SFI
OFFSHORE
MECHATRONICS

ANNUAL REPORT 2021

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Annual Report 2021

Summary

HISTORY

SFI Offshore Mechatronics has its origins from the Agder cooperation within the field of Mechatronics, initiated by University of Agder with partners from the local industry related to offshore engineering. This cooperation has been active for several years, and has its origin in the establishment of Master and PhD education to produce candidates for the regional and national labour market. Since then, the cooperation has developed to include R&D projects and mobility between industry companies and UiA. During the project period a strong relation between the industry partners and the other universities and research institute partners (NTNU, Aalborg University, RWTH Aachen and NORCE) have been formed.

THE RESEARCH

The main goal is to develop new concepts for autonomous systems where the construction, engineering, and design invite autonomy to minimize the number of manual processes, as well as to improve accuracy and quality, and to reduce risk and cost related to offshore engineering and operations. The research will result in enabling technologies, equipment, processes and solutions for higher degree of autonomy and monitoring of heavy machinery, and for handling and analysing large data flows under demanding conditions. The research is carried out in seven work packages: WP1 Drives, WP2 Motion Compensation, WP3 Robotics and Autonomy, WP4 Modelling and Simulation, WP5 Monitoring Techniques, WP6 Data Analytics, IT Integration and Big Data and WP7 Technology Vision.

ORGANISATION

SFI Offshore Mechatronics is hosted by UiA, Faculty of Engineering and Science. UiA is responsible for three work-packages, NTNU for two, University of Aalborg for one and NORCE for one work package. In addition, NTNU Aalesund and RWTH Aachen participate in different WPs. GCE NODE heads a non-scientific work package for technology vision. In 2021 the industrial partners have been Bosch Rexroth, Cameron, Klueber Lubrication, Egde Consulting, Lundin, MacGregor, MHWirth, National Oilwell Varco, Skeie Technology Consulting and Stepchange. The SFI Offshore Mechatronics Steering board consists of 7 partners, where the industry partners hold majority. The Centre Director heads the daily operations, assisted by an administrative manager.

SCIENTIFIC ACTIVITIES AND RESULTS

Each PhD dissertation is a milestone in the SFI Offshore Mechatronics centre. In 2021, seven PhD fellows defended their thesis. A large share of the scientific publications was at the highest level (Level-2 in Norway). Out of 15 journal papers 7 (47%) were published at the highest level, in 2021.

INTERNATIONAL COOPERATION

The SFI Offshore Mechatronics centre is distributed with industry and research partners across four countries (Norway, Denmark, The Netherlands and Germany). In addition to this, the researchers in the centre utilize their extensive international networks. Due to COVID-19, the opportunities to travel and accommodate guest researchers have been very limited also in 2021.

RECRUITMENT

In 2021 one new Post.Doc positions was hired, while no more PhD fellows were hired as by the end of 2020 all final PhD positions had been filled. During the project period a total of 40 researcher and technicians have been recruited. Unfortunately, it was not possible to recruit any female as PhD student or Post.Doc in 2021.

COMMUNICATION AND DISSEMINATION ACTIVITIES

The main event for communication and dissemination in the project is the SFI Offshore Mechatronics Annual Conference. The conference was planned on May 12-13, however due to the situation with COVID-19 it was postponed and eventually cancelled. To compensate for the cancellation of the annual conference short webinars were arranged with attendees from both industry and the research partners.

Vision and Objectives

VISION

"The SFI Offshore Mechatronics will become the international knowledge and research hub for the next generation of advanced offshore mechatronic systems for autonomous operation and condition monitoring of offshore engineering systems under the control of land-based operation centres, to ensure safe and efficient operation in deeper water and in harsh environments. The centre shall contribute significantly to growth and innovation in the industry, creating jobs and business with potential both within the target sector, and beyond, such as maritime industry, with a net positive impact on society."
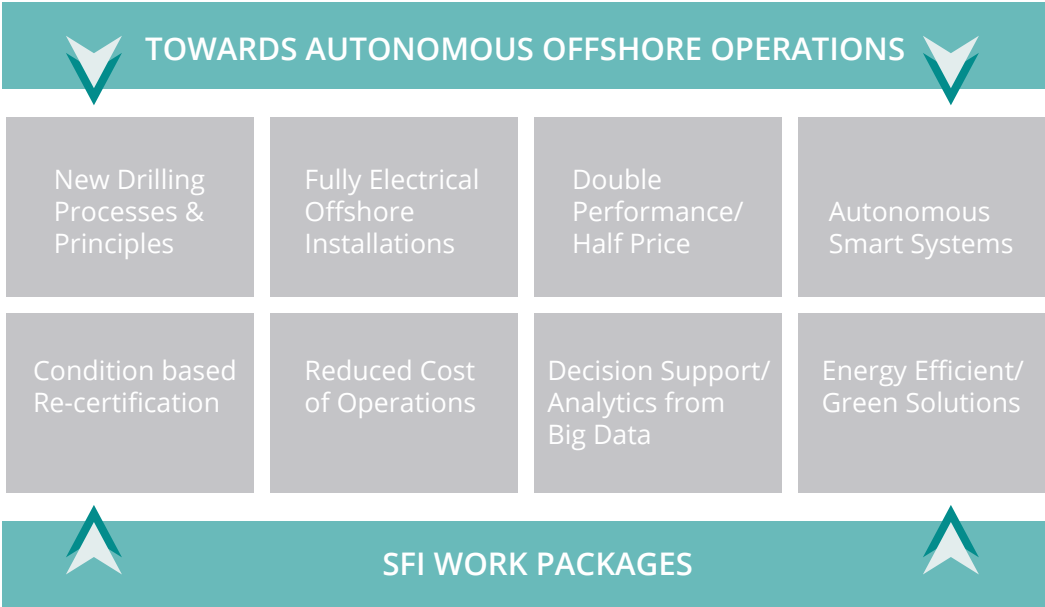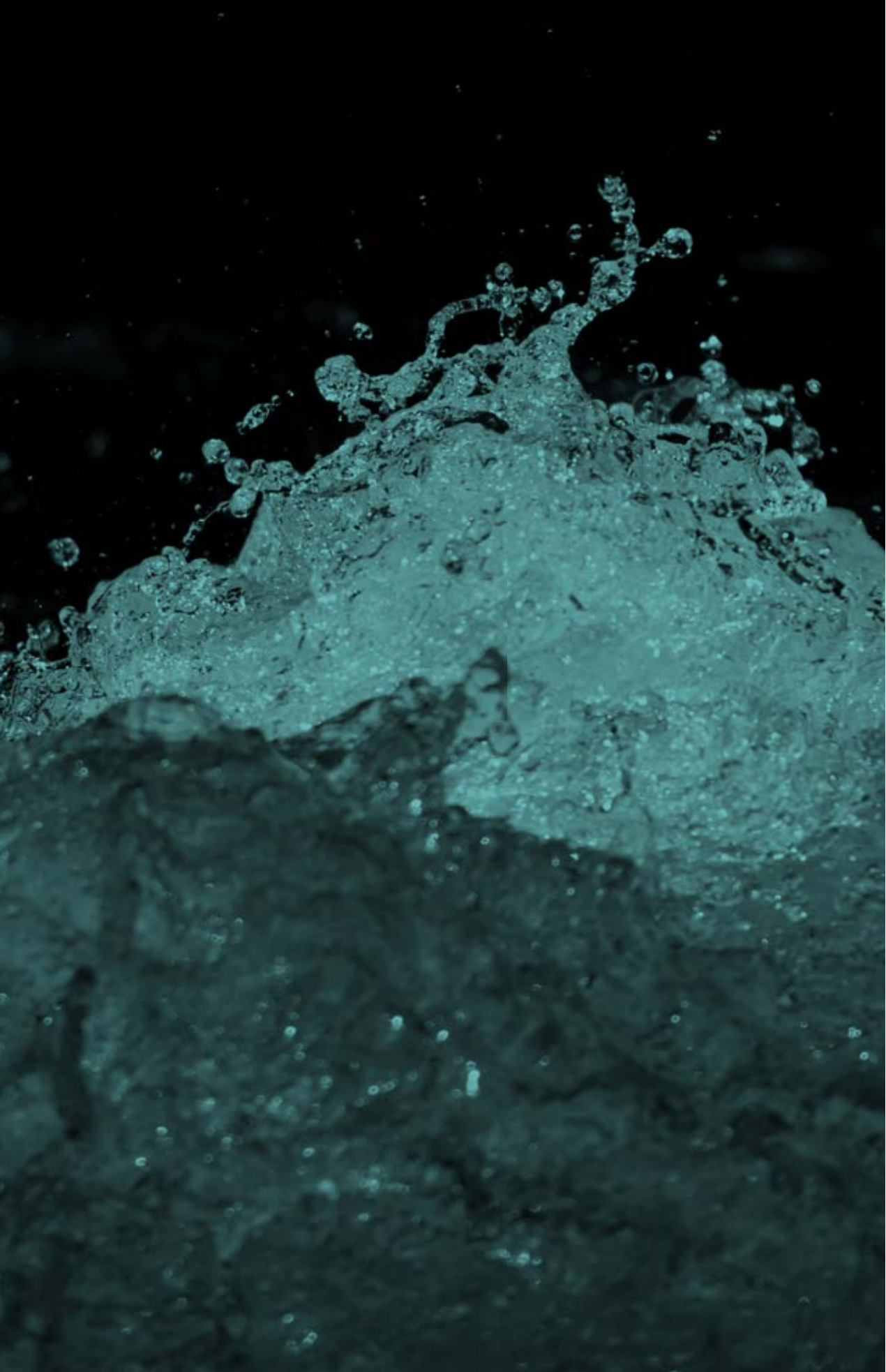
MISSION STATEMENT

By 2023, SFI Offshore Mechatronics shall have succeeded in becoming an internationally renowned research-based innovation centre reaching national, international and long-term targets.

National target – develop new concepts for autonomous systems where the construction, engineering, and design invite autonomy to minimize the number of manual processes, as well as to reduce risk and cost related to offshore operations.
International target – support the industry partners to strengthen the global position by developing the most efficient and safe future offshore operations.
Long-term target – enable technologies, equipment, processes and solutions for autonomy and monitoring of heavy machinery, and for handling and analysing large data flows under demanding conditions.

GRAND CHALLENGES

The grand challenges are:

TOWARDS AUTONOMOUS OFFSHORE OPERATIONS			
New Drilling Processes & Principles	Fully Electrical Offshore Installations	Double Performance/ Half Price	Autonomous Smart Systems
Condition based Re-certification	Reduced Cost of Operations	Decision Support/ Analytics from Big Data	Energy Efficient/ Green Solutions
SFI WORK PACKAGES			

Research Plan/Strategy

The research shall result in enabling technologies, equipment, processes and solutions for autonomy and monitoring of heavy machinery, and for handling and analysing large data flows under demanding conditions. Since there are several companies in the centre which operate in the same business segment, it has been decided that the researchers focus on enabling technologies and technological building blocks, rather than working too closely with product specific development.

The research themes of all the positions have been defined in close cooperation with the partner companies. The work program of each work-package is approved annually by the General Assembly.

The research is carried out in seven work packages:
- Work-Package 1: Drives
- Work-Package 2: Motion Compensation
- Work-Package 3: Robotics and Autonomy
- Work-Package 4: Modelling and Simulation
- Work-Package 5: Monitoring Techniques
- Work-Package 6: Data Analytics, IT Integrationand Big Data
- Work-Package 7: Technology Vision

WORK-PACKAGE 1: DRIVES

2015				2016				2017				2018				2019				2020				2021				2022				2023			
1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4

- WP1.2 Sondre Nordås (PhD, UiA)
- WP1.6, Wei Zhao (PhD, UiA)
- WP1.4 Daniel Hagen (PhD, UiA)
- WP1.3 Viktor H. Donkov (PhD, Aalborg)
- WP1.7, Thomas Farsakoglou (PhD, Aalborg)
- WP1.5 Søren Ketelsen (PhD, Aalborg)
- WP1.8, Mohit Bhola (Post.Doc, Aalborg)

WORK-PACKAGE 2: MOTION COMPENSATION

2015				2016				2017				2018				2019				2020				2021				2022				2023			
1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4

- WP2.1 Geir Ole Tysse, (PhD, NTNU)
- WP2.2 Torstein Myhre, (Post.Doc, NTNU)
- WP2.3 Andrej Cibicik, (PhD, NTNU)
- WP2.7, Hans Kristian Holen (PhD, NTNU)
- WP2.4 Alexander Meyer Sjøberg, (PhD, NTNU)
- WP2.8, Alexander Meyer Sjøberg (Post.Doc, NTNU)
- WP2.5 Sondre Sanden Tørdal (PhD, UiA)
- WP2.6 Philip Schubert, IRT, (PhD, RWTH Aachen)

WORK-PACKAGE 3: ROBOTICS AND AUTONOMY

2015				2016				2017				2018				2019				2020				2021				2022				2023			
1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4

- Researcher, Dr. Knut Berg Kaldestad (UiA)
- WP3.1 Joacim Dybedal, (PhD, UiA)
- WP3.2 Atle Aalerud, (PhD, UiA)
- WP3.3 Aksel Sveier, (PhD, NTNU)
- WP3.5 Thilina Nuwan Weerasinghe (PhD, UiA)
- WP3.6 Dipendra Subedi, (PhD)
- WP3.7 Ronny Landsverk (PhD)
- WP3.8 Yvonne Murray, (integr. master/ PhD, UiA)
- WP3.9/WP6.5 Jose Amendola, (PhD, UiA)

WORK-PACKAGE 4: MODELLING AND SIMULATION

2015				2016				2017				2018				2019				2020				2021				2022				2023			
1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4

- WP4.1 Savin Viswanathan (PhD, NTNU)
- WP4.2 Njål Tengesdal (PhD, NTNU)
- WP4.3 Lars Ivar Hatledal (PhD, NTNU Aalesund)
- WP4.4 Gaute Fotland (PhD, NTNU)
- WP4.5 Savin Viswanathan (Post. Doc NTNU)

WORK-PACKAGE 5: MONITORING TECHNIQUES

2015				2016				2017				2018				2019				2020				2021				2022				2023			
1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4

- WP5.1 Martin Hemmer, (PhD, UiA)
- WP5.2 Rune Schlanbusch - NORCE
- WP5.3 Shaun Falconer (PhD, UiA)
- WP5.4 Achim Feldermann and Lothar Wöll, (PhD, IME - Aachen)
- Mohammed Yusuf, (PhD IME Aachen)
- WP5.5 Zbigniew Mikulski, (PhD, UiA)
- WP5.6 Vignesh Shanbhag - NORCE

WORK-PACKAGE 6: DATA ANALYTICS, IT INTEGRATION AND BIG DATA

2015				2016				2017				2018				2019				2020				2021				2022				2023			
1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4

- WP6.1 Luis M. Lopez-Ramos (Post.Doc, UiA)
- WP6.2 Emilio Ruiz Moreno, (PhD, UiA)
- WP6.3 Kevin Roy, (PhD, UiA)
- WP6.4 Luis M.Lopez-Ramos, (Post.Doc, UiA)
- WP3.9/WP6.5 Jose Amendola, (PhD, UiA)

WORK-PACKAGE 7: TECHNOLOGY VISION

2015				2016				2017				2018				2019				2020				2021				2022				2023			
1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4

- WP7.1 Marius Kristiansen (PhD, UiA)

The working titles of the positions

WP1.2 Using digital hydraulic in secondary control of motor drive.

WP1.3 Using digital hydraulic in secondary control of cylinder drive.

WP1.4 Electrical and electrohydraulic linear actuators.

WP1.5 Cylinder direct drive.

WP1.6 Energy efficient mobile hydraulic systems with focus on rotary actuation.

WP1.7 Energy efficient mobile hydraulic systems with focus on linear actuation.

WP1.8 Energy efficient mobile hydraulic systems with focus on digital valve technology.

WP2.1 Computer vision and 3D sensors for topside automation of offshore drilling.

WP2.2 High-performance control for motion compensation.

WP2.3 Nonlinear friction compensation in motion compensation systems with significant elasticity.

WP2.4 Vision systems for offshore crane control in ship-to-ship operations.

WP2.5 Real-time multiple DOF motion compensation using an industrial robot, sensor fusion and conformal geometric algebra.

WP2.6 Real-time teleoperation and model-based control of cranes with loads.

WP2.7 Vision systems for supervision of offshore drilling operations.

WP2.8 Fusion of vision, Lidar and IMU data for 3D tracking of objects in offshore crane operations.

WP3.1 Development of offshore 3D sensor package.

WP3.2 Autonomy systems foundation development.

WP3.3 Handling of sensor fusion, point-clouds and 3D maps.

WP3.4 Implementation of situational awareness/human factors concepts for operators using virtual arena.

WP3.5 Reliable Communication in 5G.

WP3.6 Instrumentation and real-time control of long-reach, light-weight arm intended for use offshore (associated PhD position).

WP3.7 Coupled dynamics between vessel and crane (associated PhD position).

WP3.8 Formal Methods in Robotics (integrated MSc / PhD position).

WP3.9 /WP6.5 Sensor fusion for perception, collision avoidance and navigation towards autonomous systems

WP4.1 Integrated simulation of multi-physical systems in offshore operations.

WP4.2 Component-based simulation systems for drilling automation and crane systems.

WP4.3 Protocols and standard for integration of simulation models and co-simulation.

WP4.4 Modelling and simulation of cable and pulley systems in offshore cranes.

WP4.5 Modeling and simulation of the motion of ships, cranes and drilling systems in waves

WP5.1 Tapered big bearings.

WP5.2 Large diameter steel ropes.

WP5.3 Fibre ropes.

WP5.4 Condition-based lifetime prediction as result of calculated component loads.

WP5.5 Modelling the fatigue damage mechanism in welded joints (associated PhD position).

WP5.6 Monitoring of Hydraulic Cylinders

WP6.1 Distributed in-network intelligence across multiple components.

WP6.2 Coordinated multi-variable data acquisition, intelligent data reduction, as well as automatic data quality verification and validation.

WP6.3 Design of soft-sensors based on novel context-aware data fusion techniques

WP6.4 Optimization of energy consumption and emission reduction for O&G production platforms.

WP6.5/WP3.9 Sensor fusion for perception, collision avoidance and navigation towards autonomous systems

WP7.1 The management of digital business model innovation

Organisation

CENTRE MANAGEMENT

The SFI Offshore Mechatronics centre is hosted by UiA and the management is led by Centre Director, Professor **Geir Grasmo** (Since 1. April 2021) with assistance from Administrative Manager **Asle Pedersen**. In addition, UiA provides necessary resources from the Faculty and Central management.
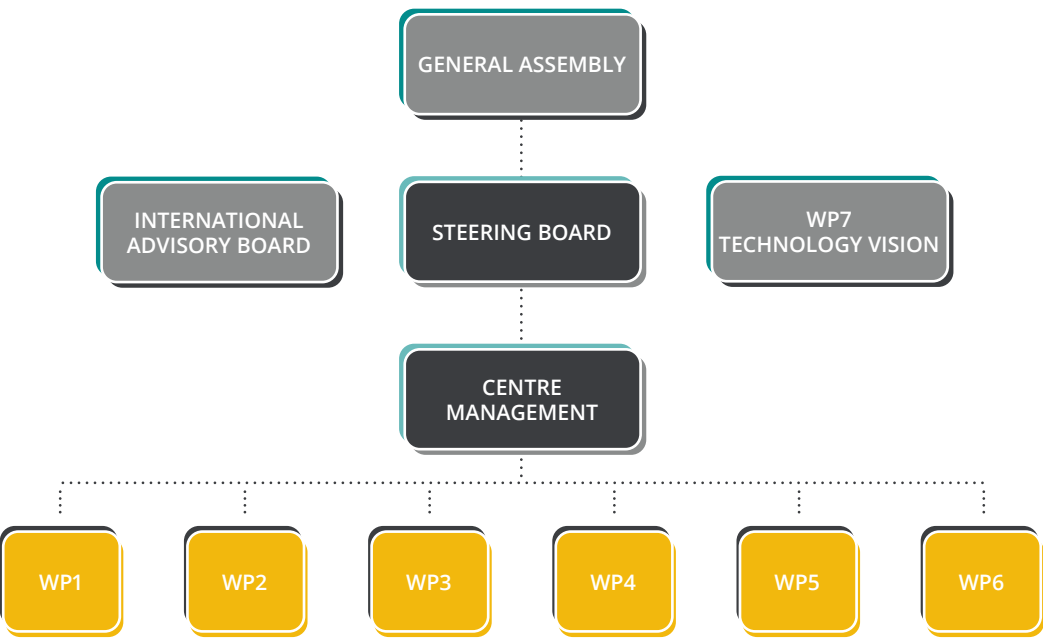
Geir Grasmo   Asle Pedersen

ORGANISATION MAP


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        GENERAL ASSEMBLY

INTERNATIONAL        STEERING BOARD        WP7
ADVISORY BOARD                             TECHNOLOGY VISION

                     CENTRE
                     MANAGEMENT

WP1   WP2   WP3   WP4   WP5   WP6
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Work Packages WP1 – WP7

Overall, the management and work-package leaders have been very stable during the project, but in 2021 several of the work-packages had a change in the wp-leader.

WP3: Jing Zhou (UiA) replaced Geir Hovland (UiA)
WP5: Rune Schlanbusch (NORCE) replaced Thomas J.J. Meyer (NORCE)
WP7: Christian von der Ohe (GCE Node) replaced Marianne Engvoll (GCE Node)

The departing work-package leaders deserves a big thanks for their good work and we welcome onboard the new work-package leaders.

WP1

WP1 LEADER 1
Morten Kjeld Ebbesen, UiA
Co-sup. WP1.2, co-sup. WP1.3, and sup. WP1.4

WP1 LEADER 2
Torben Ole Andersen, AAU
Sup. WP1.2, sup. WP1.3, and co-sup WP1.4

WP1.2
Sondre Nordås
UiA

WP1.3
Viktor Hristov Donkov
AAU

WP1.4
Daniel Hagen
UiA

WP1.5
Søren Ketelsen
AAU

WP1.6
Wei Zhao
UiA

WP1.7
Thomas Farsakoglou
AAU
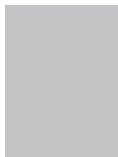
WP1.8
New position
AAU

WP2

WP2 LEADER
Olav Egeland, NTNU
Supervisor WP2.1-2.8

Dirk Abel
RWTH Aachen
Sup. WP2.6

Geir Hovland
UiA
Sup. WP2.5

WP2.1
Geir O. Tysse
NTNU

WP2.2
Torstein Myhre
NTNU

WP2.3
Andrej Cibicik
NTNU

WP2.4
Alexander M. Sjøberg, NTNU

WP2.5
Sondre S. Tørdal
UiA

WP2.6
Philip Schubert
RWTH Aachen

WP2.7
Hans Kristian Holen, NTNU

WP2.8
Alexander M. Sjøberg, NTNU

WP3

WP3 LEADER
Jing Zhou, UiA
Supervisor WP3.1 and WP3.2, Co-supervisor WP3.6, WP3.7

Olav Egeland
NTNU
Sup. WP3.3

Geir Hovland
UiA
Sup. WP3.1, WP3.2, WP3.6, WP3.7

Ilya Tyapin
UiA Sup. WP3.6

Jing Zhou
UiA Sup. WP3.7

David Anisi
NMBU
Co.Sup WP3.8

Ajit Jha
UiA
Sup. WP 3.9

Frank Y. Li
UiA
Sup. WP 3.5

Knut Berg Kaldestad
UiA
Technician
Sup. WPs

Charlotte Skourup
ABB
Co.Sup WP3.4

WP3.1
Joacim Dybedal
UiA

WP3.2
Atle Aalerud
UiA

WP3.3
Aksel Sveier
NTNU

WP3.4
Thiago G. Monteiro
NTNU
Aalesund

WP3.5
Thilina N. Weerasinghe
UiA

WP3.6
Dipendra Subedi
UiA

WP3.7
Ronny Landsverk
UIA

WP3.8
Yvonne Murray,
UiA

WP3.9
Jose Amendola
UiA

WP4

WP2 LEADER
Olav Egeland, NTNU
Supervisor WP4.5, Co-sup, WP4.1, WP4.2, WP4.4

Christian Holden, NTNU
Sup. WP4.1 & WP4.2

Houxiang Zhang
NTNU Aalesund
Sup. WP4.3

Terje Rølvåg
NTNU
Sup. WP4.4

Geir Hovland
UiA
Co-Sup. WP4.3

Bjørn Haugen
NTNU
Co-sup. WP4.4

Arne Styve
NTNU
Aalesund
Co-sup. WP4.3

WP4.1
Savin Viswanathan
NTNU

WP4.2
Njål Tengesdal
NTNU

WP4.3
Lars Ivar Hatledal
NTNU Aalesund

WP4.4
Gaute Fotland
NTNU

WP4.5
Savin Viswanathan
NTNU

WP5

WP5 LEADER
Rune Schlanbusch
NORCE

Ian K. Jennions
Cranfield U.

| Subtask 5.1 «Big tapered roller bearings» | Subtask 5.2 «Big steel ropes» | Subtask 5.3 «Big fiber ropes» | Subtask 5.4 "Winch Lifetime predictions" | Subtask 5.5 "Welded joints fatigue predictions" |

Tor Inge Waag
Task leader, NORCE

Rune Schlanbusch
Task leader, NORCE

Ellen Nordgård-Hansen
Task leader, NORCE

Stephan Neumann
Task leader, Aachen IME

Tom Lassen
Task leader, UiA

Kjell Gunnar Robbersmyr
UiA
Sup. WP5.1

WP51
Martin Hemmer
UiA

WP5.3
Shaun Falconer
UiA

Geir Grasmo
UiA
Sup. WP5.3

WP5.4
Mohammed Yusuf
Aachen IME

WP5.5
Zbigniew Mikulski
UiA

WP5.6
Vignesh Shanbhag
NORCE

WP6

WP6 LEADER
Baltasar Beferull-Lozano, UiA
Supervisor WP6.1 - WP6.2

Daniel Romero
UiA
Co. Sup. WP6.1

Linga Cenkeramaddi
UiA
Co. Sup.

Jing Zhou
UiA
Co. Sup. WP6.2

Ajit Jha
UiA
Sup. WP6.3 and WP6.5

WP6.1/WP6.4
Luis M. Lopez-Ramos
UiA

WP6.2
Emilio Ruiz Moreno
UiA

WP6.3
Kevin Roy
UiA

WP6.5/WP3.9
Jose Amendola
UiA

WP7

WP7 LEADER
Christian von der Ohe, GCE NODE

WP7 LEADER
Ellen Nordgård-Hansen, NORCE

Thor Helge Aas, UiA
Supervisor WP7.1

Jan Helge Viste, GCENode
Supervisor WP7.1

WP7.1
Marius T. Kristiansen
UiA

Steering Board

The Steering board (2021-2022) consists of 7 members, and 2 deputy members: Tom Fidjeland (GCE NODE), Morten Halvorsen (NOV), Sjur Henning Hollekim (MHWirth), Jisha Panikar (Klueber Lubrication, Anstein Jorud (Cameron, deputy member) Olav Egeland (NTNU), Torben Ole Andersen (Aalborg University), Jorun Gislefoss (UiA), Thomas Meyer (NORCE, deputy member)

The majority of the SFI Offshore Mechatronics Steering Board members are from the Industry Partners. The Steering board is appointed for 2 years. It is the General Assembly which appoints the Steering board.

Tom Fidjeland
GCE NODE
Chairperson

Morten Halvorsen
NOV
Deputy Chairperson

Sjur Henning Hollekim
MHWirth

Jisha Panikar
Klueber Lubrication

Olav Egeland
NTNU

Torben Ole Andersen
Aalborg University

Jorun Gislefoss
UiA

Anstein Jorud
Cameron

Thomas Meyer
NORCE

The Centre has one General Assembly every year, where all partners meet and work-plans for the following year are presented and discussed.

The General Assembly was held on November 11, 2021, where the budget for next three years and the WP annual work plans were presented and approved.

KEY NUMBERS 2021

Steering Board Meetings	4
WP leader meetings	7
Workshops/Webinars	6
Reference Group Meetings	9
Conferences	0
General Assembly	1

Partners

Partners gathering on the SFI OM annual conference.

Geir Grasmo new Centre Director from April 1st 2021

In 2015, SFI Offshore Mechatronics was the first project and centre hosted by University of Agder to be accepted into the competitive SFI program in Research Council Norway.

Professor Geir Hovland served as the Centre Director as well as work-package leader in WP3 since early in the start of the project in 2015. Geir played a crucial role in building up the centre and successfully managing the center for nearly six years until April 2021. The partners and colleagues in the centre are grateful for the excellent work and collaboration with Geir. As Geir moves on he will devote his time and efforts in building a new industrial startup company in Grimstad.

The successor in the role as Centre Director is also named Geir, Geir Grasmo that is. Geir Grasmo is professor in materials engineering and until recently Geir Grasmo has served as head of department at engineering sciences in University of Agder. Before joining University of Agder in 2015, he spent almost 18 years of his career in various positions in the materials industry in companies such as Alcoa and Elkem and before that as a researcher in SINTEF and scholar in HiS (now UiS).

What's next?

The end of the SFI funded project in 2023 is approaching fast. This naturally triggers the challenging question of what should come after? Will there be a continuation, and in that case, in what shape and form? The answer to this question is not obvious and for this reason this topic was put on the agenda throughout 2021 at all board meetings, work-package leader meetings and reference group meetings.

The discussions are supported by a top-down approach and a bottom-up approach. The aim of the bottom-up process is to gain insight into small and large unresolved problems in the industry and relevant research that can help to solve it. This work is carried out in reference group meetings and work-package leader meetings. The aim of the top-down process is to define windows of opportunity based on market drivers, key societal challenges, competing initiatives, collaboration opportunities, available funding schemes, industry commitment and more.

The offshore environment is a gateway to abundant natural resources and opportunities, especially related to energy and food. E.g. offshore wind resources are stronger, and blow more consistently than land-based wind resources. But the offshore environment is also naturally challenging due to the remoteness of the locations, ocean depths and the harsh and changing weather conditions.

Back in 2015 when the centre was established, offshore operations was dominated by oil and gas exploration and production. Because several of the large industry partners in the centre had their major income from the oil and gas market, there was early on an association between the centre and this business and application area. It is important to emphasize that the results from the research in the centre are applicable to offshore operation in general. The industry partners are already demonstrating the use of the research in innovations and new products and solutions targeting emerging markets such as offshore wind.

Reduced costs and increased productivity without compromising health, safety and environmental requirements is critical for sustainable and competitive offshore operations. Research that contributes to new solutions and innovation is addressed across the work packages, e.g. reliability and reduced energy use (WP1), decreased weather downtime (WP2), robotics/autonomy (WP3), remaining useful lifetime calculation (WP5), decreased unplanned downtime (WP6), and business models (WP7). There is strong evidence that offshore mechatronics will be in high demand also in the next decades and more reliable, faster, safer and cheaper will remain key drivers of innovation.

The phase-out strategy process of the centre is still ongoing and is not yet concluded. Ultimately, each partner in the current consortium will need to decide if and how they want to proceed and get involved in new initiatives.

Scientific Activities and Results

**Each PhD defense is a milestone in the SFI Offshore Mechatronics centre.
In 2021 seven PhD fellows defended their thesis:**

Viktor H. Donkov (AAU), PhD thesis defended on January 15, 2021. Title of the thesis: Secondary Control of Multi-chamber Cylinders for Low-speed High-force Applications

Lars Ivar Hatledal (NTNU Aalesund), PhD defended on Friday March 19, 2021. Title of the thesis: Protocols and Standards for Simulation and Co-simulation.

Thiago G. Monteiro (NTNU Aalesund), PhD thesis defended on February 3, 2021. Title of the thesis: A Cross-modal Integrated Sensor Fusion System for Fatigue and Awareness Assessment in Demanding Marine Operations.

Savin Viswanathan (NTNU), PhD thesis defended on May 11, 2021. Title of the thesis: Multiphysical Simulation of Ocean Engineering Systems

Thilina Weerasinghe (UiA), PhD thesis defended on May 25, 2021. Title of the thesis: Enabling mMTC and URLLC in 5G: Initial Access, Traffc Prediction, and User Availability.

Atle Aalerud (UiA), PhD thesis defended on October 14, 2021. Title of the thesis: Industrial Perception of a Human World: A Hitchhiker's Guide to Autonomy.

Njål Tengesdal (NTNU), PhD thesis defended on October 18, 2021. Title of the thesis: Modelling and Simulation of Offshore Drilling Systems.
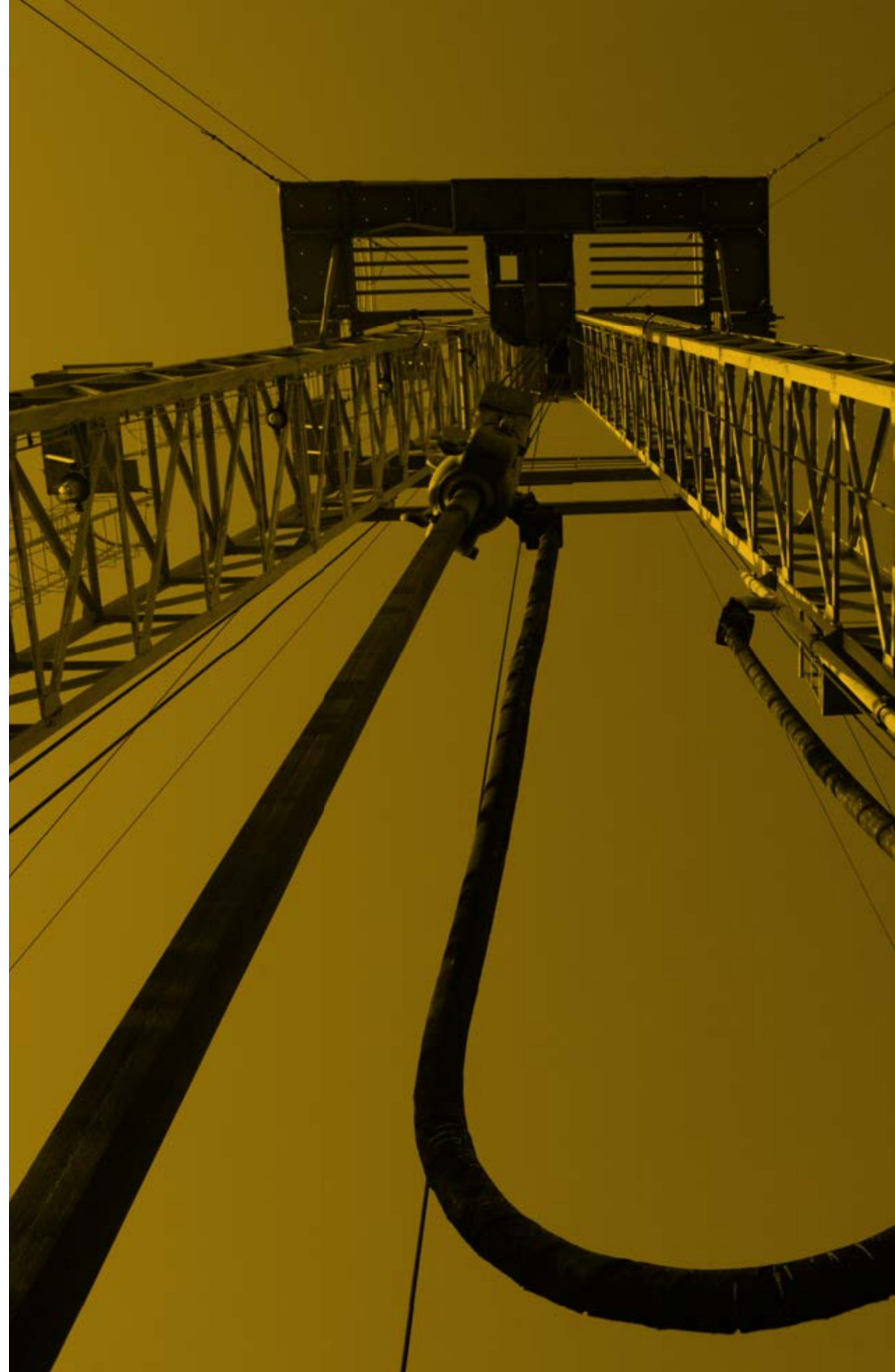
International Cooperation

The SFI Offshore Mechatronics centre is distributed with industry and research partners across four countries (Norway, Denmark, The Netherlands and Germany). In addition to this the researchers in the centre utilize their extensive international networks.

The centre has a small international advisory board. It consists of the following persons: Professor Rolf Johannsson, Lund University, Sweden, Professor Ian Jennions, Cranfield University, UK and Professor Iraj Ershagi, University of Southern California, USA. This board was more active in the early stages of the centre.

Due to COVID-19, the opportunities to travel and accommodate guest researchers have been limited in 2021. However, most of the PhD defenses have international opponents. The written examination reports serve as valuable feedback on the relevance, quality and impact of the research in the centre. The following are a few excerpts of some very positive feedback:

- Dr. Isabelle Fantoni, France: "The contributions of the thesis are substantial with a thorough theoretical foundation and are also well documented experimentally."
- Prof. Lorenzo Marconi, Italy: "The thesis is extremely rigorous from a mathematical viewpoint and definitely provides an elegant and powerful framework by contributing with new knowledge to the state of the art."
- Prof. Joris de Schutter, Belgium: "The contribution is original and the development of the theoretical framework and the presentation in the thesis is of high quality."
- Prof. Oliver Sawodny, Germany: "The candidate made important achievements in modelling of ship crane and load dynamics, in combination with the wave excitation."
- Prof. Demba Diallo, France: "A significant contribution of the candidate is the development of a test rig for replicating the scoring on roller end and the analysis of the observed arc-shaped scoring through an analytical model."
- Prof. Svante Gunnarsson, Sweden: "Throughout the thesis the candidate combines solid theoretical work with extensive experiments, and this combination gives a strong support for the industrial relevance of the results."
- Prof. Heikki Handroos, Finland: "The author's clearly novel individual contribution in the overall study is the proposed new version of the partial stroke displacement control strategy."

PhDs and Post.Docs in SFI Offshore Mechatronics

Recruitment

By the end of 2021 all final PhD and Post.Doc positions have been filled. During the project period a total of 40 researcher and technicians have been recruited. The following researchers and technicians were hired in SFI Offshore Mechatronics in 2015-2021. Unfortunately, it was not possible to recruit any female PhD students or Post.Doc positions in 2021.

NAME	POSTITION / INSTITUTION	PERIOD
Torstein Myhre	Post.Doc, NTNU	2015-2017
Geir Olav Tysse	PhD, NTNU	2015-2018
Sondre Sanden Tørdal	PhD, UiA	2015-2018
Achim Felderman	PhD, RWTH Aachen	2015-2017
Atle Aalerud	PhD, UiA	2016-2019
Andrej Cibicik	PhD, NTNU	2016-2019
Joacim Dybedal	PhD, UiA	2016-2019
Shaun Falconer	PhD, UiA	2016-2019
Daniel Hagen	PhD, UiA	2016-2019
Martin Hemmer	PhD, UiA	2016-2019
Sondre Nordås	PhD, UiA	2016-2019
Aleksander Meyer Sjøberg	PhD, NTNU	2016-2019
Aksel Sveier	PhD, NTNU	2016-2019
Thilina Nuwan Weerasinghe	PhD, UiA	2016-2019
Philipp Schubert	PhD, RWTH Aachen	2016-2019
Lothar Wöll	PhD, RWTH Aachen	2016-2019
Zbigniew Mikulski	PhD, UiA (associated)	2016-2019

Viktor H. Donkov	PhD, Aalborg	2017-2019
Thiago G. Monteiro	PhD, NTNU Aalesund	2017-2021
Savin Viswanathan	PhD, NTNU	2017-2020
Njål Tengesdal	PhD, NTNU	2017-2020
Lars Ivar Hatledal	PhD, NTNU Aalesund	2017-2020
Gaute Fotland	PhD, NTNU	2017-2020
Luis Miguel Lopez Ramos	Post.Doc, UiA	2016-2018
Søren Ketelsen	PhD, Aalborg	2018-2021
Emilio Ramiz Moreno	PhD, UiA	2018-2021
Yvonne Murray	PhD, UiA (associated)	2018-2021
Hans Kristian Holen	PhD, NTNU	2019-2022
Dipendra Subedi	PhD, UiA (associated)	2019-2022
Ronny Landsverk	PhD, UiA (associated)	2019-2022
Vignesh Shanbhag	Post.doc NORCE	2019-2021
Mohammed Yusuf	PhD. RWTH Aachen	2019-2023
Alexander Meyer Sjøberg	Post.doc NTNU	2020-2022
Kevin Roy	PhD, UiA	2020-2023
Marius Kristiansen	PhD, UiA	2020-2023
Wei Zhao	PhD, UiA	2020-2023
José Amendola	PhD, UiA	2021-2023
Savin Viswanathan	Post.doc NTNU	2021-2023
Tomas Farsakoglou	PhD, AAU	2021-2023
Mohit Bhola	PostDoc, Aalborg	2022-2023

Communication and Dissemination Activities

The main event for communication and dissemination in the project is the SFI Offshore Mechatronics Annual Conference. In 2021, the conference was planned on May 12-13, however due to the situation with COVID-19 it was postponed and eventually cancelled.

To compensate for the cancellation of the annual conference short bi-weekly webinars were introduced targeting attendees from both industry and the research partners. The topics of the webinars are various technical subjects with both internal and external presenters. In 2021 in total 6 webinars and seminars were arranged. The work-packages also invite people from the industry partners to reference group meetings which are a good opportunity to disseminate results to participate in discussions and to get valuable feedback from an industrial perspective.

SFI Offshore Mechatronics has a web page (sfi.mechatronics.no) for news and general information about the Project. The web site is both for partners and the general public. All information about the organization, activities and results that are not sensitive is published here. From the web site there is generated a monthly newsletter, with over 350 subscribers.

Dissemination Activities

PUBLICATIONS

JOURNAL PAPERS

Thilina N. Weerasinghe, Vicente Casares-Giner, Indika A. M. Balapuwaduge, and Frank Y. Li, **"Priority Enabled Grant-Free Access with Dynamic Slot Allocation for Heterogeneous mMTC Traffic in 5G NR Networks,"** IEEE Transactions on Communications, May 2021. (Level 2).

S. Mollaebrahim, B. Beferull-Lozano, **"Design of Asymmetric Shift Operators for Efficient Decentralized Subspace Projection"** , IEEE Transactions on Signal Processing, Vol. 69, pp. 2056-2069, March 2021. (Level 2)

Dipendra Subedi, Ilya Tyapin and Geir Hovland: **"Dynamic Modeling of Planar Multi-Link Flexible Manipulators",** MDPI Robotics, May 2021.

Shanbhag, V. V., T. J. J. Meyer, L. W. Caspers and R. Schlanbusch (2021). **Failure Monitoring and Predictive Maintenance of Hydraulic Cylinder – A State of Art Review.** IEEE/ASME Transactions on Mechatronics, January 2021. (Level2)

Shanbhag, V. V., T. J. J. Meyer, L. W. Caspers and R. Schlanbusch (2021). **Defining acoustic emission-based condition monitoring indicators for monitoring piston rod seal and bearing wear in hydraulic cylinders.** The International Journal of Advanced Manufacturing Technology, May 2021. (Level 2)

Shaun Falconer, Ellen Nordgård-Hansen, Geir Grasmo, **"Remaining useful life estimation of HMPE rope during CBOS testing through machine learning",** Ocean Engineering, Volume 238, October 2021.

Joacim Dybedal and Geir Hovland, **"CNN-based People Detection in Voxel Space using Intensity Measurements and Point Cluster Flattening",** Modeling, Identification and Control, 2021, Vol 42, No. 2, pp. 37-46.

Savin Viswanathan, Christian Holden, Olav Egeland and Marilena Greco, **"An Open-Source Python-Based Boundary-Element Method Code for the Three-Dimensional, Zero-Froude, Infinite-Depth, Water-Wave Diffraction-Radiation Problem",** Modeling, Identification and Control, 2021, Vol 42, No. 2, pp. 47-81.

Pedersen, J. F., R. Schlanbusch, T. J. J. Meyer, L. W. Caspers and V. V. Shanbhag (2021). **Acoustic Emission-Based Condition Monitoring and Remaining Useful Life Prediction of Hydraulic Cylinder Rod Seals.** Sensors, 21(18):6012.

Holen, Hans K.R. and Sjøberg, Alexander M. and Egeland, Olav, **"Estimation of Ship-Deck Motion using LIDAR, Gyroscopes and Cameras",** Modeling, Identification and Control, 2021, Vol 42, No. 3, pp. 99-112.

A. M. Sjberg and O. Egeland, "**Lie Algebraic Unscented Kalman Filter for Pose Estimation,"** in IEEE Transactions on Automatic Control. (Level2)

A. Cibicik and O. Egeland, "**Kinematics and Dynamics of Flexible Robotic Manipulators Using Dual Screws,"** in IEEE Transactions on Robotics, vol. 37, no. 1, pp. 206-224, Feb. 2021. (Level2)

Hatledal, Lars Ivar; Chu, Yingguang; Styve, Arne; Zhang, Houxiang, **"Vico: An entity-component-system based co-simulation framework",** Simulation Modelling Practice and Theory, Volume 108, April 2021, 102243

Ketelsen S, Michel S, Andersen TO, Ebbesen MK, Weber J, Schmidt L. **Thermo-Hydraulic Modelling and Experimental Validation of an Electro-Hydraulic Compact Drive. Energies.** 2021; 14(9):2375.

A. Sveier and O. Egeland, **"Dual Quaternion Particle Filtering for Pose Estimation,"** in IEEE Transactions on Control Systems Technology, vol. 29, no. 5, pp. 2012-2025, Sept. 2021. (Level2)

CONFERENCE PAPERS

Kandukuri, S. T., V. V. Shanbhag, T. J. J. Meyer, L. W. Caspers, N. S. Noori, R. Schlanbusch (2021). **Automated and Rapid Seal Wear Classification Based on Acoustic Emission and Support Vector Machine.** PHM Society European Conference.

L. M. Lopez, K. Roy, B. Beferull-Lozano, **"Explainable nonlinear modelling of multiple time series with invertible neural networks",** International Conference on Intelligent Technologies and Applications (INTAP), 2021.

S. Mollaebrahim, D. Romero and B. Beferull-Lozano, **"Fast Decentralized Linear Functions Via Successive Graph Shift Operators,"** ICASSP 2021 – 2021 IEEE International Conference on Acoustics, Speech and Signal Processing (ICASSP), 2021, pp. 5255-5259.

Student Projects

UiA
Sindre Bokneberg and Even Falkenberg Landås
Pick and Place using Computer Vision and an Industrial Robot

Jørgen Fone Pedersen
Detecting fluid leakage in hydraulic cylinder using acoustic emission

RWTH Aachen:
Nagarjuna Avula (Stralsund University)
Load Distribution and Lifetime Analysis of an Offshore Winch Drivetrain

AALBORG UNIVERSITY
Stefan Siray, Niklas Simonsen, Frederik Peter Kløvborg
Automated Pressure Control Loop Tuning

NTNU
Martin Mjølhus Helle
Pose Estimation of ships in Real-Time with camera technology and AI

Øyvind Wormdal Mjølhus
Simultaneous Localization and Mapping

Johannes Giercksky Nilssen
Machine learning in an adaptive control setting

Petter Hoem Sletsjøe
Multi-Vehicle GPS-Aided SLAM

Ola Alstad
3D scanning of objects with reflective surfaces

Eivind Torsrud Nerol
Measurement and AR Assembly Instructions Based on Structured Light System

Thea Holmedal
Implementing Offline Programming for Welding Robots

Henrik Duus Berven
Development of an industrial robotic bin picking system for Siemens Energy

William Skeide Eikrem
Synthetic Data Generation for 6D Pose Estimation

Morten Melby Dahl
ROS2 Integration of KUKA Manipulators and Mobile Platforms

Harald Osnes Rimstad
Automated Camera Calibration of Picking Robot

Vebjørn Bergsholm Bjørhovde
Implementing a System for Robotic Welding using Constraint-Based Robot Programming

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UiA University of Agder