Norwegian Centre for Research-based Innovation

ANNUAL REPORT 2022

UNIVERSITAS BERGENSIS

SFI SMART OCEAN

PARTNERS

SFI Smart Ocean is a Centre for Research-based Innovation (SFI) funded by the Research Council of Norway (grant number 309612). The consortium consists of research partners, user partners from industry and industry clusters, and national authority observers.

RESEARCH PARTNERS

UNIVERSITETET I BERGEN

FFI Norwegian Defence Research Establishment

NORCE

Western Norway University of Applied Sciences

NERSC

USER PARTNERS / INDUSTRIES

AANDERAA a xylem brand

REACH SUBSEA

W • SENSE

bouvet

tampnet

AkerBP

METAS

TSC

KONGSBERG

USER PARTNERS / INDUSTRY CLUSTERS

GCE | NODE | GLOBAL CENTER OF EXPERTISE

GCE Ocean Technology

NATIONAL AUTHORITY OBSERVERS

DIRECTORATE OF FISHERIES

PETROLEUM SAFETY AUTHORITY NORWAY

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On the cover: Jean-Baptiste Danre of the Institute of Marine Research removes marine growth from a sensor mooring.
Photo: Rune Øyerhamn, NORCE

SUMMARY

Marie Bueie Holstad
Acting Centre Director

SFI Smart Ocean is a Centre for research-based innovation, funded by the Research Council of Norway and Centre partners. The Centre started on 1. December 2020, and has 6 research partners, 9 industry partners, 2 industry-cluster partners and 2 partners from national authorities.

Our goal is to enable sustainable ocean management through real-time measurements from autonomous and smart sensor networks.

2022 has been a very interesting and engaging year for SFI Smart Ocean. After having started with a year and a half with covid-restrictions, the Centre activities, including physical meetings and field testing, have accelerated significantly. Two-day gatherings at Austevoll in May and at Nordnes in Bergen in October have strengthened the SFI Smart Ocean team and allowed for detailed discussions across partners and work packages, paving the way for even better cooperation in the continuation of the Centre period. Another highlight from the gathering in October was welcoming our 9th industry partner, W-Sense AS, into the consortium.

A lot has happened throughout the year. The technology development is progressing in all work packages, and the interesting and challenging task of connecting all the activities to allow for one, integrated ocean observation system with all components working together is receiving increased attention. Additional sensors and modems have been installed and tested at the IMR test site at Austevoll. Several of our partners have been working together here to gain experience with both the sensors and various communication and data collection solutions. Several PhD students are now using the SFI Smart Ocean data from the Austevoll test site in their research, both for development of advanced measurement strategies, and for development of software ensuring collection of high-quality data. This means that the activities in the scientific work packages are now integrated through the testing activities at Austevoll. Algorithms and hardware that have been developed and tested have been implemented in new innovations, so that some of our partners are already offering improved products and services as part of their portfolio.

Smart Ocean meeting in Austevoll, Spring 2022

All in all, Centre activities have significantly accelerated during 2022, and a lot of important milestones have been reached. We are all excited to continue the work and tackle the challenges that lie ahead.

A significant number of publications have been submitted, and presentations have been held, informing the scientific communities and ocean industries of our results and the work undertaken. It is great to see that this raises interest for the work we are doing, and that the quality of the work is acknowledged. Two highlights were our PhD students winning awards with their conference papers:

- PhD student **Astrid Marie Skålvik**, UiB, won the best student paper award at the Underwater Technology Conference, which by many is considered to be the best international underwater technology industry conference.
- PhD student **Keila Lima**, HVL, won the best paper award at PROFES together with second author PhD student **Ngoc-Thanh Nguyen**, HVL, and the rest of the co-authors. PROFES is the International Conference on Product-Focused Software Process Improvement, which is among the top internally recognized software development and process improvement conferences.

PhD and Master's students are important resources for the Centre, and an increasing number of students are fully integrated participants in the scientific teams working in the Centre.

It is also great to see that we are still receiving a lot of interest from various industrial companies, including companies that are interested in collaboration. This is most welcome as good collaboration across projects, initiatives and organisations is crucial for a solid understanding of needs, limitations and possibilities. Presentations held at events hosted by our cluster partners GCE Ocean Technology and GCE NODE, as well as other events, have resulted in valuable feedback from a wide range of stakeholders in the ocean industries.

Smart Ocean PhD students: (from left) Astrid Marie Skålvik, Keila Lima and Ngoc Thanh Ngyuyen

Another important focus, cooperation with relevant projects, has been continued and strengthened. An example is the field trials at Austevoll together with the ERA-NET Cofund MarTERA project UNDINA. Dialogue and cooperation have been established with several new, important, international projects including two EU-funded projects coordinated by SFI Smart Ocean partners, HiAOOS coordinated by NERSC and OLAMUR coordinated by IMR.

All in all, the activities have significantly accelerated during 2022, and a lot of important milestones have been reached. We are all excited to continue the work and tackle the challenges that lie ahead.

VISION & OBJECTIVES

Our vision is the realization of a generic, autonomous and flexible wireless multi-parameter marine observation system for reliable management of a productive and healthy ocean.

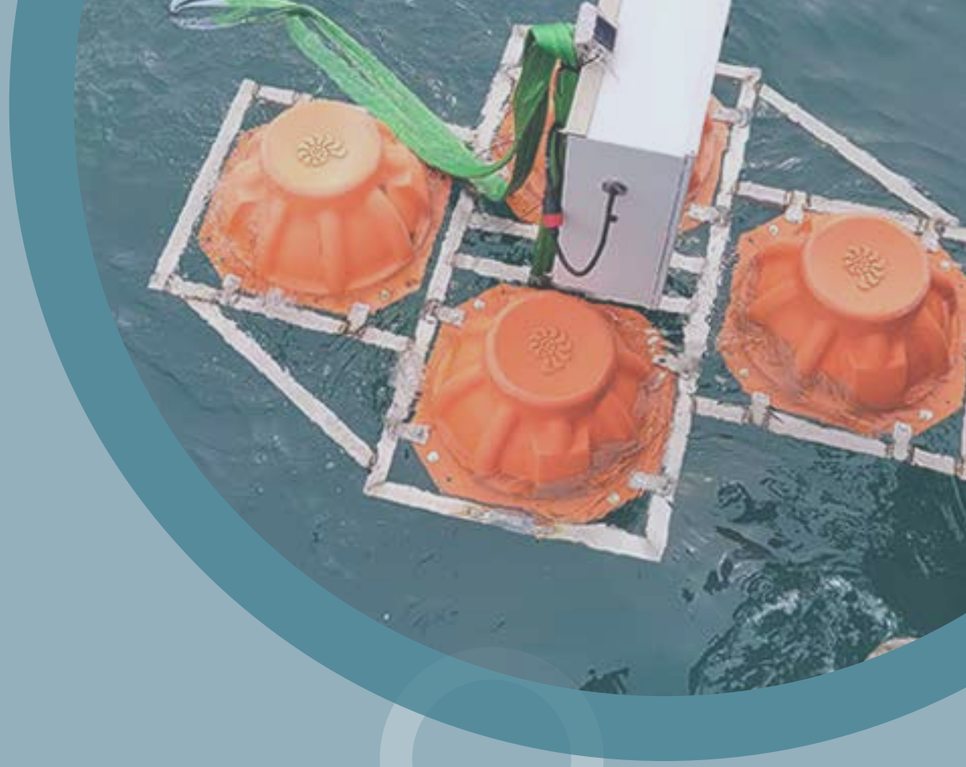
SFI Smart Ocean is focusing on enabling real-time high-quality data for increased autonomy, and increased value of coastal and oceanic management models and systems. This will lead to sustainable and profitable ocean industry operations, and to fact-based ocean resource management. The observation system key factors are highly cross-disciplinary:

- sensors and measurement parameters
- flexibility and adaptive sampling in time and space
- point measurement vs. monitoring over large areas
- distributed measurements
- measurement uncertainty and reliability
- time history as input to big-data analysis
- cloud-based data and application
- data format aggregation and safety
- low power consumption and local sensor intelligence

Organising this as a centre that spans multiple scientific disciplines and sectors ensures a vendor-neutral approach to the system and enables a diversity of applications.

Standardized interfaces enable the integration of a diversity of sensor types, during and after the Centre's lifetime. SFI Smart Ocean implements sensors for monitoring environmental, structural, and marine life parameters.

These are all parameter values needed for well-founded decisions by industry and authorities, in optimization of operations or maintenance, and evaluations of license to operate. They are building blocks for filling knowledge needs and meeting societal challenges.



Placement of underwater rig at Austevoll
Photo: Anders Jakobsen

PRIMARY OBECTIVE

The centre objective is to create a wireless observation system for multi-parameter monitoring of underwater environments and installations.

The system based on autonomous smart sensors will serve as an enabling fundament in realizing flexible, distributed, robust, energy efficient, cost-effective, and safe marine measurements and big-data handling, to support the Centre's vision in respect to societal and industrial challenges.

RESEARCH PLAN & STRATEGY

The activity in SFI Smart Ocean is divided into three work packages (WP) and two integrating functions (IF). The three WPs are edge-cutting disciplinary activities, with necessary and strong mutual interaction. The IFs are cross-cutting interdisciplinary activities, integrating the three WPs.

WP1: AUTONOMOUS SENSORS & MEASUREMENT STRATEGIES

This work package focuses on enabling and developing autonomous sensor technology for marine environmental and structural integrity measurements. The research and development are both on existing marine sensors and novel sensor technologies for real-time observations in an underwater wireless network.

Marine smart sensors will have embedded pre-processing of data in the sensor, compression of data, acoustic modem compatibility, and smart operation for low energy use. Research and innovation on new sensor technology include guided ultrasonic wave sensors for integrity measurements, distributed fibre optic sensors with acoustic sensing of environmental noise and structural vibrations, and nano technology for improved pH sensors. Our research also includes nanostructured surfaces for anti-biofouling of sensor and modem surfaces, to ensure high signal quality and longer deployment in the ocean. Research on measurement strategies aims to reduce measurement uncertainty and ensure trustworthy data. This includes self-validation and self-diagnostic capabilities of the smart marine sensors, and the uncertainty propagation from the marine sensors to the data presented to the end user.

Existing sensors, new sensor technologies, nanostructured self-cleaning surfaces, and the measurement strategies for trustworthy data are tested at pilot demonstrators in the Centre.

WP2: WIRELESS NETWORK COMMUNICATIONS

SFI Smart Ocean depends heavily on underwater communications. This work package focuses on communication technology for SFI Smart Ocean, and will develop a low-cost, miniaturized, and short-range acoustic underwater wireless technology platform assembled to an energy-efficient underwater wireless sensor network (UWSN). Hardware and software will need to be optimized with respect to limited battery capacity, efficiency, and reliability. To support a wider range of use cases, WP2 may also study longer-range links and/or links with moving platforms like AUVs. Acoustic modem and communication protocols will build on state-of-the-art within underwater acoustic communication technology.

The system will be interfaced towards mobile networks (4G, 5G), satellite communication, fiber optic "backbone" networks, and unmanned surface vehicles. The communication requirements for SFI Smart Ocean are established in cooperation with the other work packages. Communication solutions to use in SFI Smart Ocean are defined based on the requirements in combination with limitations and possibilities for communication in the harsh underwater environment.

On the physical layer, a testbed is established to investigate different modulation methods and coding techniques and methods for energy optimization. Experiments are employing the infrastructure of IF1. On the network layer, different protocols and network architectures, including multi-hop and mesh protocols, are investigated with respect to efficient data transfer and low energy requirements.

WORK PACKAGES (WP) & INTEGRATING FUNCTIONS (IF)	IF1		IF2
	TEST FACILITIES		OVERARCHING ACTIVITIES
WP1: AUTONOMOUS SENSORS & MEASUREMENT STRATEGIES	COORDINATION OF NEEDS AND TESTING FACILITIES	LOCATIONS FOR TECHNOLOGICAL SEGMENTS: • ENVIRONMENT • OFFSHORE WIND • OIL AND GAS • AQUACULTURE	ADMINISTRATION EDUCATION DATA MANAGEMENT COMMUNICATION COMMERCIALISATION INNOVATION & IPR
WP2: WIRELESS NETWORK COMMUNICATION			
WP3: SOFTWARE TECHNOLOGY & BIG-DATA MIDDLEWARE			

WP3: SOFTWARE TECHNOLOGY AND BIG-DATA MIDDLEWARE

The work package on software technology and big-data middleware focuses on a digital ecosystem providing cloud-based ocean data services and supporting cost-effective development of software applications that provide and consume ocean data services.

The cloud-based smart ocean platform is to comprise a set of software frameworks enabling the integration of external and internal ocean data sources, data storage and processing, and application deployment. The platform is to enable data spaces based on a uniform and standardised set of APIs, dataand metadata formats. The software technology being developed in the work package is validated through the development of application prototypes linked to consortium pilot demonstrators and through the deployment of a reference implementation that integrates with external systems and data services.

The main topics of the work package include development and implementation of the smart ocean platform, system-of-systems software architecture, engineering technology for smart software systems, sensor-cloud integration middleware and protocols, edge computing, interoperability and data service APIs, data quality- and integrity, software security and reliability, machine learning and analytics, and intelligent visualisation of big datasets. The work package is organised into subprojects focussing on applications and use cases, the SFI Smart Ocean data platform, and software engineering.

IF1: TEST ARENAS

This is an overarching Work Package that includes the sites where results from WPs 1-3 will be tested in various environments. The list of test sites is dynamic and is presumed to be expanded during the life cycle of SFI Smart Ocean.

A local scale environmental monitoring test site is operational at the IMR Austevoll Research Station near Bergen. This will be our main test arena, and the infrastructure will be utilized for testing of components and systems developed in SFI Smart Ocean. Here two rigs with sensors are placed; the rigs are modular, and a range of sensors and communication systems are included and available for data collection and equipment tests. A third rig, connected with a new large-scale facility for aquaculture sea-cages, plus an underwater system operated in connection with the LoVe project (IMR) will become operational during the summer months of 2023. The research station has provided an existing infrastructure under continuous development, making modifications and maintenance of the rigs easier. The Austevoll facilities will be further developed to include a mesoscale test facility will be established as an extension of the local scale system. , paving the way for longer scale communication, geo-positioning, and mesoscale environmental monitoring, using acoustic tomography and passive acoustics. Logistically, this system will be an extension of the already developed system for local scale tests.

Furthermore, a mesoscale system for environmental monitoring will be established in the Arctic Ocean north of Svalbard. Recently, our partner NERSC was granted the EU project HiAOOS where a large observation system will be installed for two years in the Nansen and Amundsen Basin. This system will provide year-round acoustic and oceanographic observations as well as facilitate testing of new technologies for observations and data recovery from underwater installations. Systems and equipment developed for SFI Smart Ocean are complementary to HiAOOS, and may be tested in connection to the HiAOOS system.

Test facilities for offshore wind installations are being prepared, as are systems for monitoring oil and gas installations. Our activities also include the Norwegian Ocean Observation Laboratory, where several of the partners of SFI Smart Ocean are collaborating.

IF2: OVERARCHING ACTIVITIES

Integrating Function 2 includes the administration of the Centre, and coordination of overarching activities such as commercialisation, innovation and IPR aspects, internal and external communication.

ORGANIZATION

SFI Smart Ocean is hosted by the University of Bergen (UiB), and the Centre is organized to ensure influence and contributions from all partners

MARIE BUEIE HOLSTAD
Acting Centre Director, IF2
Photo: Rune Rolvsjord, NORCE

SFI Smart Ocean is hosted by the University of Bergen (UiB), and the Centre is organized to ensure influence and contributions from all partners.

The General Assembly (GA) is the body responsible for major decisions regarding the Centre. All partners are represented in GA, and Dean Gunn Mangerud chairs the GA on behalf of UiB as host institution.

In 2022, the Centre Board consisted of Tove Lie (chair, former Lundin Energy Norway AS, now Aker BP ASA), Owe Hagesæther (GCE Ocean Technology), Jan Erik Faugstadmo (Kongsberg Maritime AS), Inger Graves (Aanderaa Data Instruments AS), Annette Fagerhaug Stephansen (NORCE Norwegian Research Centre AS), Jens Kristian Fosse (Western Norway University of Applied Sciences) and Øyvind Frette (University of Bergen).

The members of the Scientific Advisory Committee (SAC) are Professor Frank Reichert (University of Agder), Professor João Borges de Sousa (Porto University) and Assistant Professor Paolo Casari (University of Trento). They give advice to the Centre Board on scientific issues and priorities, to ensure high-quality scientific impact.

The Technology Advisory Committee (TAC) consists of one representative from each of the Consortium participants and advises the Centre Board via the Centre Director on technical issues and priorities, including IPR questions and possibilities for innovations, to ensure both industrial and scientific value creation. Camilla Sætre (UiB) is chair of TAC.

Some changes were made to the Centre administration throughout the year, and at the end of the year the Centre management team comprised of Acting Centre Director Marie Bueie Holstad (UiB and NORCE), Acting Deputy Director Camilla Sætre (UiB), Communication Manager Kavitha Østgaard (UiB), Administrative Manager Terje Restad (UiB) and work package managers Camilla Sætre (WP1, UiB), Roald Otnes (WP2, FFI), Lars Michael Kristensen (WP3, HVL), Jan-Erik Stiansen (IF1, HI) og Marie Bueie Holstad (IF2, NORCE).

CAMILLA SÆTRE
WP1, TAC, Dep. Ctr. Director

ROALD OTNES
WP2

LARS M. KRISTENSEN
WP3

JAN E. STIANSEN
IF1

TERJE RESTAD
Admistrative Mgr.

KAVITHA ØSTGAARD
Communication Mgr.

North mooring, Austevoll, at sunrise. *Photo: Jean Pierre Baptiste*

COOPERATION BETWEEN THE CENTRE'S PARTNERS

SFI Smart Ocean is working across multiple scientific disciplines, across several ocean industries and ocean management sectors, and integrates a significant amount of technology components.

The technological challenge is complex and requires close cooperation between the various partners who have different, but complementary, technologies and competence areas.

During 2022, the collaboration between partners has further increased. Several partners are involved in all the activities in the Centre, and in particular, the increasing activities related to testing of various solutions in the ocean outside Bergen, has increased the need for coordination of activities between work packages. At the test site at Austevoll, industrial partners and research partners have worked together to complete test set-ups, giving us valuable experience on both technology components and integrated systems. The collected data has been used by several scientists and PhD students working on measurement strategy and software architecture.

In addition to the ordinary, day-to-day collaboration between partners, we continue to set up supervision of students as a cooperative effort among partners with complementary competences in order to strengthen the students' learning experience. Students at Master's and PhD levels are in general a very valuable resource to the Centre and contribute to various project and Centre meetings and workshops. They have become a very important part of the project team.

Collaboration between partners also brings additional, invaluable input from industry as both scientific and industrial associates have an extended network of collaborators with whom they are working on related technological challenges. The industry clusters GCE Ocean Technology and GCE NODE in particular – both partners in SFI Smart Ocean – bring with them contributions from a wider group of member companies. This year GCE Ocean Technology arranged a workshop set to give SFI Smart Ocean, and ERA-NET Cofund MarTERA project UNDINA with which the Centre is cooperating, valuable input from their member companies. GCE NODE invited SFI Smart Ocean to present at their Aquaculture seminar, and at meetings with their member companies after the seminar.

Kristian Kasin Nordlie (W-sense), Erik Bjerke (Kongsberg Maritime) and Beatrice Tomasi (NORCE) working together on equipment tests at Austevoll.

SCIENTIFIC ACTIVITIES & RESULTS

Throughout 2022, the activities have accelerated significantly, and a range of goals have been achieved.

Placement of underwater rig at Austevoll. *Photo: Anders Jakobsen*

Robust sensing
The work on transmission requirement for the different sensors is finalized in an internal report, including an evaluation of embedded processing vs. cloud computing, standardised data and metadata formats. Challenges and best practices for self-validation and self-diagnostics for marine sensors and sensor networks, were surveyed and presented at the Underwater Technology Conference (UTC) in Bergen. Algorithms for real-time data quality control were tested on time series of environmental measurements, including an initial evaluation of the need for self-validation or self-diagnostics by other means.

Within anti biofouling, a biofilm synthesis procedure for tests of surfaces has been established, and the work on development of novel anti biofouling coatings has been started. For novel sensor technology, two nano technologies for pH indication are investigated: a specific pH sensitive molecule and nano structure carbon dots. The work on carbon dots was presented at the TNNN conference in Trondheim.

Post-pandemic 2022 has truly accelerated the collaboration across the centre. The physical workshops gave us valuable insights and discussions for the work ahead. The high value of cross disciplinary research for enabling a smart sensor network is quite evident, and there is very good engagement of all partners in the centre. Throughout the year we have also welcomed three new PhD students. The PhDs and MSc students in SFI Smart Ocean all work closely with industry partners in the centre and are valuable ambassadors for both research and education. – *Camilla Sætre, UiB, Work Package Manager, WP1*

Reliable and flexible underwater communication network
An internal report on requirements, limitations, and possibilities for underwater communications in SFI Smart Ocean was finalized. This report includes information on underwater acoustic communication, subsea optical communication, radio-frequency systems, and cloud facilities. A literature survey and a hardware review shed light on the limitations and possibilities of these technologies. Network technology to be developed must provide reliable and efficient data transfer while limiting network traffic and energy consumption. Various Medium Access Control (MAC) and Network layer protocols were investigated and discussed in a survey conference paper. An eye is also kept on underwater communications standardization activities, including the efforts of the SWiG group.

Underwater communication experiments have started at the Austevoll test site, using various systems available in the project. This includes gaining experience with communication conditions and system performance, as well as interfacing towards sensors.

Efficient and flexible transmission solutions for wireless underwater communications are required, and the design and testing of software defined modems (SDM) proceeded in 2022. The SDM's are prepared for remote access over Internet, and secure communication (VPN) has been implemented. This is an essential functionality for efficient field trials and remote modifications after deployment. Further preparations for implementation of a compact and power-efficient transceiver for field trials have been carried out. This, together with the rest of the efforts related to wireless underwater communications and network technology, gives us great flexibility in further developments, implementation and testing.

Increased focus on the data flow through the complete system from pre-processing in the sensors via the communication network to the data storage solutions has given us interesting findings. This is an essential activity in the Centre, and will be a main priority in further work.

Integration of equipment and solutions from different consortium partners is an exciting and challenging task, and key to verify the functionality and performance of the innovations in the center. – *Ingvar Henne, Research Director, NORCE*

The SFI Smart Ocean Data and Application Platform

The software technology platform that is to facilitate the integration of the acoustic underwater sensor network data streams and provide data services to applications has been conceptualised. The platform is comprised of a data space service for data sets, a messaging service for real-time data, and security services for authentication and authorisation. In addition, the platform provides an edge integration service targeting the requirements induced using acoustics underwater communication. The set of services allows systems to provide and consume data, and it allows external data sources to be integrated into applications. Initial prototypes of the platform services are now being implemented in collaboration between the research and industrial partners and evaluated in the context of the Austevoll testing facilities. The development undertaken also includes storage of data on the NMDC national infrastructure for research purposes, and the further development of advanced interactive data set visualisation.

Bouvet's participation in SFI Smart Ocean enables the company to stay at the forefront of ocean technology, gaining access to cutting-edge research and collaborating with leading companies and organizations.

The benefits of attending SFI Smart Ocean extend beyond access to research and collaboration opportunities. By participating in this program, Bouvet contributes to building the society of the future by committing to sustainable solutions for the ocean economy. With our partners in SFI Smart Ocean, Bouvet creates digital solutions with great significance for society.

Bouvet has already demonstrated its dedication to sustainable ocean solutions through the successful execution of two summer projects. These projects, completed with eight students from several of the largest student institutes in Norway, resulted in creating of a dataplatform with attached architecture that allows for real-time monitoring and analysis of ocean conditions.. – *Mads Bratland Claussen, Bouvet Norge*

Vidar Forsmo (FFI) deploying equipment for testing at Austevoll. *Photo: Jean-Baptiste Danre, HI*

Developments and tests performed at the Austevoll Research Station

During 2022, all work packages have become involved with developments and testing of equipment. The establishment of two autonomous rigs for sensors and communication systems at the Austevoll Research Station in May 2022 was a key milestone for SFI Smart Ocean. Since then, the project has had a data stream providing oceanographic data from the coastal waters adjacent to the station. Adaptation of the rigs was later performed to provide a near-real-time data flow over a longer time. The key instrument in both rigs is a Aanderaa Seaguard II Acoustic Doppler Profiler, providing a series of hydrographic data. In addition, each rig has an Anderaa SeaBird Microcat CTD. Together, the instruments provide data on wave direction, oxygen, conductivity, turbidity, and temperature. Both rigs communicate via the GSM network, but it is the plan to add underwater communication as well while the communication via the GSM network will serve as a reference.

The sea-cage facility at Austevoll has been replaced during the first months of 2023, and a third rig will soon be placed adjacent to the sea-cages. In contrast to the two other rigs, the third rig will also have the possibility to communicate via cables. Also, an advanced underwater node, obtained from IMR´s collaborating LoVe-project will be placed within the test area at the station.

During the autumn of 2022, the focus of the activities at Austevoll was on underwater communication. The project partners Aanderaa–a Xylem brand, Kongsberg Maritime, W-Sense, Institute of Marine Research, and NORCE Norwegian Research Centre AS have worked together, testing different instruments for acoustic underwater communication. The field trials were combined with testing of the NORCE coastal drone, and two underwater drones: the Seasam by Notilo Plus and Blueye X3 by Blueye robotics, from the MarTERA UNDINA project.

The sensors and communication systems are providing stable data access, and it is very encouraging to confirm that consortium participants are working efficiently together, combining knowledge and technologies into a more complete system.

INTERNATIONAL COOPERATION

Centre partners all have international cooperation and/or offices abroad, and cooperation with the international networks of the partners directly or via affiliated activities is an important part of the focus in the Centre. As SFI Smart Ocean aims at a flexible, vendor neutral network technology, cooperation with end users and vendors on the world market is crucial. Such cooperation will ensure both that the Centre implements standard technology solutions where such are available and maximise impact for the technology solutions developed in the Centre.

The Centre continues the collaborations that were established in 2021 with the international industry standardisation initiative Subsea Wireless Group (SWiG), and the ERANET Cofund MarTERA project "The underwater robotics with multimodal communication and network-aided positioning system" (UNDINA).

In UNDINA, the Centre participants are collaborating with, amongst others, ISEN in France, and this collaboration has during the last year expanded to also include other activities relevant to SFI Smart Ocean.

Further, the Centre has established cooperation with Helmholz Institute for Environmental Research and Max Planck Institute for Medical Research related to anti biofouling treatments for transparent substrates. This activity is crucial for the Centre to make underwater sensors more robust towards biofouling.

The PhD students within software development and their supervisor have established cooperation with Gran Sasso Science Institute in Italy, and as part of their 2022 activities, they visited the institute for common workshops. In addition, the research group in software engineering is cooperating with Chalmers University of Technology (Sweden), and University Sorbonne Paris Nord (France).

In addition to the general cooperation between research groups mentioned above, more specific cooperation has been established with new, international projects funded and established in 2022:

Beatrice Tomasi, NORCE, preparing Seasam drone

The University of Bergen is participating in the SEAS program, a cofund PostDoc mobility program. In relation to this, an American PostDoc has been hired by UiB, and his activities are strongly associated with SFI Smart Ocean. Three more PostDocs will be hired in 2023, working closely with the Centre.

- The Institute for Marine Research was awarded the EU project OLAMUR, focussing on multi use of offshore wind farms. The Centre will cooperate with OLAMUR related to field trials of components from our observation system.

- The Nansen Environmental and Remote Sensing Centre was awarded two international projects: The EU-funded project HiAOOS – High Arctic Observation system, that will cooperate with SFI Smart Ocean related to field trials, and the INTPART-project UAK – Useful Arctic Knowledge, which will be strongly connected to SFI Smart Ocean and work to strengthen education, research, and innovation within ocean observation technologies.

- Metas AS is cooperating with Brazilian partners in the project "Development of a Stand Alone Subsea Instrumentation (SASI) Platform for hydrocarbon leakage detection". They are exploiting common need for data, and share their experiences and relevant data from that project with SFI Smart Ocean.

Additionally, funding applications have been sent to Horizon Europe and the Research Council of Norway together with a long list of international partners, and both the project development work and future potential cooperation projects strengthen our international cooperation and impact.

RECRUITMENT – PHD/POSTDOC

In 2022, three new PhDs started in SFI Smart Ocean.

Keila Lima started working 1. January 2022 on HVL, with Rogardt Heldal and Tosin Oyetoyan as supervisors. Keila is working on software architecture in WP3.

Astrid Marie Skålvik also started working 1. January 2022. She is employed at UiB with supervisors Camilla Sætre (UiB), Kjell Eivind Frøysa (HVL) and Ranveig Nygaard Bjørk (NORCE). Astrid Marie is working in WP1, with self-diagnostics and self-calibration methodologies for underwater sensors.

Amr Abboud started in the centre in September 2022, at UiB. Supervisors are Per Lunde (UiB) and Jan Kocbach (NORCE), and Abboud will be working with Ultrasonic guided waves for non-destructive testing in multilayer media in WP1.

Also, a few associated PhDs and postdocs have joined in 2022, funded by other sources.

Daniel Koestner (UiB) is a postdoc in marine optics who started in June 2022. Daniel is funded by the SEAS Fellowship Programme at UiB, a COFUND-project under Marie Skłodowska-Curie.

And finally, in December 2022, **Shea Cheatham** started as a PhD in Marine Optics at UiB, with Børge Hamre, Camilla Sætre, Arne Kristoffersen (all UiB) and Christian Pedersen (DTU) as his supervisor-team.

ASTRID MARIE SKÅLVIK
UiB

KEILA LIMA
HVL

Advances in sensing technologies have allowed us to collect terabytes of marine data on the well-being and sustainable use of ocean resources.

A main challenge is that that marine data is often contaminated due to numerous physical impacts of the ocean and technical limitations of data networks and sensors. Furthermore, it is currently a labour-intensive task to ensure that data of sufficiently high-quality is used in data-driven application and hence serve as basis for decision making.

In my PhD project, I am conducting research into software-based solutions for automated data quality checks. The aim is to reduce labour costs in data quality assessment, shorten data release time, and thereby support more effective and accurate data-driven application and decision making. – *Ngoc Thanh Nguyen, PhD candidate, HVL*

AMR ABBOUD
UiB

DANIEL KOESTNER
UiB

SHEA CHEATHAM
UiB

COMMUNICATION & DISSEMINATION

Our website, www.sfismartocean.no, contains public information, along with news about the Centre. Our LinkedIn profile is used for publication about recent, important happenings and upcoming events.

An open seminar series was started in September 2022. Topics from the seminars cover results from the Centre activities and other associated activities. The seminars serve as a channel for information both internally in the Centre and externally.

We have been very visible in both the scientific communities, industry and in the educational system. A range of publications, presentations and other contributions have been prepared:

- **14** scientific papers published in journals or conference proceedings
- **22** scientific presentations, posters or guest lectures at industrial and scientific conferences, workshops and seminars
- **8** overall presentations of SFI Smart Ocean and activities in the Centre to industry and other users
- **8** contributions to external papers, web pages and exhibitions
- **12** Master's students completed studies related to SFI Smart Ocean.

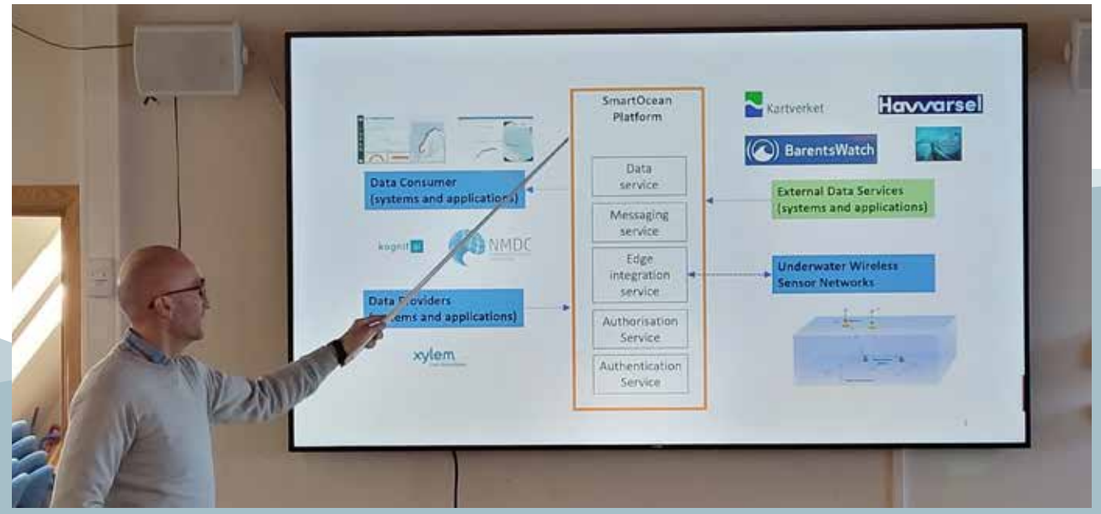
Three of our PhD students have, as mentioned in the Summary section, been well recognised for their contributions:

- PhD student Astrid Marie Skålvik, UiB, won the best student paper award at the Underwater Technology Conference, which is considered by many to be the best underwater technology industry conference. The award-winning presentation was entitled “Smart subsea wireless sensing – Challenges, limitations, and promising measurement strategies for ensuring data quality and reliability”.

- PhD student Keila Lima, HVL, won, together with second author PhD student Ngoc-Thanh Nguyen, HVL, and the rest of the co-authors the best paper award at PROFES, the International Conference on Product-Focused Software Process Improvement, which is among the top recognized software development and process improvement conferences. The award-winning paper was entitled, "Marine Data Sharing: Challenges, Technology Drivers and Quality Attributes".

An example of general dissemination towards the Norwegian politicians, industry and research was the article (in Norwegian) “Fremtiden under vann er trådløs” which was published in an insert in the newspaper “Dagens Næringsliv” during Arendalsuka. Arendalsuka is the largest political gathering in Norway held annually since 2012. The event’s mission is clear: strengthen the belief in political empowerment and democracy through open debate and involvement.

Internally in the Centre, communication was significantly strengthened by the two physical workshops held over two days each, one in May and one in October.



Lars M. Kristensen presenting results from WP3

ANNUAL ACCOUNTS 2022

FUNDING	AMOUNT (1000 NOK)
THE RESEARCH COUNCIL	10 376
UIB	2 356
RESEARCH PARTNERS*	4 147
ENTERPRISE PARTNERS**	5 066
PUBLIC PARTNERS***	122
TOTAL	**22 067**

COSTS	AMOUNT (1000 NOK)
THE RESEARCH COUNCIL	
UIB	5 295
RESEARCH PARTNERS	13 135
ENTERPRISE PARTNERS	3 515
PUBLIC PARTNERS	122
TOTAL	**22 067**

* *NORCE, HVL, NERSC, IMR, FFI*

** *Aanderaa Data Instruments AS, Monviro AS, TSC Subsea AS, Metas AS, Kongsberg Maritime AS, Tampnet AS, Bouvet Norge AS, Aker BP AS, WSENSE AS, GCE NODE Service AS, GCE Ocean Technology*

*** *Directorate of Fisheries, Petroleum Safety Authority*

PERSONNEL SFI SMART OCEAN 2022

CENTRE ADMINISTRATION

MARIE BUEIE HOLSTAD	UIB	CENTRE DIRECTOR
CAMILLA SÆTRE	UIB	DEPUTY CENTRE DIRECTOR
TERJE RESTAD	UIB	ADMINISTRATIVE MANAGER
KAVITHA ØSTGAARD	UIB	COMMUNICATION MANAGER

KEY RESEARCHERS

		MAIN CONTRIBUTIONS
CAMILLA SÆTRE	UIB	MEASUREMENT STRATEGY & UNCERTAINTY
PER LUNDE	UIB	GUIDED ULTRASONIC WAVES (GUW)/DISTRIBUTED ACOUSTIC SENSING (DAS)
BODIL HOLST	UIB	NOVEL SENSOR TECHNOLOGY & ANTI-BIOFOULING: PH SENSING
AUDUN O. PEDERSEN	UIB	GUIDED ULTRASONIC WAVES (GUW)/DISTRIBUTED ACOUSTIC SENSING (DAS)
TORE SKODVIN	UIB	NOVEL SENSOR TECHNOLOGY & ANTI-BIOFOULING: PH SENSING
ANNE-LENA KAMPEN	HVL	COMMUNICATION PROTOCOLS & NETWORK ARCHITECTURE
KJELL EIVIND FRØYSA	HVL	MEASUREMENT STRATEGY & UNCERTAINTY
LARS M. KRISTENSEN	HVL	ADAPTIVE DATA RETRIEVAL METHODS AND VISUALISATION
ROGARDT HELDAL	HVL	SOFTWARE ENG. METHODOLOGY: SOFTWARE QUALITY, MODELLING & VALIDATION
TOSIN D. OYETOYAN	HVL	SOFTWARE ENG. METHODOLOGY: SOFTWARE QUALITY, MODELLING & VALIDATION
BEATRICE TOMASI	NORCE	UNDERWATER COMMUNICATIONS: REQUIREMENTS, LIMITATIONS, & POSSIBILITIES
BÅRD HENRIKSEN	NORCE	UNDERWATER COMMUNICATIONS: REQUIREMENTS, LIMITATIONS, & POSSIBILITIES
INGVAR HENNE	NORCE	UNDERWATER COMMUNICATIONS: REQUIREMENTS, LIMITATIONS, & POSSIBILITIES
JEREMY COOK	NORCE	ADAPTIVE DATA RETRIEVAL METHODS & VISUALISATION
PETER JAMES THOMAS	NORCE	NOVEL SENSOR TECHNOLOGY – DISTRIBUTED ACOUSTIC SENSING (DAS)
TOR LANGELAND	NORCE	ADAPTIVE DATA RETRIEVAL METHODS & VISUALISATION
JAN ERIK STIANSEN	IMR	MAIN PILOT DEMONSTRATOR: AUSTEVOLL OCEAN TECH TESTING FACILITY
ØIVIND BERGH	IMR	MAIN PILOT DEMONSTRATOR: AUSTEVOLL OCEAN TECH TESTING FACILITY
HANNE SAGEN	NERSC	MESO-SCALE PILOT DEMONSTRATOR
ESPEN STORHEIM	NERSC	MESO-SCALE PILOT DEMONSTRATOR
ROALD OTNES	FFI	UNDERWATER COMMUNICATIONS: REQUIREMENTS, LIMITATIONS, & POSSIBILITIES
PAUL VAN WALREE	FFI	UNDERWATER COMMUNICATIONS: REQUIREMENTS, LIMITATIONS, & POSSIBILITIES
VIDAR FORSMO	FFI	SENSOR TECHNOLOGY ADAPTION
INGER M. GRAVES	AADI	SENSOR TECHNOLOGY ADAPTION
JAN FLATLANDSMO	AADI	SOFTWARE TECHNOLOGY
E.J. ALTAMIRANDA-MALDONADO	AKER BP	UNDERWATER COMMUNICATIONS: REQUIREMENTS, LIMITATIONS, & POSSIBILITIES
MADS B. CLAUSSEN	BOUVET ASA	SYSTEM ARCHITECTURE FOUNDATION FOR A SMART OCEAN SOFTWARE SYSTEM
JAN ERIK FAUGSTADMO	KONGSBERG	UNDERWATER COMMUNICATIONS: REQUIREMENTS, LIMITATIONS, & POSSIBILITIES
MICHAEL T. SMITH	METAS	MEASUREMENT STRATEGY & UNCERTAINTY
STEINAR BJØRNSTAD	TAMPNET	NOVEL SENSOR TECHNOLOGY – DISTRIBUTED ACOUSTIC SENSING (DAS)
RENATE GRINDHEIM	TSC SUBSEA	MEASUREMENT STRATEGY AND UNCERTAINTY, PILOT DEMONSTRATOR OFFSHORE WIND
KJETIL ÅSGARD	MONVIRO	MEASUREMENT STRATEGY & UNCERTAINTY
CHIARA PETRIOLI	WSENSE	UNDERWATER COMMUNICATIONS: REQUIREMENTS, LIMITATIONS, & POSSIBILITIES

POSTDOCS WORKING ON CENTRE PROJECTS WITH FINANCIAL SUPPORT FROM OTHER SOURCES

DANIEL KOESTNER	H2020: SEAS-PROJECT	MARINE OPTICS

PHD STUDENTS WITH FINANCIAL SUPPORT FROM THE CENTRE BUDGET

WIKTORIA SZAPOCZKA	UIB	ANTI-BIOFOULING & PH SENSOR
ASTRID MARIE SKÅLVIK	UIB	SELF-DIAGNOSTICS AND SELF-CALIBRATION METHODOLOGIES FOR UNDERWATER SENSORS
KEILA LIMA	HVL	SOFTWARE ARCHITECTURE
AMR ABBOUD	UIB	ULTRASONIC GUIDED WAVES FOR NON-DESTRUCTIVE TESTING IN MULTILAYER MEDIA

PHD STUDENTS WORKING ON CENTRE PROJECTS WITH FINANCIAL SUPPORT FROM OTHER SOURCES

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HÅVARD S. UGULEN	UIB	MARINE OPTICS
SHEA CHEATHAM	UIB	MARINE OPTICS

MASTER'S STUDENTS

ANDREAS GARVIK	HVL	A COMPILER & RUNTIME ENVIRONMENT FOR EXECUTION OF COLOURED PETRI NET MODELS
SONDRE L. GJESDAL	HVL	A MODULER IDE FOR CPN MODELS
MARCUS K. MORLANDSTØ	HVL	PROTOTYPING & EVALUATION OF SENSOR DATA INTEGRATION IN CLOUD PLATFORMS
BENEDICTE JENSEN & IDA GRIEG-LIE	HVL	SHARED DATA AND SUSTAINABILITY IN THE MARINE INDUSTRY: A CASE STUDY OF THE SFI SMART OCEAN PROJECT
BJØRNAR H. RØSVIK	UIB	MULTIDISCIPLINARY MOORINGS IN THE ARCTIC & COASTAL AREAS
MIRANDA R. VEIM	UIB	SIMULATION-BASED METHODS OF SPHERE SELECTION FOR CALIBRATION OF BROADBAND ECHOSOUNDERS IN FISHERIES ACOUSTICS
MAREN F. RONG	UIB	APPLICATION OF CW AND FM SONAR TECHNOLOGY TO DETECT A DECREASE IN AIR IN THE SWIM BLADDER OF ATLANTIC SALMON, MEASUREMENTS & MODELING
PHILIP TRÆTTEBERG	UIB	AN ANALYSIS ON MATERIAL CONSTANTS ESTIMATION FOR THE LOW CHARACTERISTIC IMPEDANCE PIEZOCERAMIC PZ37HD USING MEASUREMENTS & FEM MODELING
CELINE PRØYTZ	UIB	UNDERWATER ULTRASONIC TRANSDUCER TECHNOLOGY. CONSTRUCTION, CHARACTERIZATION & FINITE-ELEMENT MODELLING
ESPEN FOSSE	UIB	FINITE ELEMENT MODELING AND EXPERIMENTAL CHARACTERIZATION OF PIEZOELECTRIC CERAMIC DISK IN AIR
JOACHIM G. KRISTENSEN	UIB	MEASUREMENT CELL FOR SOUND SPEED IN LIQUIDS: THE 3-WAY PULSE METHOD
HANNAH D. S. BENUS	UIB	MEASUREMENT CELL FOR SOUND SPEED IN LIQUIDS: PULSE-ECHO BUFFER ROD METHOD
MARIT N. LUND	HVL	FEATURES IMPACTING THE MESOPELAGICLAYER IN THE OCEAN: A MACHINE LEARNING-BASED APPROACH

PUBLICATIONS 2022

Kampen, A.-L.; Otnes, R. W. *MAC and Network Layer Solutions for Underwater Wireless Sensor Networks*. International Journal On Advances in Networks and Services 2022; Volum 15.(1 & 2) s. 18-28

Ugulen, H.S.; Sandven, H.; Hamre, B.; Kristoffersen, A.S.; and Sætre, C. *Efficient Monte Carlo simulation reveals significant multiple scattering errors in underwater angular scattering measurements.* Opt. Express 30, 10802-10817 (2022)

Bernard, C.; Bouvet, P.-J.; Tomasi, B. *Spread Spectrum Modulation with Grassmannian Constellations for Mobile Multiple Access Underwater Acoustic Channels*. Sensors 2022, 22, 8518.

Lima, K.; Nguyen, N.; Heldal, R.; Knauss, E.; Oyetoyan, T.D.; Pellicione, P.; Kristensen, L.M. *Marine Data Sharing: Challenges, Technology Drivers and Quality Attributes*. In: Taibi, D., Kuhrmann, M., Mikkonen, T., Klünder, J., Abrahamsson, P. (eds) Product-Focused Software Process Improvement. PROFES 2022. Lecture Notes in Computer Science, vol 13709. Springer, Cham. (2022).

Pedersen AO.; Lunde P.; Tichy FE. & Korneliussen RJ. *Finite-amplitude sound propagation effects in volume backscattering measurements for fish abundance estimation*. Acta Acustica, 6, 14. (2022)

Sæther, M.M.; Midtbø, S.H.; Lunde, P. *Interaction of three-dimensional acoustic beam with fluid-loaded solid plate: Axial near- to far-field transmission at normal beam incidence.* Ultrasonics, Volume 125, 2022.

Sæther, M.M.; Almenningen, S.; Ersland, G.; Lunde, P. *Compressional wave phase velocity measurements during hydrate growth in partially and fully water saturated sandstone.* Fuel, Volume 324, Part A, 2022.

Mosland; E., N.; Kocbach; J.; Storheim; E.; Lunde; P. *Radiation in air from a piezoelectric ceramic disk in radial mode vibration. Contributions from front, side and rear surfaces*. Proc. 45th Scandinavian Symposium on Physical Acoustics, Online, Jan 31 – Feb. 1, 2022.

Pedersen; O., A.; Lunde; P.; Korneliussen; R. J. and Tichy, F. E. *Finite-amplitude sound propagation effects in fish abundance estimation.* Proc. 45th Scandinavian Symposium on Physical Acoustics, Online, Jan 31 -Feb. 1, 2022

Sæther; M., M.; Lunde; P. *Ultrasonic beam transmission in the backward and forward-wave frequency-wavenumber bands of a fluid-embedded steel plate*. Proc. 2022 IEEE International Ultrasonics Symposium, Venice, Italy, 10-13 October 2022

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Ågren, S.M.; Heldal, R.; Knauss, E.; Pellicione, P. Agile Beyond Teams and Feedback Beyond Software in Automotive Systems in IEEE Transactions on Engineering Management, vol. 69, no. 6, pp. 3459-3475, Dec. 2022

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PRESENTATIONS & POSTERS 2022

Skålvik, A.M.: "Smart subsea wireless sensing - Challenges, limitations, and promising measurement strategies for ensuring data quality and reliability", UTC–Underwater Technology Conference

Bergh, Ø. *et al*: "A local scale demonstrator for a marine observation system with autonomous sensors and wireless communication", UTC–Underwater Technology Conference

Thomas, P.T. *et al*: «Distributed fibreoptic sensors and their applications», The Sensor Decade conference

Solberg, M., Lunde, P., Vestrheim, M.: "Energy-flux density in real-, imaginary-, and complex-valued branches of Lamb modes in an isotropic plate", 45th Scandinavian Symposium on Physical Acoustics, Online

Sæther, M., Lunde, P., Vestrheim, M.: "Ultrasonic beam transmission through a water-immersed steel plate in the vicinity of the ZGV angle", 45th Scandinavian Symposium on Physical Acoustics, Online

Bergh, Ø.: «Hvordan samarbeide til havs», AquaNext 2022

Cook, J.: "Digital ocean", Forskningsdagene 2022 – The state of the ocean

Lima, K.: "SmartOcean IoT middleware and metrics", Smart City seminar/workshop Italy

Nguyen, N.: "On cost-effective and real-time marine data quality control: an unsupervised machine learning approach", Smart City seminar/workshop Italy / Robotics and Software Engineering

Bergh, Ø.: "IMR in SmartOcean, LoVe, ClimeFish and CERES", ClimateFutures seminar, Salmon Eye, Rosendal

Ugulen, H.S.: "Simulation and correction of LISST-VSF multiple scattering errors", Ocean Optics 2022

Sætre, C.: "Underwater optical communications and contribution from forward scattered light", Ocean Optics 2022

Kristensen, L.M.: "Software Technology for SmartOcean", EU2020 COEMS Forsterk Workshop

Szapoczka, W.K.: "Fluorescence Intensity and Fluorescence Lifetime Measurements of Various Carbon Dots as a Function of pH presented with Background Information on the Development of a Novel, Affordable, Compact, and Stable Optical pH-sensor for Long-term Seawater Monitoring Applications", The 1st TNNN Conference 2022