing the beam.
In addition, 3 MSc projects were carried out in the fall 2016, and will continued towards MSc theses due in summer 2017. The topics covered are:

- **Empirical prediction of speed loss**, by Jens Christoffer Gjølme. This comes as a continuation of a study of speed loss and added power due to wind and waves from in-service data taken from Grieg Star vessels in the summer 2016.
- **Rational calculation of sea margin**, by Anna Karina Magnussen.
- **Voluntary speed loss**, by Sigbjørn Wiik

ANALYSIS OF FULL-SCALE DATA (SP4, WP2)

Contact: L. Prasad Perera, MARINTEK

There are many industrial challenges that are encountered in full-scale data handling situations in on board as well as onshore. These large-scale data handling issues have often been categorized as "Big Data" challenges in shipping; therefore, various solutions to overcome such situations should be identified.



The proposed data-handling framework consists of a marine engine centered data flow path with various handling layers to overcome the respective challenges (see Figure). Data classification and structural identification steps along the data flow path are executed, where the respective data driven models, digital models, are derived. In general, such data driven models consist of identifying various data clusters within the data set and the structure of each data cluster, in which will create a vector structure to represent vessel performance and navigation conditions. Then, the same data sets are transferred through the pre and post processing sections. The data pre-process consists of sensor faults detection and parameter reduction/error compression steps supported by the same data driven models. The data post-process consists of parameter expansion/data recovery, integrity verification & regression and data visualization & decision supporting steps supported by the same models. Detecting sensor and DAQ fault situations and removing those erroneous data regions from the ship performance and navigation data set are considered in the next step in the data pre-process. The last step in data pre-process is the parameter reduction step and the first step in data post-processing is the parameter expansion step. Data regions that are clustered under the previous step are considered separately for these parameter reduction and expansion steps. One should note the same steps can be used as the error compression and data recovery applications in the same. Therefore, a cleaner and reduced data set can be derived from these analytics. The next step of post-processing is integrity verification and regression and that is done by considering other data sources (i.e. AIS, weather data, etc.). The last step in data pre-processing is data visualization and decision supporting that can be into energy efficiency and system reliability further divided. Several ship performance and navigation data sets are analysed through this framework and the results are published under several conference and journal papers.

VIRTUAL PROTOTYPING / SIMULATION OF LONG-TERM SHIP PERFORMANCE (SP3, WP4)

Contact: Trond Johnsen, MARINTEK

Virtual testing of ships as a complete system in a realistic environment represents a leap forward for design solution assessment.

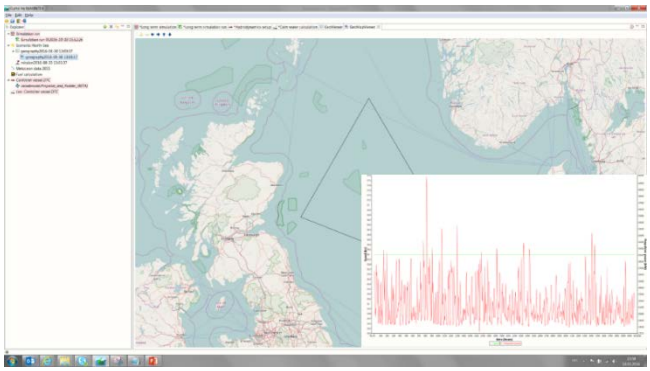
Towards virtual prototyping

The purpose of ship performance simulation is to improving early stage design decisions by enabling simulation of long-term performance of new ship technology and design solutions, and validate simulations against full-scale performance.

Achievements 2016

In cooperation with **Vard**, **Havyard**, **Rolls-Royce**, **DNV GL** and **NTNU**, **MARINTEK** has developped the application GYMIR.

- Application for early-stage design assessment simulating the long-term performance of a ship in realistic operational profiles
- Models of different ship sub-systems can be integrated (i.e. Hull and Propulsion models from WP2; Power System models from WP3)

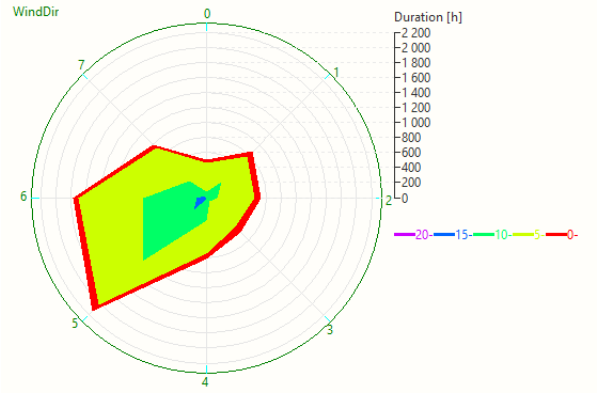


GYMIR functionalities

- Documentation of ship performance in realistic operational profiles
- Ability to test impact of new technology and prove concepts
- Ship design optimization

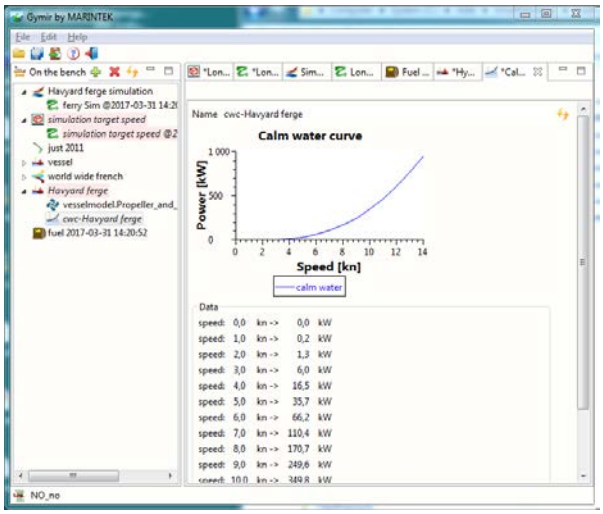
The main interest of designers has so far been on fuel consumption under different loads. This allows the optimization of engine configuration.

Work in the project also focused on retrieving key performance values of interest to the ship designer. One are polar diagrams showing experienced weather conditions or vessel capabilities.



The flexibility of the Gymir platform allowed for an evaluation of a ferry scenario. In this case, the vessel completes different phases from loading cars and passengers to docking at the other end. Time consumption and power requirements during the transfer and the dockside time are very important parameters when evaluating the concept of battery-powered ferries. In this case, the weather data came from scatter diagrams.

Simulation creates a wealth of output data, which are then aggregated and presented both as curves and as data sets.



GYMIR in use

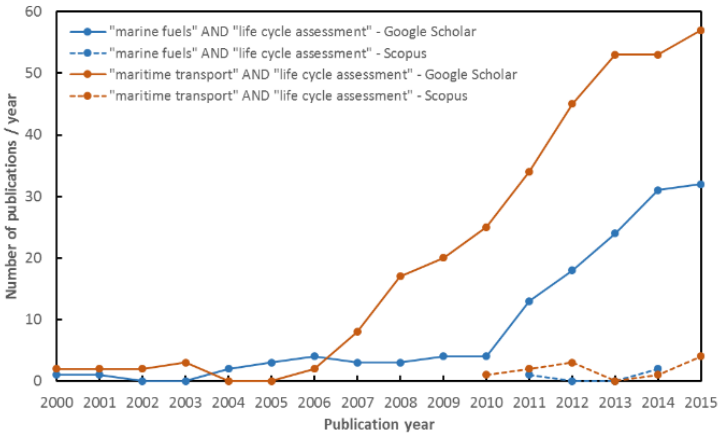
The Gymir application has been used to obtain real life performance data of ships with historical weather data in order to validate performance estimates. The work will be presented by L. P. Perera at the conference OMAE 2017.

SHIP TRANSPORT ENVIRONMENTAL ASSESSMENT MODEL: STEAM (WP5)

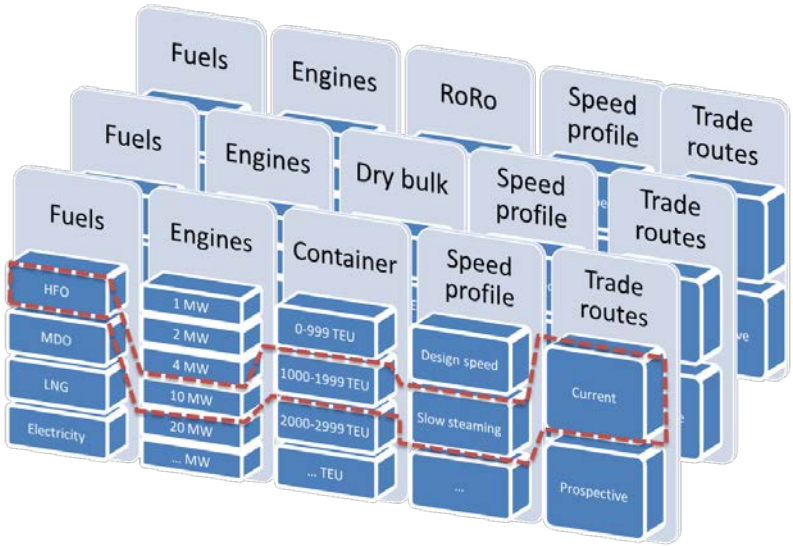
Contact: Evert Bouman, NTNU

A first test version of a tool for calculating environmental impacts of individual ships over their entire life-cycle has been developed. The model enables quick life cyle assessment (LCA) studies of individual ships and its key modules will be tested in the coming year with specific cases. LCA is a method to quantify the environmental impacts of products, services, or processes throughout the life-cycle, and we see that the interest for LCA studies on ships over time increases gradually.

Further development of the model will focus on scaling-up assessments from ship level to fleet level, to support development of the sector towards a two-degree climate target. In addition, we aim to add complexity to the model to ensure its validity in assessing the impacts of ships types and to test the effect of emissions abatement measures or fuel switching options.



Dr Bouman outlined the philosophy and motivation behind the life-cycle model at the SNAME Maritime Convention 2016. In addition, he presented a test-case assessing environmental impacts of an Aframax tanker and the benefits of reducing block coefficient and/or operational speed.



An illustration of the design of the model is presented here. A set of different modules enables representation of ships with different fuels, engines, and operational profiles. Testing, improvement, and addition of the different modules is a key priority for 2017.

During the fall of 2016 Industrial Ecology MSc students Anna Ringvold and Mafalda Silva carried out LCA studies on container ships and bulk carriers as part of their project thesis work. These studies provide a good basis to improve input data to the assessment model. The students continue in 2017 with MSc theses related to Smart Maritime.

International Cooperation

Industry cooperation

The Maritime Industry with Shipping, Equipment Industry, Ship Building and Design are in its nature an international industry and several of the members are multinational companies.

R&D cooperation

Cooperation at European level around the EU H2020 research program. This includes one ongoing project and several applications initiated in 2016, with high relevance for the Centre's partners.

Scientific and academic cooperation

Cooperation with international Universities through Scientific advisory committee:

- DTU – Technical University of Denmark
- Techn. Univ. of Hamburg-Hamburg
- Chalmers
- Strathclyde University

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Associated projects

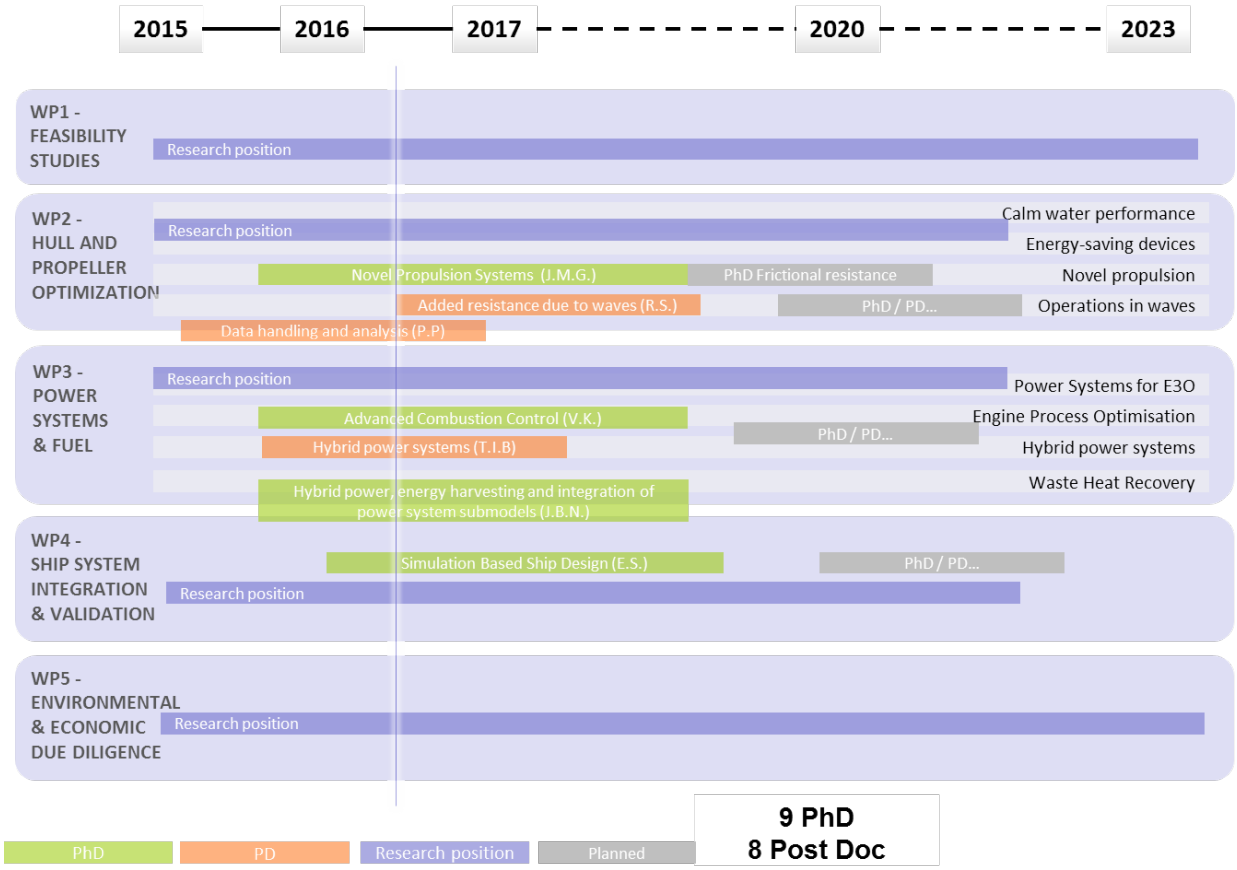
Project name	Description	Synergi with Smart Maritime	Schedule & Funding
HOLISHIP ***HOLIstic optimisation of SHIP design and operation for life cycle***	The vastly increasing complexity of European built ships and maritime structures as well as the growing number of rules and regulations call for novel concepts of product design and testing. The project will develop a mMulti-objective, -disciplinary and multi-fidelity ship design and optimisation framework. www.holiship.eu	WP4, SP3 Virtual prototyping	2016-2020 EU H2020 MG-4.3-2015
ViProma ***Virtual Prototyping of Maritime Systems and Operations.***	Objective: to design an open framework for virtual prototyping and simulation of maritime systems and operations. https://viproma.no/doku.php?id=viproma:about	WP4, SP3 Virtual prototyping	2013-2016 NRC MAROFF
Vista ***Virtual sea trial by simulating complex marine operations***	The purpose of VISTA is to develop an innovative, integrated software-package for design of the ship of the future. This will give te possibility to simulate, analyse and compare effectively the performance of a complete system.	WP4, SP3 Virtual prototyping	2014-2016 NRC MAROFF
Hybrid testing ***Real-Time Hybrid Model Testing for Extreme Marine Environments***	The project focuses on resolving the challenges in the model test in the laboratory with regard to scaling, physical availability and expenses by replacing a substructure of the model by a numerical simulation running in parallel. Among other work packages, the work package 4 concentrates on the testing of a marine hybrid power plant with the simulation of the vessel motion and propulsion.	WP3 Power systems WP4 Ship system integration	2016-2020 NRC MAROFF
Methane emissions from gas engines	Methane emissions from gas engines: mapping, verification, technologies for reduction. This projet aims at strenghening knowledge om harmfull air emissions and measures for emissions reduction .	WP3, SP1 Fuels and abatement technologies	2016-2017 Miljødirektoratet NOx-fondet

Recruitement

Smart Maritime is a scientific and industrial network of over 100 people. The research team consists of over research scientists from two institutions NTNU and MARINTEK, including 3 Postdocs and 5 PhD students.

PhD students and Postdoc researchers

Smart Maritime has reached almost 50% of its recruitment target of 9 PhD and 8 Postdocs by 2023. In addition, 7 PhDs and 1 Postdoc with funding from other sources are connected to Smart Maritime activity. The NTNU team is also supervising 8 MSc for the period 2016-2017.
Training of PhD candidates and MSc students is a prioritized activity. The new, methodological platform for innovations and verification of ship designs will give universities and university colleges a platform for education of a new line of engineers (MSc and PhD) with a multi-disciplinary focus.
New announcements of PhD and Post Doc positions are published on www.smartmaritime.no and through normal recruitment channels at NTNU.
PhDs and Postdoc are involved mostly in activities from WP2, 3 and 4, while activities from WP1 and WP5 are covered by fixed research positions at MARINTEK and NTNU.



Roadmap of Smart Maritime long-term research

Jørgen Nielsen

PhD Candidate WP3/WP4 (2015-2018)

Energy recovery and harvesting in hybrid power systems

His PhD will evolve around energy utilization in marine power systems looking at possibilities emerging with hybrid power technology and energy harvesting. The main area of research is system dynamics, which plays an important role in the control and optimization of complex systems. The approach includes creating dynamic models of required equipment in the power system and simulation of complex power system solutions. If possible, model validation with real world systems will be a priority. The outcome of the work is aimed at providing concept evaluation of new marine power system design with improved energy efficiency and increased system flexibility both for the deep sea and offshore segments.

Endre Sandvik

PhD candidate WP4 (2016-2019)

Ship System Integration and Validation

His work for Smart Maritime involves methods and models for ship system integration and validation, primarily by developing a simulation environment for the virtual testing and benchmarking of new technology and design solutions. Modelling and integration of hydrodynamics, power systems and service equipment in an operational context defined by transport logistics, marine operations and environmental conditions will be important research topics for his PhD thesis. The output of the model will be the ship´s lifecycle performance with respect to energy efficiency, operability and safety, both for service type vessels (offshore) and deep-sea shipping. The title for his PhD thesis is "Simulation Based Design of Ships With Regards to System Performance".

John Martin Kleven Godø

PhD Candidate WP2 (2015-2018)

Biomimetic Propulsion Systems for Increased Propulsive Efficiency

During his master thesis, John Martin worked on design and experimental and theoretical studies of a biomimetic ship propulsion system attempting to replicate swimming motions found in nature. Through his PhD thesis work, John Martin will continue the development of such a propulsion system with the aim of achieving significantly higher propulsive efficiencies than what is possible with today's propeller solutions. The first milestones will comprise experimental studies of a series of different motion patterns of a fish-tail-like propulsive device, validation of theoretical models for describing forces on such a system and studies of live creatures exhibiting efficient swimming.

Vladimir Krivopolianskii

PhD Candidate WP5 (2015-2018)

Fuel injection and combustion

His PhD project aims at elaborating a research tool for further investigation of sprays of different fuels with help of optical and thermodynamic techniques. Unique big volume combustion rig is to allow to experimentally assess marine injection valves performance at relatively wide operation range. Thorough and multidisciplinary analysis of in-chamber processes is to contribute to precisely estimate conditions for injection, ignition and combustion activities in different gas engine concepts. By the end of the project, it is expected to develop recommendations and best practices for engine manufactures and ship-owners.

Torstein Ingebrigtsen Bø

Postdoc WP4 (2015-2017)

Hybrid propulsion, integrating new power sources for marine power plants.

Torstein I. Bø holds a PhD in Engineering Cybernetics from NTNU. In Smart Maritime, he will contribute with his modelling and control expertise into the power systems and fuel project (WP3). The first milestone will be to establish a model of the hybrid power lab at NTNU, which is a joint laboratory of NTNU, Marintek, and ABB.

This model will be thoroughly verified with data from the lab. The models will be used to investigate the potential in fuel and emission reduction by different hybrid power system solutions. This can be combination of diesel electric and diesel mechanic propulsion, AC and DC distribution, and combinations including energy storage such as batteries. It will also be used to establish model based controllers, for optimal load and energy management of hybrid marine electric power plants.

Lokukaluge Prasad Perera

Postdoc Smart Maritime WP (2015-2017)

Data analytics

L. P. Perera a Research Scientist at MARINTEK. His research interests include Maritime and Offshore Systems, Instrumentation, Intelligent Guidance & Control, Condition Monitoring and Condition based Maintenance, Energy Efficiency, Safety, Risk and Reliability. In Smart Maritime, L. P. Perera works primarily with sub-project 4. Various data sets that are collected by vessels with respect to their fuel consumption will be evaluated under this project. That consists of developing data analytics to capture ship performance under full economic conditions, where technical and environmental due diligence of the alternative fuels and abatements technologies will also be investigated.

Renato Skejic

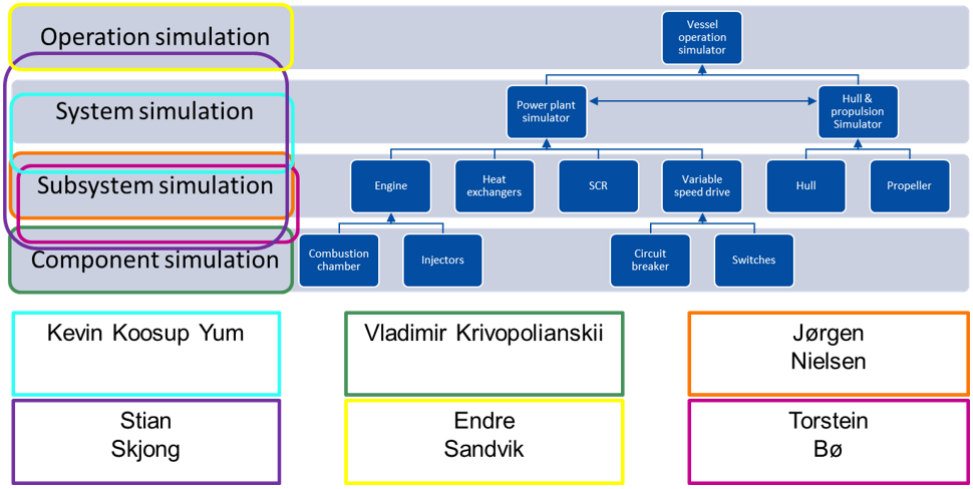
Postdoc WP2 (2016-2018)

Marine Engineering and Ships/Offshore Structures Hydrodynamics and Hydrostatics

Post doc Renato Skejic is working with development of medium-fidelity computational methods for added resistance due to waves. This means potential flow methods that are less complicated, faster and more robust than full 3-D non-linear panel methods while still being more accurate than the current linear potential flow methods implemented in ShipX and applied in Gymir. The methods he is aiming at will be computationally fast, but will require input of 3-D hull geometry. The deliverables are expected to be in terms of scientific paper(s) and computer implementation(s) of the method(s). However, final implementation and integration with (for instance) ShipX and Gymir will be outside the scope of the post doc project.

Integrated and collaborative research activity

WP3 gives a good example of interdiscipline collaboration. In addition to collaborating within the common areas of interest, the researches within WP3 also set-up a unique group that covers all the stages of simulation hierarchy, starting from simulation of single components and up to the operational simulations, as shown in Figure above. The utilization of such approach increases both the efficiency of work and leads to more valuable results not only in terms of publications, but also in terms of rutines and practices that can be later adopted and used within maritime industry.



Here the work of Vladimir Krivopolianskii (NTNU/SFI, PhD student) is mainly dedicated to the study and analysis of the injection and combustion processes of alternative marine fuels with possibility to simulate these processes. Jørgen Nielsen (NTNU/SFI, PhD student) uses simulation approach to model the work of waste heat recovery systems and emission abatement systems, while Torstein Bø (NTNU/SFI, Postdoc) simulates the potential hybrid systems (with emphasis on energy conversion efficiency) for marine application. Kevin Koosup Yum (Sintef Ocean/SFI, Research scientist) applies his own simulation model of ship's power plant, which can be improved based on the findings of the other group members, to perform so-called simulation-based concept design, i.e. to find the most effective concept of vessel for certain application. Stian Skjong (NTNU, PhD student project ViProMa) and his co-simulation approach allows to link together various models of different fidelity levels and run them together to achieve the specified goals. At the same time co-simulation can be coupled to the operation-oriented simulation software, where the performance of a vessel in certain real operational conditions can be simulated and optimized, as for example is done by Endre Sandvik (NTNU/SFI, PhD student) who is using Gymir software created in MARINTEK.

Personnel

Industry network (by company)

ABB AS	Bergen Engines AS	DNV GL AS	Grieg Star AS
Børre Gundersen	Jan Eikefet	Hendrik Brinks	Roar Fanebust
Jan-Fredrik Hansen*	Leif Arne Skarbø*	Christos Chryssakis*	Jan Øivind Svardal*
	Erlend Vaktskjold	Hans Anton Tvete	Henry Svendsen
		Bjørn Johan Vartdal	Svenn Sørstrand

Havyard Group ASA		Jotun AS	Kristian Gerhard Jebsen Skipsrederi AS
Daniel Aaro	Ole Rorhus	Geir Axel Oftedahl	Jan Berntzen
Kay Lorgen	Kristian V. Steinsvik*	Stein Kjølberg	Ole-Johan Haahjem*
Arve Nedreberg	Rolf Arild Topphol	Andreas Krapp*	Øyvind Monsen

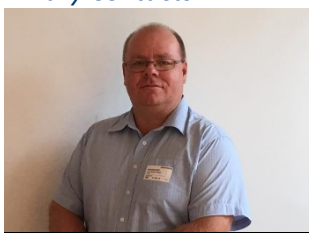
Kystrederiene	Norwegian Electric Systems AS	Rolls-Royce Marine AS	
Siri Hatland*	Frithjof Hustig	Martijn de Jongh	Sverre Torben
Ivar Ulvan	Stein Ruben Larsen	Hans Martin Hjørungnes	Erlend Vaktskjold
	Ottar Skjervheim*	Per Ingeberg*	Leif Vartdal
		Kristen Jomås	Einar Vegsund
		Kåre Nerland	Bjørnar Vik

Norges Rederiforbund	Siemens AS		Sjøfartsdirektoratet
Tor Christian Sletner*	Lars Barstad	Stig-Olav Settemsdal*	Lasse Karlsen*
Jostein Vaagland	Paul Gjerpe	Odd Moen	John Malvin Økland
	Vemund Kårstad	Kenneth Presttun Tjong	

Solvang ASA	VARD Design AS	Wilh. Wilhelmsen ASA	Wärtsilä Moss AS
Jone Ask	Henning Borgen*	Per Brinchmann*	Stian Aakre
Tor Øyvind Ask*		Lars Dessen	Sigurd Jenssen*
Alexander Grødeland		Gunnar Malm Gamlem	

* Primary contact persons

Primary Contacts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Skipsrederi AS


Siri Hatland
Kystrederiene


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Rolls-Royce Marine AS


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Stig-Olav Settemsdal
Siemens AS


Lasse Karlsen
Sjøfartsdirektoratet


Tor Øyvind Ask
Solvang ASA


Henning Borgen
VARD Design AS


Sigurd Jenssen
Wärtsilä Moss AS


Per Brinchmann
Wilh. Wilhelmsen ASA

RESEARCH TEAM

MARINTEK / NTNU employees

Name	Company	Main Focus area	Role
Sverre Anders Alterskjær	MARINTEK	Hull and propeller hydrodynamics	WP2
Per Magne Einang	MARINTEK	Power systems and fuel	Centre director
Dariusz Fathi	MARINTEK	Data simulations and optimization	WP4
Trond Johnsen	MARINTEK	Data simulations and optimization	WP4 leader
Kourosh Koushan	MARINTEK	Hull and propeller hydrodynamics	WP2
Haakon-Elizabeth Lindstad	MARINTEK	Feasibility studies	WP1 leader
Matthias Nowak	MARINTEK	Data simulations and optimization	WP4
Agathe Rialland	MARINTEK	Feasibility studies	WP1
Martin Rindarøy	MARINTEK	Data simulations and optimization	WP4
Andrew Ross	MARINTEK	Hydrodynamics	WP2
Florian Sprenger	MARINTEK	Hydrodynamics	WP2
Dag Stenersen	MARINTEK	Hybrid propulsion	WP3
Ole Thonstad	MARINTEK	Full scale data harvesting	WP3
Ingebrigt Valberg	MARINTEK	Power systems and fuel	WP3
Anders Valland	MARINTEK	Hybrid propulsion	WP3
Kevin Koosup Yum	MARINTEK	Simulation, Machinery	WP4
Bjørn Egil Asbjørnslett	NTNU	Feasibility studies	WP1
Harald Ellingsen	NTNU	Hydridynamics	WP2
Stein Ove Erikstad	NTNU	Data simulations and optimization	WP4
Evert Bouman	NTNU	Environmental assessment	WP5
Eilif Pedersen	NTNU	Power systems and fuel	WP3 leader
Sverre Steen	NTNU	Hull and propeller hydrodynamics	WP2 leader
Anders Strømman	NTNU	Environmental assessment	WP5 leader
Sergey Ushakov	NTNU	Exhaust emissions	WP3
Vilmar Æsøy	NTNU Ålesund	Power systems and fuel	WP3

MARINTEK

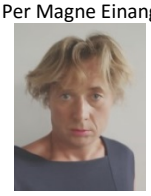

Sverre Anders Alterskjær


Per Magne Einang


Dariusz Fathi


Trond Johnsen


Kourosh Koushan


Haakon-Elizabeth Lindstad


Matthias Nowak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Martin Rindarøy


Andrew Ross


Florian Sprenger


Dag Stenersen


Ole Thonstad


Ingebrigt Valberg


Anders Valland


Kevin Koosup Yum

NTNU


Bjørn Egil Asbjørnslett


Evert Bouman


Harald Ellingsen


Stein Ove Erikstad


Eilif Pedersen


Sverre Steen


Anders Strømman


Sergey Ushakov


Vilmar Æsøy, NTNU Ålesund

PhD students and Postdoctoral researchers

Name	Funding source	NAL	Period	Topic
Postdoctoral researchers				
Lokukaluge Prasad Perera	SFI Smart Maritime	LK	2015 - 2017	Data handeling and analysis
Torstein Ingebrigtsen Bø	SFI Smart Maritime	NO	2015 - 2018	System Simulation
Renato Skejic	SFI Smart Maritime	HR	2016-2018	Computation of added resistance due to waves
Erik Bøchmann	KPN LEEDS	NO	2015-2017	Hydrodynamic
PhD students				
John Martin Godø	SFI Smart Maritime	NO	2015-2018	Hydrodynamics
Jørgen Nielsen	SFI Smart Maritime	NO	2015-2018	System simulation
Vladimir Krivopolianskji	SFI Smart Maritime	UA	2015-2018	Fuel injection and combustion
Endre Sandvik	SFI Smart Maritime	NO	2016-2019	Simulation Based Design of Ships
Stian Sjong	KPN ViProma	NO	2013-2017	System Simulation
Øyvind Øksnes Dahlheim	Rolls-Royce UTC	NO	2015-2018	Hydrodynamics
Anna Swider	Rolls-Royce Ind. PhD	PL	2015-2018	Hydrodynamics
Sabah Alwan	KPN LEEDS	AU	2013-2017	Simulation based design
Dig Vijay Singh	KPN LEEDS	UK	2012-2016	Machinery
Bhushan Taskar	KPN LEEDS	IN	2013-2016	Hydrodynamics
Jarle Kramer	KPN LEEDS	NO	2013-2018	Hydrodynamics

Smart Maritime


Lokukaluge Prasad Perera, MARINTEK


Torstein Ingebrigtsen Bø, NTNU


Renato Skejic, MARINTEK


John Martin Godø, NTNU


Jørgen Nielsen, NTNU


Vladimir Krivopolianskii, NTNU


Endre Sandvik, NTNU


Stian Sjong, NTNU

MSc students - MSc thesis within Smart Maritime

MSc students	University, Department	Year	Topic MSc thesis
Mats William Snåre; Jon Halfdanarson	NTNU, Energy and Process Engineering	2015	Implementation and application of an integrated framework for economic and environmental assessment of maritime transport vessels
Jørgen Rørvik	NTNU, Marine Technology	2016	Application of Inviscid Flow CFD for prediction of Motions and Added Resistance of Ships
Haakon Utby	NTNU, Marine Technology	2016	Hydrodynamic optimization of bulk and tank ship hulls
Anna Karina Magnussen	NTNU, Marine Technology	2017	Rational calculation of sea margin
Jens Christoffer Gjølme	NTNU, Marine Technology	2017	Empirical prediction of speed loss
Sigbjørn Wiik	NTNU, Marine Technology	2017	Voluntary speed loss
Fredrik Gyberg	NTNU, Marine Technology	2017	Design, modelling and control of a generic crane for marine application
Thomas Evang	NTNU, Marine Technology	2017	Crane Dynamics and Control
Jan Olav Øksnes	NTNU, Marine Technology	2017	Regeneration in Crane Operation
Anna Ringvold	NTNU, Industrial Ecology	2017	LCA of containerships
Mafalda Silva	NTNU, Industrial Ecology	2017	LCA of bulk carriers


Mats William Snåre


Jon Halfdanarson


Jørgen Rørvik


Haakon Utby


Anna Karina Magnussen


Jens Christoffer Gjølme


Sigbjørn Wiik


Fredrik Gyberg


Thomas Evang


Jan Olav Øksnes


Anna Ringvold

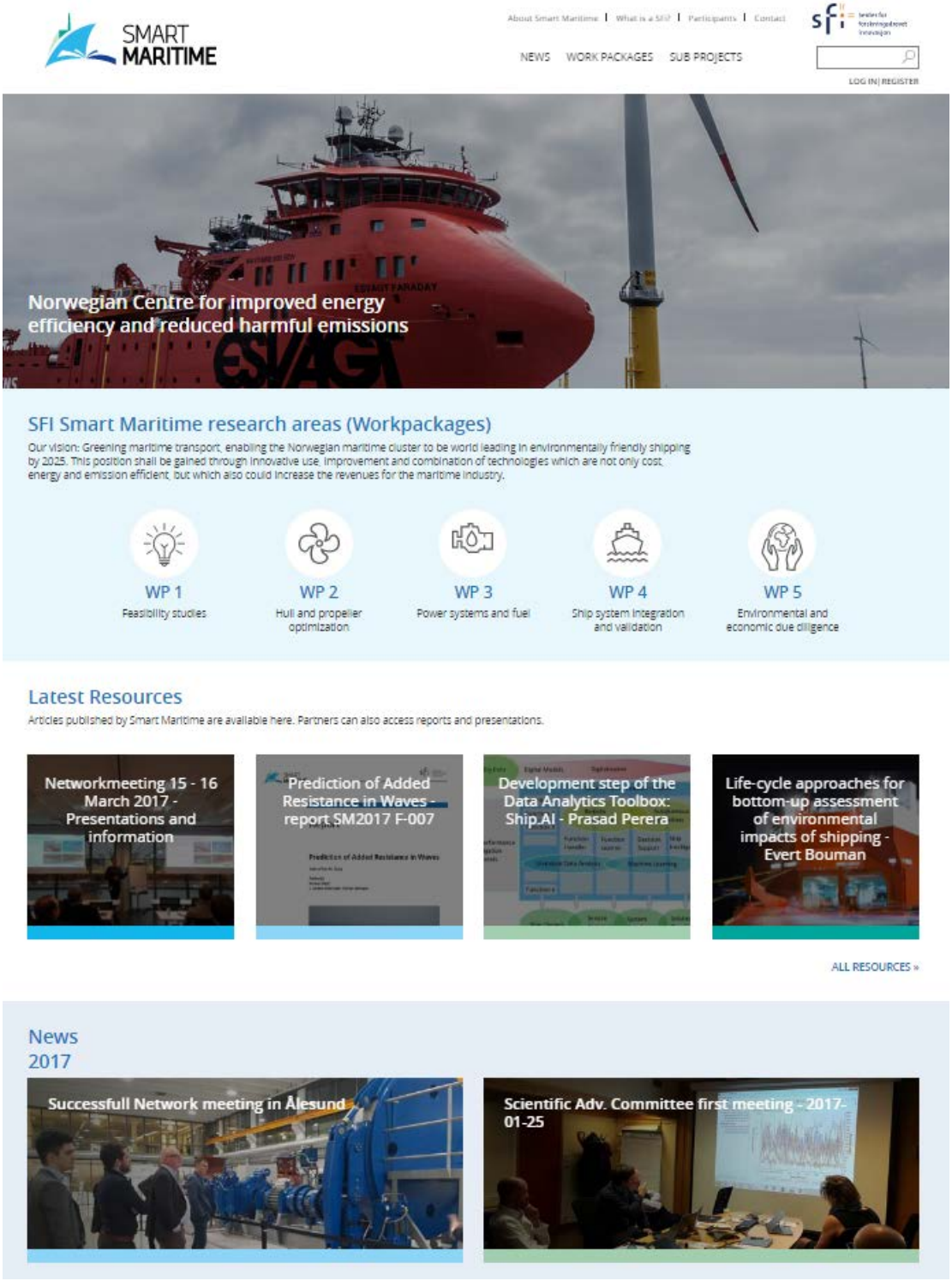

Mafalda Silva

Communication and dissemination activity

Communication

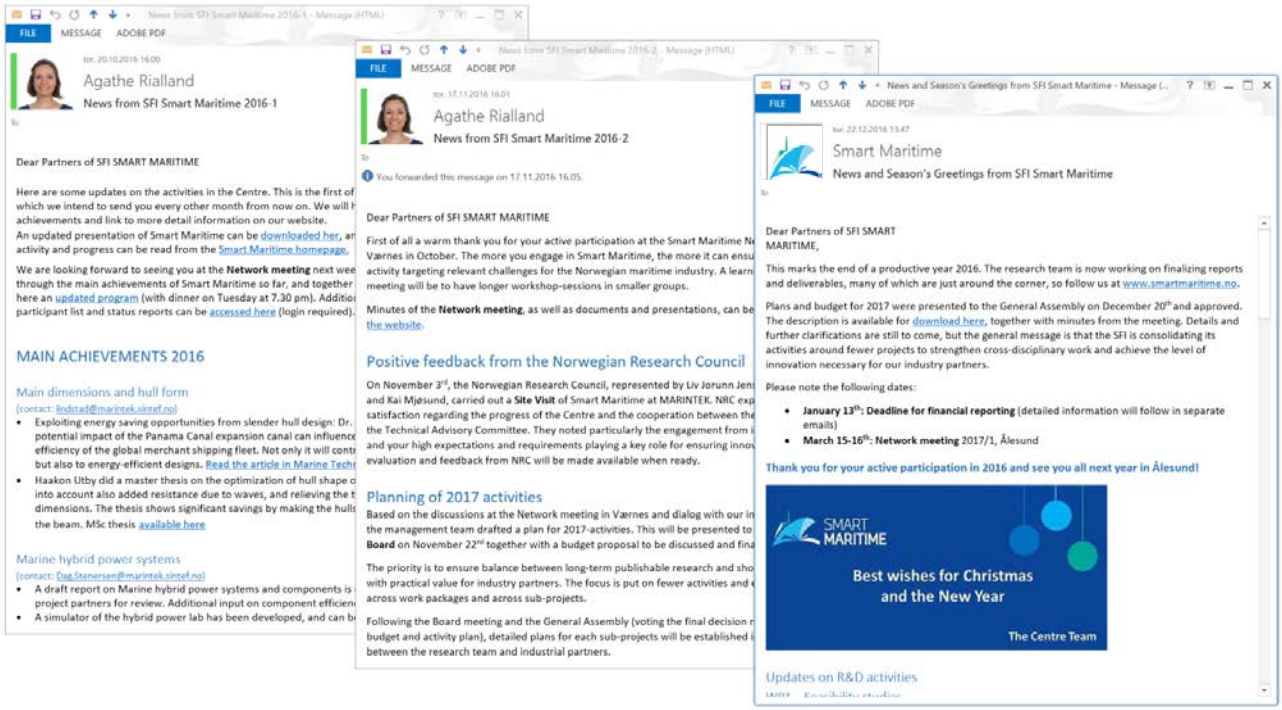
Website

The web page has an open public access and a closed member access. This platform is used for public information and for internal member communication and distribution of documentation and publications.



Newsletters

An e-mail newsletter was launched in the fall 2016 and is now distributed regularly. Its contains information about the Centre's activity, main results, links to publication and information on the website, and main deadlines and upcoming events.



Interviews

Einang, P.M. **Making heavy fuel oil clean**. www.solvangship.no [Internet] 2016-02-08, MARINTEK

Einang, P.M. **Glemmer at grønt må være konkurransedyktig**. Forskningsrådet - MAROFF [Internet] 2016-03-08, MARINTEK

Einang, P.M. **Slår sammen blå krefter**. http://www.forskningsradet.no/prognett-maroff/Nyheter/Slar_s [Internet] 2016-03-08, MARINTEK

Publications and Representations

Scientific Journal Papers

Lindstad, H.E. **How the Panama Canal expansion is affecting global ship design and energy efficien***cy MT-Marine Technology* October 2016, pp. 42 – 46 . Sname.org

Lindstad, H. Asbjørnslett, B. E., Strømman, A., H. **Opportunities for increased profit and reduced cost and emissions by service differentiation within container liner shipping**. *Maritime Policy & Management*, Volume 43, Issue 3, 2016, pp. 280–294

Lindstad, H. E., Eskeland. G., S. **Policies leaning towards globalization of scrubbers deserve scrutiny** *Transportation Research Part D* 47, 2016, pp. 67-76

Perera, L.P. **Marine Engine Centered Localized Models for Sensor Fault Detection under Ship Performance Monitoring**, In Proceedings of the *3rd IFAC Workshop on Advanced Maintenance Engineering, Service and Technology* (AMEST'16), Biarritz, France, October, 2016.

Perera, L.P. **Statistical Filter based Sensor and DAQ Fault Detection for Onboard Ship Performance and Navigation Monitoring Systems,** In Proceedings of the *8th IFAC Conference on Control Applications in Marine Systems* (CAMS 2016), Trondheim, Norway, September 2016. IFAC-PapersOnLine 2016 (2405-8963) Vol. 49 (23), pp. 323-328

Perera, L.P. and Mo, B. **Data analysis on marine engine operating regions in relation to ship navigation**. *Ocean Engineering 2016* (0029-8018) Vol. 128, pp. 163-172

Perera, L.P. and Mo, B. **Emission Control based Energy Efficiency Measures in Ship Operations**, *Journal of Applied Ocean Research*, vol. 60, 2016, pp. 29-46.

Perera, L.P. and Mo, B. **Marine Engine Operating Regions under Principal Component Analysis to evaluate Ship Performance and Navigation Behavior**, In Proceedings of the *8th IFAC Conference on Control Applications in Marine Systems* (CAMS 2016), Trondheim, Norway, September 2016. IFAC-PapersOnLine 2016 (2405-8963) Vol. 49 (23), pp. 512-517

Article in business/trade/industry journal

Lindstad, H.E.. **Bigger picture suggest effects of IMO emission efforts are counter productive**. *TradeWinds* 5. August 2016, page 10. www.tradewindnews.com

Discussion paper

Lindstad, H.E. and Eskeland, G. S. and Rialland, A. **Batteries in Offshore Support Vessels - Pollution, Climate Impact and Economics** (December 7, 2016). *NHH Dept. of Business and Management Science* Discussion Paper No. 2016/21. Available at SSRN: https://ssrn.com/abstract=2882009

Lecture, Conference presentation

Einang, Per Magne. **Bedre energieffektivitet, lavere utslipp**. *Haugesundskonferansen 2016*; 2016-02-02 - 2016-02-03 MARINTEK

Lindstad, H.E. **Effects of Regulation in the Big Picture**. *The 37th International Bunker Conference*, 2016-04-27 - 2016-04-29

Einang, P.M. **Smart Maritime**. *Ocean Week 2016*; 2016-05-09 - 2016-05-12 MARINTEK

Lindstad, H. E. **Shorter shipping routes through the Arctic are not necessarily more climate friendly**. *The LSE US Centre's daily blog on American Politics and Policy*, 2016-11-30.

Lindstad, H.E. **Cost and Environmetally efficiency of alternative 2020 Sulphur abatement options**, *Marine Fuels and Lubricants Conference*, December 7-8, 2016, Rotterdam, the Netherlands

Conference paper

Lindstad, H. E., & Eskeland, G. **Environmental Regulations in Shipping: Policies Leaning Towards Scrubbers Entail Important Penalties**. In *Energy: Expectations and Uncertainty, 39th IAEE International Conference*, Jun 19-22, 2016. International Association for Energy Economics.

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Hassani, V., Rindarøy, M., Kyllingstad, L. T., Nielsen, J. B., Sadjina, S. S., Skjong, S., & Pedersen, E. (2016,). **Virtual Prototyping of Maritime Systems and Operations**. In *ASME 2016 35th International Conference on Ocean, Offshore and Arctic Engineering* (pp. V007T06A018-V007T06A018). American Society of Mechanical Engineers.

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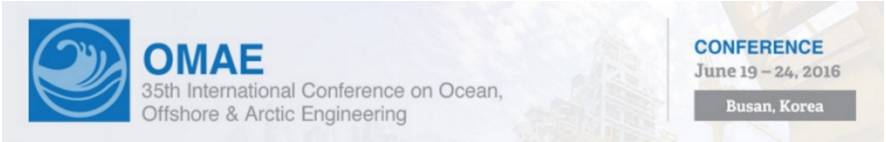
Perera, L. P., Machado, M. M., Manguinho, D. A., & Valland, A. **System Failures of Offshore Gas Turbine Engines in Maintenance Perspective**. *IFAC-PapersOnLine*, *49*(28), 280-285.



Statement of Accounts 2016

	Funding		Cost	
Research council	12 324	(46%)		
The Host Institution (MARINTEK)	5 133	(19%)	13 079	(48%)
Research Partners*	3 300	(12%)	9 398	(35%)
Industry partners	6 273	(23%)	4 187	(15%)
Equipment			367	(1%)
Total	27 031		27 031	

Smart Maritime in brief

- Norwegian centre for improved energy efficiency and reduced harmful emissions from the maritime sector
- Centre for research-based innovation (SFI) granted by the research council (SFI-iii)
- Main goals:
  - ✓ Improve energy efficiency
  - ✓ Reduce harmful emissions
  - ✓ Strengthen the competitiveness of the norwegian maritime industry
- Duration: 2015 - 2023
- Budget: 24 mnok / year
- Financing:
  - 50% research council
  - 25% industry partners
  - 25% research partners
- Host institution: MARINTEK (SINTEF Ocean, from 1 january 2017)
- Web: www.smartmaritime.no
- Contact: smartmaritime@sintef.no