2022 ANNUAL REPORT

CIUS

Centre for Innovative Ultrasound Solutions

sfi Centre for Research-based Innovation

cius

NTNU Norwegian University of Science and Technology

Academic Partners

NTNU Norwegian University of Science and Technology

SINTEF

UiO : University of Oslo

USN University of South-Eastern Norway

Industry Partners

equinor

Archer

AUROTECH ULTRASOUND

InPhase Solutions

GE Vingmed Ultrasound

GE Healthcare Women's Health Ultrasound

MEDISTIM

KONGSBERG

NDT GLOBAL

Sensorlink

EXACT THERAPEUTICS

Re{Lab}

xfab

Health Sector Partners

HELSE MIDT-NORGE

HELSE NORD-TRØNDELAG

ST. OLAVS HOSPITAL TRONDHEIM UNIVERSITY HOSPITAL

SØRLANDET SYKEHUS

Levanger kommune

VERDAL KOMMUNE

Associated Partner

FFI Forsvarets forskningsinstitutt Norwegian Defence Research Establishment

Host

NTNU | Faculty of Medicine and Health Sciences
Department of Circulation and Medical Imaging

Contents

Photo: Kari Williamson/NTNU

Svein-Erik Måsøy
Centre Director

Dear CIUS family

In 2022, CIUS passed an important milestone: Two CIUS inventions were commercialised by GE Vingmed Ultrasound globally in a total of 6 different products. This is what CIUS is all about, creating innovations from research that have an impact on the world. Our partner GE Vingmed Ultrasound has more than 40% of the global cardiovascular ultrasound market, so these inventions will be used while examining the hearts of many patients in the years to come. You can read more about one of these technologies (cSound Adapt) in this report (p.42).

In addition, 3 new CIUS developed methods have been adopted by user and industrial partners; 28 industry-oriented R&D results have been reported based on the CIUS collaboration; 4 new innovations have been submitted in 2022; 1 patent has been approved in the USA; 65 articles have been published in peer-reviewed international journals, 46 conference contributions have been made; 1 PhD directly funded by CIUS was defended and 5 in related projects; 11 students were supervised to an MSc or Forskerlinjestudent degree. This represents a considerable effort from all our researchers and partners activities.

CIUS activity is at an all-time high, also coinciding with the soon-to-come winding down of the project. We only have one more year of full operation before the centre comes to halt in April 2024. I would like to thank all contributors to CIUS for all their effort in 2022 and hope for a prosperous 2023 for the centre.

Brita Pukstad
Vice Dean

Greetings from the Vice Dean

Knowledge for a better world is NTNU's strategy, and our strength lies in our competence in science and technology. Great results are achieved through interdisciplinary and collaborative work. Centres for research-based innovation, such as CIUS, are an important part of this. The Faculty of Medicine and Health Sciences (MH) at NTNU is proud to be the host for such an outstanding centre.

Health for a better world is the strategy of the MH faculty. Our aim is to develop knowledge, skills and solutions that contribute to good health through research, education, innovation, and dissemination while staying true to the UN Sustainable Development Goals. While COVID-19 is still a part of our everyday lives, and war in Europe threatens democracy, we see more than ever how important it is to have a global perspective and awareness of ethical responsibilities and integrity in our research and education. Our students are our future, and we need to stay true to ethical principles and be good role models in all aspects of scholarly activities. Our researchers continue to publish their work, PhD-dissertations are defended both physically and on digital platforms, and new ideas are being brought forward to be patented and commercialised. CIUS has contributed greatly here, and we are excited to be a part of it.

The strategy Health for a better world is indeed ambitious. We need to continue to find ways to enable a fairer distribution of knowledge and resources, fight inequality and strengthen our commitment to address the challenges in global health and of climate change. The pandemic has required us to travel less, and with fewer flights and a reduced carbon footprint we have started to contribute to these global challenges. We have learnt that it is possible to collaborate through digital platforms. Although virtual networking cannot fully replace the opportunities that arise in face-to-face meetings, we will continue to travel less in the future and take steps to reduce our effect on the climate.

An increased focus on innovation and collaboration between academia, industry and the public sectors is central for the MH Faculty. We are pursuing these goals at every level in the organisation and continue to have high expectations of our student-lead health innovation lab, DRIV NTNU. DRIV is established to facilitate innovative activity for our future health workers, academic colleagues, and collaborators, and is open to all students interested in health innovation. We continue to support and contribute to an increasing demand in innovative skills and knowledge by supporting the School of Health Innovation for PhD students, clinicians, postdoctoral fellows, and supervisors. We also pursue the opportunities our membership in EIT Health will bring in the coming years.

The centres for research-based innovation, such as CIUS, embody the culture NTNU aspires to in its strategy. CIUS manages to maintain its scientific and innovative activity, creating great value in working with ultrasound technologies across different academic fields in collaboration with industrial partners.

We look forward to continuing our engaging collaboration with CIUS in 2023!

Eva Nilssen
Board Leader

Greetings from the CIUS Board

We are now in the last year of full activity for the CIUS programme. And although it is, and has been, a great experience to be part of the CIUS programme, it is time to focus on the future: The future for ultrasound research in Norway and how this impacts our industry and products.

CIUS is now fully operational for all areas: Medical, O&G and Maritime. This is a great foundation for applying for a new SFI. RCN has confirmed that we can apply for new SFI with the same/similar partner organisations, but with new focus areas and some new partners. The preparation for new SFI applications has already started – the working title is "CIUS-2".

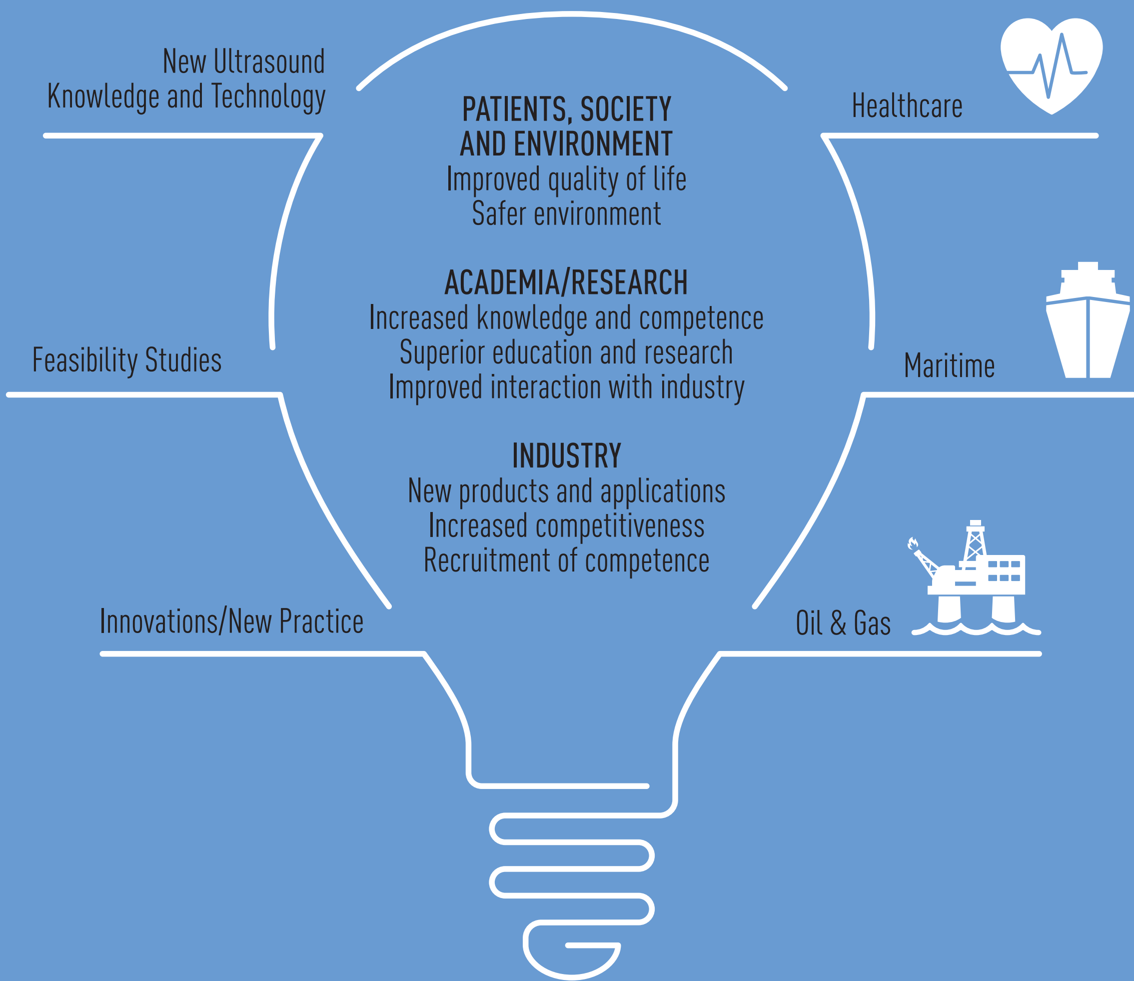
Experience and learnings from CIUS are a great input for improvements for the next SFI. This is some feedback from the industry partners:

- There is a need to be more specific about the expected outcome of the research activity. With a more detailed description of the planned research, the expectation to the parties involved is clarified, and it is easier to adjust according to research findings as the programme progresses.
- There is also a need for a better overview of how the programme resources are to be distributed for each domain. This is correlated to cash and in-kind contributions, but with adjustments for differences in equipment costs depending on the industry (O&G vs. Medical for example).
- Networking with the other partners – academic and industrial – is a key advantage of being a participant in the consortium. Although direct engagement from the smaller partners is limited, the research and the results are still important and relevant – including access to academic expertise in the field and networking.
- It has been a good experience to have an industry partner, which covers several of CIUS' domains (InPhase Solutions). They understand the needs of several of the partners, and with this background are also able to look for further opportunities for ultrasound technology utilisation. For example: Using ultrasound to solve fish-farming challenges.
- Dissemination of knowledge between academic and industry researchers is of great value for both parties. The academic researchers have access to state-of-the-art equipment and tools together with world-class knowhow in the respective industries. Industry research staff is motivated by working with other top researchers in the field, in academia and with other industry partners, creating technology with global impact.

The SFI programme is a very attractive programme for both academia and industry, and so it is important that we focus on our key differentiators. CIUS research has physical results such as sensors, probes, electronics, etc. This is not so common in other SFIs and it is therefore important that we have a solid plan for these results. Also, we will utilise AI in CIUS-2, but we have to make sure that our SFI is not presented as "yet another AI project". With the results that CIUS has achieved, the consortium is well positioned for a successful application for the next SFI grants.

CIUS Idea

CIUS delivers novel ultrasound technology solutions for the benefit of the involved partners, new diagnostic tools for the benefit of patients and the healthcare providers, important knowledge disseminated in highly recognised scientific journals, and skilled personnel to further exploit the future potential of ultrasound imaging in Norwegian industries, healthcare and academia.



The CIUS Concept

The Centre for Innovative Ultrasound Solutions (CIUS) combines frontier academic research in ultrasound technology development with innovation in leading Norwegian ultrasound companies working in medical, maritime, and oil & gas application areas.

The core of CIUS' projects revolves around three main topics within the three application areas: Healthcare: Improvement of cardiovascular ultrasound; Maritime: Sonar imaging and fish health; Oil & gas: Monitoring the integrity and safety of wells and pipelines.

The potential impact of CIUS innovations within these areas is described with examples from CIUS' partners:

- Healthcare: Cardiovascular disease is the leading cause of death and morbidity worldwide. Ultrasound is the leading image modality for assessing cardiovascular disease. GE Vingmed Ultrasound is the world leader in cardiovascular ultrasound, and their systems are used to investigate more than 300 000 people on a daily basis.
- Maritime: More than 90% of the global fleet mapping the world's fishing resources, and therefore determining quotas for fishing, use SONARs from Kongsberg Maritime Subsea. Also, 99% of the ocean floor is still unexplored and KM is a world leader in SONARs and AUVs for seabed mapping. Furthermore, Norwegian fish farming has a turnover of more than NOK 65 million annually – CIUS is exploring the use of ultrasound to improve the health of farmed fish/broodfish with InPhase Solutions, AquaGen and Mowi.
- Oil & gas: Equinor is going to plug & abandon (P&A) thousands of wells on the Norwegian Continental Shelf in the next 20 years. Assessing the integrity and safety of operating wells and verifying that the downhole well barriers are fit for permanent P&A, both rely heavily on sonic and ultrasonic borehole logging and imaging. Advances within these domains enable cost-efficient abandonment methods and ensure that the plugged wells are environmentally safe for generations to come.

Ultrasound technology as used in the three sectors has a tremendous unexplored potential for meeting future challenges. In CIUS, industry, academia, public institutions, and private research foundations join forces and explore synergies across disciplines, leveraging next-generation ultrasound technology for a better world. Key ultrasound research tasks are within transducer design, acoustics and image formation, Doppler and deformation imaging, as well as image analysis and visualisation. By applying these technologies to specific innovation goals within each sector, significant business opportunities in the international market will be achieved. CIUS will by unique competence and innovations, secure long-term competitive advantage within areas where Norway is internationally recognised for excellent research, innovation, and product deliveries.

CIUS is hosted by the Department of Circulation and Medical Imaging, Faculty of Medicine and Health Sciences at the Norwegian University of Science and Technology (NTNU), Norway's largest university. The ultrasound group at NTNU is known for its expertise within ultrasound research and innovation in healthcare through 40 years. Expertise and research facilities are joined in a virtual laboratory organisation including selected Norwegian academic institutions and important cornerstone enterprises as well as several small-to-medium enterprises (SMEs) in Norway. CIUS encompasses 4 research partners, 13 industrial/corporate partners, and 6 healthcare user partners.

Research Methodology

The research methodology in CIUS is an iterative process between curiosity-driven technological development and user-involved feasibility studies in laboratories in maritime and oil & gas settings, and in the clinic.

A close interaction with user partners ensures that all initiated projects are based on future needs in the different sectors. A large multidisciplinary research environment has been established across geographical locations (NTNU, Trondheim– UiO, Oslo – USN, Horten), which include scientists and engineers with backgrounds in acoustics, physics, mathematics, electronics, and computer science. Medical doctors and other healthcare personnel are included in clinical studies. Most of the budget is allocated to researcher training at the PhD and Postdoc level. The aim of these activities is to identify new innovations that can be brought to market by our corporate partners. The ultimate goal is that the new innovations created in CIUS will generate a large positive impact for Norwegian ultrasound research, the CIUS corporate partners and the healthcare sector.

Overarching Goals

1. To be a world-leading centre for research and innovation in next-generation ultrasound imaging, improving patient care, harvesting of ocean resources, and for environmental monitoring and safety.

2. To extend and strengthen the innovation culture with emphasis on rapid translation from idea to practical applications and solutions needed to facilitate new growth for the industries.

3. To be the main educational and knowledge centre for ultrasound technology to ensure sufficient competence and recruitment needed by Norwegian industries, academia, and the healthcare sector.

Organisation and Location

SFI CIUS is hosted by the Faculty of Medicine and Health sciences (MH) at the Norwegian University of Science and Technology (NTNU), and localised to the Department of Circulation and Medical Imaging.

Physically the academic research activity is divided across four institutions: NTNU, University of South-Eastern Norway (USN), University of Oslo (UiO), and SINTEF. SFI CIUS has 13 corporate partners: GE Vingmed Ultrasound, GE Healthcare Women's Health Ultrasound (GEWHUS), Medistim, Aurotech and EXACT Therapeutics within the medical sector; and Equinor, NDT Global, Sensorlink, InPhase Solutions and Archer BTC within the oil & gas sector: Kongsberg Maritime within the maritime sector, X-Fab for advanced analogue and mixed-signal process technologies and ReLab developing transducers across sectors. In addition, there are six user partners within the medical health provision sector: St. Olavs hospital, the Central Norway Regional Health Authority, Nord-Trøndelag Hospital Trust, Levanger and Verdal Municipalities, and Sørlandet Hospital Health Authority. CIUS also has an associated partner: the Norwegian Defence Research Establishment (FFI).

The research activity is divided into 9 work packages (WPs). USN is responsible for WP1, UiO for WP2, while WP3-7 are located to NTNU. WP8-9 are in collaboration with the industrial partners and headed by CIUS' industrial liaison. Activity connected to WP1 and WP2 is also localised to the CIUS host. There is extensive collaboration across WPs, and an iterative process between development of new technologies in WP1-4, and their validation and feasibility testing in WPs 5-9 is critical to SFI CIUS' success.

The daily activity of the centre is overseen by Centre Director Svein-Erik Måsøy. Further, the CIUS administration includes the Project Coordinator and Administrator Line Skarsem Reitlo, Communication and Web Officer Kari Williamson and Financial Advisor/Project Economists Urszula Mochocka and Aleksandra Hvamb. Innovation in CIUS has benefited from the expertise of Innovation manager Svein Erik Gaustad.

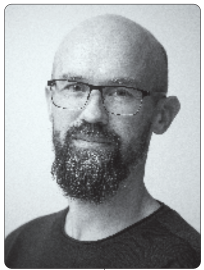
Each WP has a primary investigator (PI) who oversees the respective WP's research activity. All CIUS activities are supervised and directed by a working Board of Representatives consisting of nine members with a majority from the corporate partners. The Board Leader is Eva Nilssen, Program Manager, GE Vingmed Ultrasound.

MANAGEMENT

Board Leader Eva Nilssen, GE Vingmed Ultrasound

Vice Dean Brita Solveig Pukstad, NTNU

Centre Director Svein-Erik Måsøy, NTNU



CIUS

BOARD

ELECTED BOARD REPRESENTATIVES AMONG THE CORPORATE PARTNERS

Erik Swensen, Medistim

Hanne Martinussen, Sensorlink

APPOINTED BOARD REPRESENTATIVES

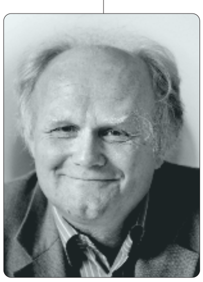
Kjell Salvesen, NTNU

Trym Holter, NTNU

Helge Haarstad, St. Olavs hospital

Pål Hemmingsen, Equinor

Frank Tichy, Kongsberg Maritime



Olav Haraldseth, NTNU

SCIENTIFIC ADVISORY BOARD

Dr. Philippe Blondel, Senior Lecturer, University of Bath

Anna Shaughnessy, previous Director of Earth Resources Laboratory, MIT

Dr. Iacob Mathiesen, CSO, Otivio, Oslo

Professor Jenny Dankelman, MISIT Group, Delft University of Technology

WORK PACKAGE LEADERS


Professor Lars Hoff, USN

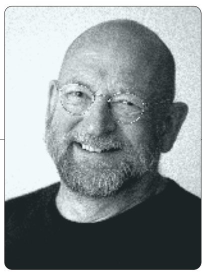

Professor Sverre Holm , UiO


Jørgen Avdal, NTNU


Professor Lasse Løvstakken, NTNU


Professor Asta Håberg, NTNU


Head of Cardiology
Ole Christian Mjølstad, NTNU/St.Olavs


Professor Asbjørn Støylen, NTNU

INNOVATION TEAM


Centre Director
Svein-Erik Måsøy, NTNU


Innovation Manager
Svein-Erik Gaustad, NTNU

WORK PACKAGE SUPERVISORS


Hefeng Dong, NTNU


Trond Ytterdal, NTNU


Tonni Franke Johansen, NTNU/Sintef


Catharina de Lange Davies, NTNU

ADMINISTRATION


Kari Williamson


Line Skarsem Reitlo


Urszula Mochocka


Aleksandra Hvamb

Partners and Collaborations

CIUS has partnered with important cornerstone enterprises, SMEs, academic institutions, and the healthcare sector.

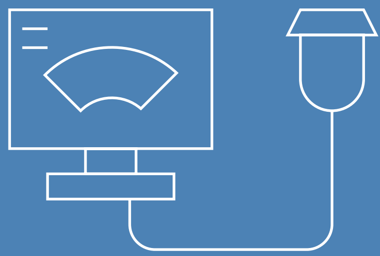
Academic Partners
Norwegian University of Science and Technology (NTNU)
SINTEF
University of Oslo (UiO)
University of South-Eastern Norway (USN)

Industry Partners
AUROTECH ultrasound AS
Archer - Bergen Technology Center
Equinor ASA
EXACT Therapeutics
GE Vingmed Ultrasound AS
GE Healthcare Women's Health Ultrasound
InPhase Solutions AS
Kongsberg Maritime Subsea AS
Medistim ASA
Sensorlink AS
X-FAB Semiconductor Foundries GmbH
ReLab
NDT Global

Health Sector Partners
Helse Midt-Norge (Central Norway Regional Health Authority)
Helse Nord-Trøndelag (Nord-Trøndelag Health Trust, Levanger Hospital)
St. Olavs hospital (Trondheim university hospital)
Innherred-samkommune (Innherred joint county primary health care)
Sørlandet sykehus HF (Sørlandet Hospital health authority)

Associated Partner
Forsvarets forskningsinstitutt (Norwegian Defence Research Establishment)

Centre for
Innovative
Ultrasound
Solutions

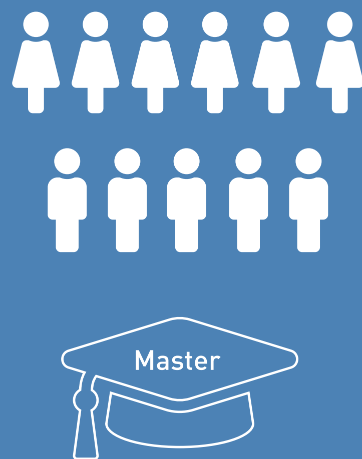


CONFERENCE CONTRIBUTIONS: 46

CIUS 2022

INNOVATION STATISTICS

- 6 NEW PRODUCTS
- 28 NEW METHODS/PROCESSES
- 1 PATENT APPLICATION
- 4 DISCLOSURE OF INVENTIONS
- 65 JOURNAL AND PROCEEDINGS ARTICLES




e4D probes.
Past, present....
2002
2010
2012
2019

Ole Marius Hoel Rindal and Anders Emil Vrålstad looking at a transesophageal ultrasound probe used to image the heart during the GE Vingmed Ultrasound company visit, CIUS Spring Conference 2022. Photo: Line Skarsem Reitlo/NTNU

1

Lars Hoff, Professor,
University of South-Eastern Norway (USN)
WP Leader

Transducer and Electronics

The ultrasound transducer and its electronic interface are essential components in any ultrasound system. WP1 covers research for design, modelling, fabrication, and characterisation of ultrasound transducers and dedicated electronics. Research topics are 1D and 2D transducer arrays, electronics for high-density arrays, transducers for harsh environments, and multi frequency band transducers. These tasks are at the core of CIUS and involve all applications and partners.

WP1-1: Acoustic Source Characterisation and Optimisation

Good theoretical models are essential for designing optimal ultrasound transducers. We have developed an extensive software library for a variety of transducer designs and characterisation methods. These methods are being continuously developed. Likewise, good experimental characterisation methods are essential to investigate the designs. The characterisation and fabrication activities are in the MST-lab at USN, providing access to equipment for characterisation of microstructures and materials. The characterisation methods are under constant development, to better determine e.g., acoustic material parameters, electro-acoustic transfer functions, beam patterns, and pulse shapes.

WP1-2: Integrated High-performance Transducer Array Electronics

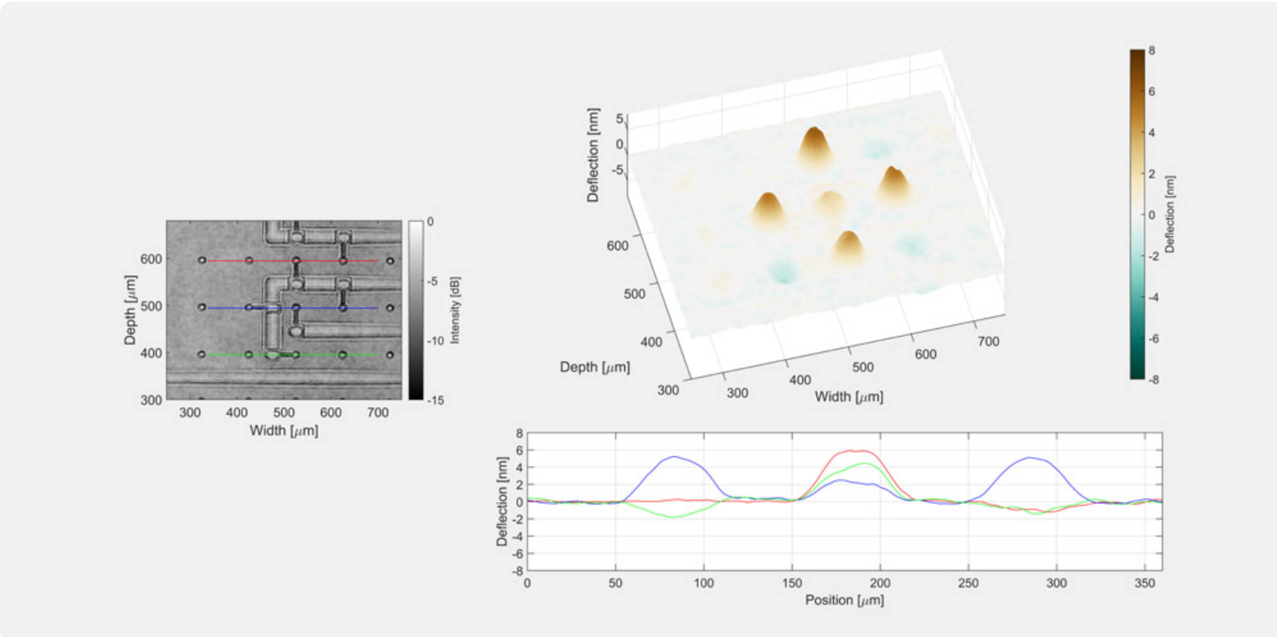
New high-density ultrasound arrays require electronics to be moved closer to the transducer. In maritime acoustics, this means moving electronics to the sonar head, while in medical ultrasound, from the scanner to the probe. A purely digital interface between the system and the transducer is preferred. In WP1, we are developing integrated circuits for low-noise receiving amplifiers, analogue-to-digital converters, and high-voltage transmitters to be integrated with the transducer inside the probe head.

WP1-3: Embedded Ultrasonic Sensors

The main emphasis in this sub-WP is on transducers that need to survive and perform well in harsh environments, such as the high pressures and temperatures found in oil wells. We explore new materials and fabrication methods to ensure reliable operation under these conditions. Methods developed here can also contribute to improved robustness and reliability of transducers operating under standard conditions.

WP1-4: Dedicated High-frequency and Multi-Bandwidth Transducers

Novel applications of ultrasound require transducers covering wider frequency bands than previously possible. Examples are nonlinear imaging methods, combined therapeutic and diagnostic ultrasound applications, and small, low-power systems requiring more functionalities put into one sensor. These needs are addressed through research on different novel technologies. We explore new piezoelectric structures with one or several active materials, and we look at micromachined silicon transducers, CMUT and PMUT, either alone or combined with piezoelectric bulk-wave structures.



Vibration pattern at the surface of a PMUT, piezoelectric micromachined ultrasound transducer, measured with a Lyncee Tec Digital Holographic Microscope. The picture shows vertical deflection in nanometers of a group of PMUT membranes driven at frequency 12.6 MHz. Illustration: Amirfereydoon Mansoori and Lars Hoff, USN

Activities in 2022

All positions in WP1 have been filled and the work is in its finishing phase. One CIUS-associated industrial PhD candidate delivered her thesis in 2022, and three CIUS-funded candidates are writing up their theses and are aiming to deliver in 2023. All these candidates are now employed in the industry doing R&D work closely related to their PhD topics. Three are employed by CIUS industry partners, the fourth by another Norwegian high-tech ultrasound company. We are very happy to see that our candidates are very attractive for the industry, confirming that their competence is relevant.

The work on the hybrid CMUT/piezoelectric ultrasound probes for medical ultrasound imaging progresses in close collaboration with GE Vingmed Ultrasound, GE Parallel Design (Nice) and University of Rome Tre has continued. The low-frequency parts of the transducers have been manufactured at USN and shipped to Rome for attaching the high-frequency CMUTs. We are now waiting to receive the transducers from Rome and are preparing characterisation setups at USN in collaboration with GE Vingmed. Research on very high temperature transducers, defined as 550°C, has started at USN. The work is done by one PhD-student in collaboration with Sensorlink. Two students started master's projects on ultrasound transducer design at USN in 2022.

Three PhD students at the Department of Electronic Systems, NTNU, are working together with GE Vingmed Ultrasound on integrated circuit design for in-probe electronics. The work involves both transmitters and receivers. Five master's students at the Department of Electronic Systems, NTNU, successfully finished their theses on integrated circuit design for ultrasound probes.

Covid-19 restrictions limited some activities in the first months of 2022, especially travel. The first visit to US universities under the INTPART project was done in November 2022.

The main challenges remain as for previous years. High activity poses challenges in lab maintenance and student supervision, and the CIUS-funded researchers are invaluable for our activity. Employees with industry partners contribute to supervision of the PhD-students, which is essential to ensure industry relevance. Our candidates are very attractive for the industry. This is good, but it also causes students to start working before their PhD is finished, delaying delivery of the PhD-thesis.

Going Forward in 2023

We aim to have three PhD-students delivering their dissertations in 2023. A hybrid CMUT/piezoelectric probe shall be tested in our labs and a novel transducer shall be tested at 500°C with industry partner Sensorlink. The bonds with the industrial partners shall be strengthened and form a basis for future collaboration after CIUS, where CIUS-candidates employed in the companies will be a resource.

2

Sverre Holm, Professor,
University of Oslo (UiO)
WP Leader

Acoustics and Beamforming

This work package covers fundamental acoustic wave propagation and image formation (beamforming) research, common to applications in oil & gas, maritime and medicine. Improved algorithms are developed for all applications to enhance image resolution and contrast, higher frame rate, and better measurement accuracy. Research systems at academic laboratories as well as computer simulations are used to investigate next-generation imaging based on channel data processing that will provide a strong basis for user partner innovation. The WP provides knowledge and tools for other WPs and thus enables impact on industrial partners and healthcare providers.

WP2-1. UltraSound Toolbox (USTB)

This project focuses on the CIUS component of the UltraSound Toolbox (USTB), an open-source toolbox for ultrasonic signal processing, www.ustb.no. USTB aims to facilitate comparison of imaging techniques and thereby generalisability and dissemination of research. USTB covers processing for tissue and flow visualisation, and other image reconstruction techniques. USTB is instrumental in the UiO Ultrasound Imaging course. We have bridged USTB with open-source libraries partly developed in CIUS, e.g., FAST (fast.eriksmistad.no/) and FLUST (FlowLine Ultrasound Simulation Tool).

Collaborating with Roy E. Hansen, FFI, synthetic aperture sonar data have been processed in USTB. Micronavigation and signal delays were done by FFIs internal processing, but the postprocessing, e.g., adaptive beamforming, was done in USTB. The results are very promising, and were presented at the CIUS spring conference, the Interational Conference on Underwater Acoustics (ICUA), the IEEE Ultrasonics Symposium, as well as the Kongsberg Maritime signal forum. This is an example of result transfer between CIUS domains: medical ultrasound and Sonar.

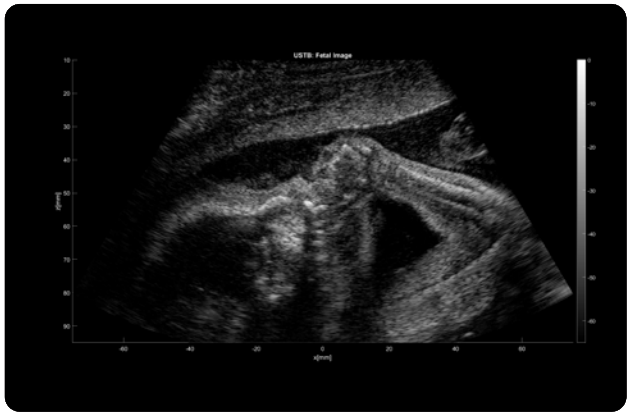
WP2-2. Ultrasound Non-destructive Testing (NDT) methods

Here we use ultrasonic NDT methods to monitor a flowing fluid with solid particles outside a pipe or a plate, to find the properties of cement on the outside of a pipe, to detect cracks in a solid pipe, and to obtain general information about the state of a pipe in terms of, e.g., cracks and corrosion.

Magnus Wangensteen is a PhD student working on pipe corrosion monitoring supported by machine learning. UiO's internally funded PhD research fellow, Håvard K. Arnestad works in the project "Wavefields and spectral estimation in acoustic imaging," and has presented at SSPA, ICUA, and IUS. He is also involved in joint projects with Erlend Viggen, NTNU. The first on simulation of ultrasonic wave propagation in coupled non-parallel plates. The second on the subsonic radiation phenomenon from vibrating surfaces. Håvard also works with Gabor Gereb (funded by the RCN in a Kongsberg Maritime joint project), "Element calibration in sonar and echo sounders". PhD research fellow Sander B. Thygesen, funded by the RCN and Equanostic AS project "Increased safety in deep wells – Using ultrasound to differentiate between fluids and solid materials behind steel pipes," is also collaborating with CIUS researchers.

WP2-3: Multibeam Sonar Imaging with Nonlinear Acoustics

No activity has taken place in 2022.



An ultrasound image of a foetus with channel data recorded on a GE Womens Health system but processed with the UltraSound ToolBox (https://www.ustb.no). Photo: Ole Marius Hoel Rindal/UiO

WP2-4: Adaptive Image Formation for Improved Image Quality

This work focuses on adaptively improved echocardiographic image quality. This means using patient-dependent ultrasound processing, adapting the image quality and processing individual patients. The goal is to improve image quality with potential for enhanced patient diagnosis and follow-up.

A journal paper was submitted on an in-vivo cardiac image quantative metric, previously reported in a DOFI. GE Vingmed Ultrasound launched the product cSound Adapt on the Vivid E95 system, a method for aberration correction (see the separate interview piece p.42), based on 5 years of research on this method in this WP.

In this sub-WP an activity on Machine Learning (ML) and ultrasound beamforming started in 2022. Assisted by Erik Smistad (CIUS researcher with ML expertise) this has become a field where translation and combination of knowledge within CIUS has led to new and fruitful activity. Several projects are ongoing developing new knowledge on how to utilize ML in beamforming.

Several clinical trials are ongoing at St. Olavs hospital to collect raw ultrasound data that can be used for research into improved image quality. These data are used by the Image Quality group at ISB (NTNU) in close collaboration with teams at GE Vingmed Ultrasound (GEVU) and GE Women's Health Ultrasound (GEWHUS) with the aim of validating results from several reported DOFIs to the CIUS consortium and to carry out research on new image improvement algorithms.

In October, GEWHUS installed their brand new Voluson Expert 22 ultrasound system with raw-data storage capabilities at the Women's and Children clinic at St. Olavs hospital. The system will be used to collect raw data in several planned and ongoing clinical projects in obstetrics and gynecology and represents an invaluable asset for the image quality team at ISB to develop image improvement algorithms further in collaboration with GE and St. Olavs Hospital.

WP2-5: Improved Mapping Rate in Seabed Mapping with Sonar

FFI funded PhD researcher Ole Jacob Lorenzen works on the "Synthetic Aperture Sonar Interferometry in Rough Seafloor Bathymetry" project. The projects of Håvard Arnestad and Gabor Gereb are also linked to this activity.

WP2-6: Suppression of Reverberation Artifacts in Ultrasound Imaging

This project has ended with Ali Fatemi's PhD thesis "On the origin of clutter in echocardiography and possible solutions" which was successfully defended at NTNU on 27 January 2022.

WP2-7: Ultrasound Elastography with Harmonic Source for Cardiology

The activity was completed in 2020.

WP2-8 Fundamental Modelling for Seafloor Acoustics

This is a new activity focused on Sri Nivas Chadrasekaran's UiO PhD project completion. A Journal of the Acoustical Society of America paper was published in 2022 on a more accurate mathematical description of the Biot model for porous media.

Going Forward in 2023

The Ultrasound Toolbox development will continue along with its integration with other CIUS-developed tools. A PhD thesis will be defended in WP2-2. PhD research in WPs 2-2, 2-5 and 2-8 will continue with the aim of validating several reported DOFI's with the ambition of commercialisation of the techniques in both medical and maritime ultrasound. WP2-4 will have a high activity in 2023 with data collection starting in several clinical trials at St. Olavs hospital, both with the GE Vingmed Vivid E95 and GE Voluson Expert 22 systems, aiming to improve and validate algorithms for enhanced image quality in echocardiography, obstetrics and gynecology.

3

Jørgen Avdal, Associate Professor, NTNU
WP Leader

Doppler and Deformation Imaging

The work package comprises technology to improve methods for detecting and measuring flow and displacements in ultrasound images. This ability is considered one of the main strengths of ultrasound compared to other imaging modalities and is fundamental for several of the CIUS innovation goals. Following is a brief description of each subpackage and activities this year.

WP3-1: Three-dimensional Vector-flow Imaging

The traditional Doppler imaging approach is limited in terms of measurement range and is inherently one-dimensional. We will develop and utilise next-generation multi-dimensional imaging of blood velocities, enabled by utilising the increased data information available using parallel acquisition techniques. The main focus will be on achieving real-time 3D (full velocity vector) imaging of blood velocities, based on spectral- and colour-Doppler imaging.

Two methods for 3D flow quantification of valve leakages have been developed in parallel, one using conventional signal processing methods and one using deep learning. Two corresponding technical papers are now finished and in the pipeline for publication. A clinical feasibility study is also in progress, with publication planned in 2023. The primary current limitation for further progress of these methods is a specific technical issue on the clinical scanners, uncovered while developing the sequences. We are currently investigating possibilities for improving this issue together with CIUS partner GE Vingmed, which could also potentially improve other applications on their scanners.

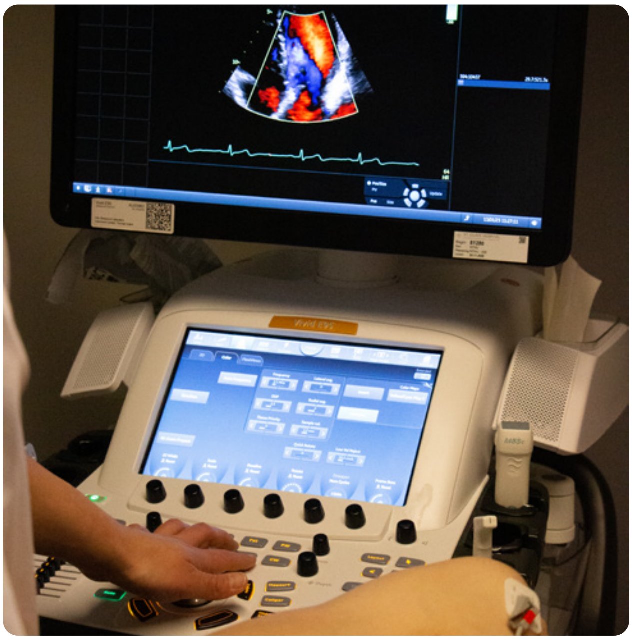
A collaboration with researchers at SINTEF and Erasmus Medical Center in Rotterdam is ongoing to develop ultrasound flow estimators using an advanced framework for development and validation, including a flow rig, optical flow methods and computational fluid dynamics models. This collaboration resulted in one publication in 2022 and will continue throughout 2023.

Intraventricular vector flow imaging has been further developed in Trondheim, and clinical studies in children has been performed at SickKids Hospital, and in adults at NTNU, Trondheim. For a study on intraventricular pressure gradients, data from 138 healthy children at Ålesund hospital and St. Olavs Hospital have been analysed, and results are in the review process at JASE.

In 2023, we will initialize investigations of 3D vector flow imaging in other vascular applications like aortic aneurisms in collaboration with Dr. Erik Groot Jebbings from University of Twente.

WP3-2: Flow Measurement in Non-stationary and Noisy Surroundings

This project focuses on the development of methods used to detect and measure flow in noisy surroundings, e.g., coronary flow in the beating heart or low flows due to leakage in cemented well isolation layers. This includes adaptive filtering approaches that utilise properties of the received signal to better separate flow from other signal sources, as well as the use of a priori information of cyclic behaviour of flow characteristics in medical applications.



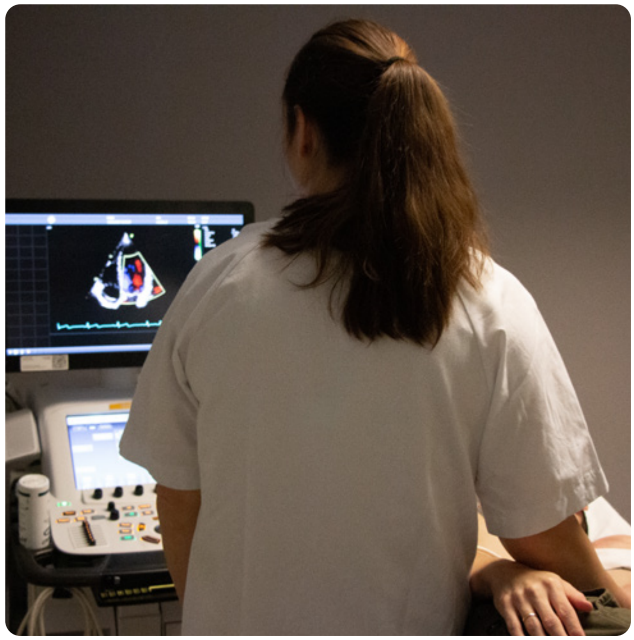


Photo: Kari Williamson/NTNU

PhD candidate Shivanandan Indimath, who started early 2021, has now published the first paper on detecting and quantifying influx/efflux in Logging-While-Drilling (LWD) borehole situations, in collaboration with CIUS partner Equinor. The paper evaluates the performance of PW Doppler ultrasound to quantify influx/efflux from fractures in the borehole walls using conventional transducers and is based on simulations and experimental setups using corn-starch suspension to emulate the drilling fluid. The possibility of improving the imaging resolution of pulse-echo methods for fractures with influx is also discussed. Results are promising and indicate feasibility of the methods.

Automatic estimation of leaking orifice geometry with resolution exceeding that of the imaging system is being investigated in collaboration with PhD candidate Sigurd Wifstad Wangen, using a technique developed in WP3 for cardiac applications. To validate methods in a more realistic scenario, a larger experimental setup with real drilling fluids has been designed together with SINTEF and Equinor. Initial testing started in the autumn of 2022 and will continue in 2023. In addition, we are developing methods for detection and potential quantification of gas bubbles passing the sensor with high velocities, as an early warning of gas reservoirs, with a technical publication planned in 2023.

WP3-3: High Frame Rate Tissue Deformation Imaging

The development of acquisition strategies and processing algorithms for high frame rate 3D tissue deformation imaging, utilises the increased data information available from parallel acquisition techniques. The overall aim is to evaluate regions with specific properties such as increased stiffness or reduced muscle contraction. Methods will be based on Doppler, speckle tracking, and acoustic radiation force principles (e.g., shear wave elastography). PhD student Mohammad Mohajery has worked on applying the previously published clutter filter wave imaging technique to track wave propagation in the heart. The technique allows us to produce a 3D mapping of tissue properties in the left ventricular walls, which again can be used to assess cardiac function. Initial results show the validity of the velocity estimation method and indicate that the method can separate healthy volunteers from patients. These results have been presented at the IEEE International Ultrasonics Symposium and will be submitted to IEEE Transactions on Medical Imaging. Future work includes investigating the efficiency of the method in the clinical setting using a larger study of patients with diffuse fibrosis. Moreover, a collaboration with the STEMI project is planned to evaluate the validity of the method for patients with infarcted myocardium. In 2023, this project will transition from technical development to clinical studies.

WP3-5: Doppler Imaging of Flow in Cement behind Steel Casing

Aberrations are phase inconsistencies caused by inhomogeneous media, that are typically associated with degradations in signal level, contrast, and resolution. This subproject has two primary aims: First, we want to quantify the effects of aberrations on signals from moving scatterers and the corresponding impact on signal strength and integrity of velocity estimation. Second, we want to assess the effectiveness of aberration correction techniques and other image quality techniques for improving blood detection and quality of velocity estimation.

The project started January 2022 and will continue throughout 2023. In a collaboration with GE Vingmed, we have implemented and optimised aberration correction methods for conventional Colour Doppler, with convincing results which will probably accelerate the process of making such methods available on GE scanners. In addition, we have initiated a study in which we quantify the effects of aberrations on flow signals. In 2023, we have planned a journal publication on this topic. In addition, we will investigate other synergies between Doppler techniques and techniques for improving image quality.

4

Lasse Løvstakken, Professor, NTNU
WP Leader

Image Analysis and Visualisation

This work package covers the development of image processing and analysis methods to extract relevant contextual information from ultrasound image data, to improve measurement quality, and to provide a more efficient workflow to reduce the time to decision. These tasks are also coupled to enhanced data visualisation to improve data exploration and interaction.

Challenges in medical, maritime and industrial applications are addressed using modern approaches in signal and image processing, with emphasis on recent machine learning algorithms (e.g. deep learning) for classification and extraction of data and image features. The work package outcome will provide improved extraction of relevant high-level information in the data, and improved data acquisition and processing at lower levels by providing an initial interpretation of the problem.

Our research aims support the main innovation goals defined in CIUS, such as ultrasound-based anatomical and functional medical imaging, improved seabed classification, and improved well integrity monitoring. The current activities also support a broader usage and have relevance for other work packages. For instance, image analysis methods developed for cardiac imaging are well suited for automated measurements, and for quality control during data acquisition, which are topics of high relevance for WP6.

The Current Updated Work Package Tasks Are:

- WP4-1: Automatic anatomical and functional measurements in echocardiography
- WP4-2: Improved detection of pores and cracks in downhole logging
- WP4-3: Machine learning for automatic seabed mapping
- WP4-4: Machine learning for automatic maturation grading in Atlantic salmon

These tasks share common challenges and can be addressed by common data and image processing approaches. The initial aim was to establish a state-of-the-art framework and expertise in machine learning algorithms, trained to recognize and segment relevant image or data features. Further, we aim to develop a model-based estimation framework for regularization and reconstruction of noisy and potentially missing image information based on physical models, a pathway towards more robust measurements. Finally, to explore how these methods can provide context for improved data acquisition and measurements.

Activities in 2022

The year 2022 was productive, with several publications and conference contributions, including applications in echocardiography, oil & gas well logging, and maritime seabed mapping. The machine learning group is growing, and now includes several PhDs and postdocs which are funded by connected research grants. The successful activity in machine learning started with CIUS in 2016 and would not have been possible without the SFI. WP4 personnel and the extended machine learning family contributed to several DOFIs. The internal DOFI prize was awarded to David Pasdeloup for his excellent work on image guiding, which was a joint effort between WP4 and WP6. Several updated and new real-time AI application prototypes have been made and are currently being tested in the echo laboratory at St. Olavs hospital. New applications have emerged.

AI technology developed in CIUS allows for efficient and accurate automated measurements done bedside and in real-time in the echo laboratory. Photo:BERRE AS

WP4 and WP2 have joined forces and produced new innovations for improved image quality where AI-tech plays a central role. Our joint activities with Equinor have, after further internal development, led to a machine learning tool for well logging which will be released as open-source software by Eqiunor. This will be a big step forward in this field.

Going Forward in 2023

In 2023 we will continue our work to integrate AI-tools in the echo lab, and to further develop methods for simplifying echo outside the hospital. We will see more results from our recent industrial projects, a PhD project on seabed classification, with a unique collaboration between CIUS, Kongsberg Maritime, and the National Geographical Survey (NGU). Here we transfer our knowledge in semantic segmentation in medical images to SONAR images of the seabed. Our PhD project on AI analysis for evaluating salmon maturation has been successful, and we will spend 2023 publishing papers and further developing a practical solution for field testing. We will continue our efforts in using machine learning in oil & gas well logging in collaboration with Equinor. Finally, a new project will focus on using AI-technology for improving image quality in medical ultrasound imaging, in collaboration with efforts in CIUS WP2.

This film can be viewed via the publication: Real-Time Echocardiography Guidance for Optimized Apical Standard Views. Ultrasound Med Biol. 2023. https://www.sciencedirect.com/science/article/pii/S0301562922005658. Film: BERRE AS

5

Asta Håberg, Professor, NTNU
WP Leader

Multimodality and Interventional Imaging

In WP5, the focus is on development and application of multimodal and interventional imaging for improved diagnostic, treatment and follow up. Multimodal imaging combines the strengths of different modalities such as US, MR, CT, and PET for diagnosis and follow-up, as well as for guidance during surgery, targeted drug-delivery, and other therapeutic procedures.

WP5-1 & WP5-2: Multimodal Imaging and 3D Volume Registration in Cardiology and Image Guided Surgery

Here we develop robust systems by combining novel US acquisition methods and artificial intelligence for automatic functional monitoring of the heart. New ways of using US during invasive cardiac procedures with emphasis on novel real-time co-registration methods are developed in collaboration with Norwegian Open Lab at NTNU. In collaboration with WP3, the clinical feasibility of new cardiac US methods for detecting and quantifying valvular disease, ventricular function and cardiac fibrosis are being assessed for improved non-invasive diagnostic workup and follow up of patients. Deep learning is used for image analysis to provide quantification of different measures and stratification of patients.

In 2022, a novel non-invasive US based method for assessment and quantification of myocardial fibrosis and stiffness has been developed in collaboration with WP3. It is feasible for both 2D and 3D echocardiography. Additionally, a new 3D Doppler US method for more precise evaluation of aortic stenosis and a new method for quantification of valvular regurgitation by 3D Doppler ultrasound have been developed. The scans obtained with the new US methods have been combined with new deep learning algorithms for automatic assessments.

WP5-3: Multimodal US and PET-MR for Improved Diagnosis in Brain and Heart Disease

Hybrid PET/MRI scanners allow for simultaneous characterisation of a tissue's anatomical and physiological properties with MRI and molecular imaging with PET scans. Studies of the added value of PET-MRI in glioma diagnostic for surgical planning and during US guided neurosurgery, is continuing. New in 2022 is the inclusion of patients with brain metastases in this pipeline. We have also started the process of synthesis of the new tracer, ^{18}F-FDOPA, locally at St. Olavs hospital in Trondheim. This tracer will be available to use in tumour patients in 2023. Furthermore, the planning and organisation of the first Norwegian theragnostic PET-study was initiated in 2022. (Theranostics or pharmacodiagnostics is defined by the U.S. Food and Drug Administration as "diagnostic devices or imaging tools that provide information that is essential for the safe and effective use of a corresponding therapeutic product".) The radiochemists at St. Olavs hospital have established a second-generation tau tracer in 2022 and we have permission from the national authorities to use this tracer in patients. Patients with mild cognitive impairment will receive both tau-tracer and either an amyloid or glucose tracer in combinations with a wide array of MRI scans. The multimodal brain imaging data will be used to identify differences in imaging features related to early versus late onset impairment and its progression and assess the added value of each of the scan types. We are planning a study in traumatic brain injury using the same PET tracers.

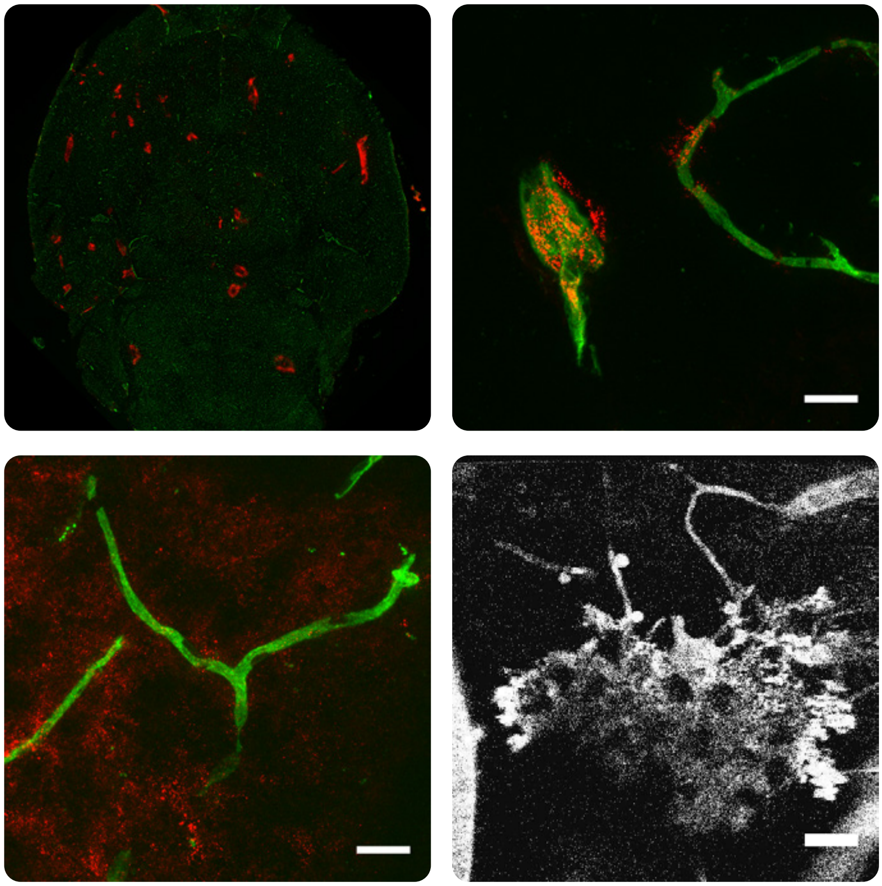


Image 1: ACT treated mouse brain. Blood vessels in green. Extravasated nanoparticles after ACT in red.
Image 2: Zoomed in image of a mouse brain used as control. Blood vessels in green, nanoparticles in red.
Image 3: Zoomed in images of a mouse brain treated with ACT. Blood vessels in green, nanoparticles in red.
Image 4: Intravital microscopy in a mouse brain during ACT. Blood vessel outpouchings seen in vessels treated with ACT.
Photos: Melina Mühlenpfordt/Exact TX and Marieke Olsman/NTNU

WP5-4: Ultrasound-Mediated Drug Delivery

A prerequisite for successful cancer therapy is that the therapeutic agents reach all tumour cells and kill them. Unfortunately, standard chemotherapy has low uptake of drugs in tumours. Focused US combined with microbubbles is a strategy reported to improve the delivery of nanoparticles with drugs as well as free drugs to tumour tissue and improve the drug's therapeutic effect. Treating patients with non-resectable pancreatic tumours are of special interest due to their poor prognosis, and new strategies for improving the therapy is highly needed.

Experimental models have been established to study the physiological mechanisms of Acoustic Cluster Therapy (ACT) in tumours and in the brain. The phenomena studied include effects of ACT on blood flow, movement of therapeutic agent across the vessel wall and into the tissue, activation of the immune system. Individual responses to ACT treatment were also examined.

Some of the studies to improve our understanding of the effect of acoustic radiation force and transport of therapeutic agents through the extracellular matrix have been in collaboration with the SFI PoreLab. We are also investigating mechanism of US-mediated uptake of the drug FOLFIRINOX in combination with the microbubble SonoVue in patients with non-resectable pancreatic tumours at St. Olavs hospital.

Going Forward in 2023

WP5-1&2: The next step for the clinical cardiac US is to investigate the usefulness of the new methods in other patient groups such as those undergoing cardiac surgery and for monitoring of critically ill patients in the intensive care unit. The two PhD students Torvald Espeland and Erik Andreas Berg plan to deliver their PhD theses in 2023. Two PhD students will have research stays at labs at INRIA Lyon, and Politecnico, Milan.

We will evaluate the added value of ^{18}F-FDOPA to MRI in gamma knife treatment of high-grade glioma and start the PET-tracer theranostic study in high-grade glioma patients, and perform the first studies with amyloid, tau and glucose PET tracers in patients with cognitive impairment and traumatic brain injury patients. Several publications are planned from the work done in 2022 in WP5-4.

The results obtained so far will also be used to optimise treatment in a new set of animal experiments, and patients with colorectal cancer will be included in a new study on chemotherapy in combination with ultrasound and microbubbles. Three PhD students connected to this work plan to defend their theses in 2023.

6

Ole Christian Mjølstad, Head of Cardiology, St. Olavs University Hospital Trondheim and NTNU WP Leader

Ubiquitous Ultrasound

Pocket-sized ultrasound devices are extremely portable and can increase the use of ultrasound imaging as part of the diagnostic workflow in different groups of patients – from rural district hospitals to nursing homes in the Western world. Development of easy-to-use ultrasound technology has significant innovation potential and can pose a paradigm shift for practices in the healthcare sector, where the goal is to offer patients quicker diagnosis outside and inside hospitals, as well as to avoid unnecessary hospital admissions.

WP6-1 Multi–Purpose Ultrasound Imaging for Non-Experts

This sub-WP focuses on the:

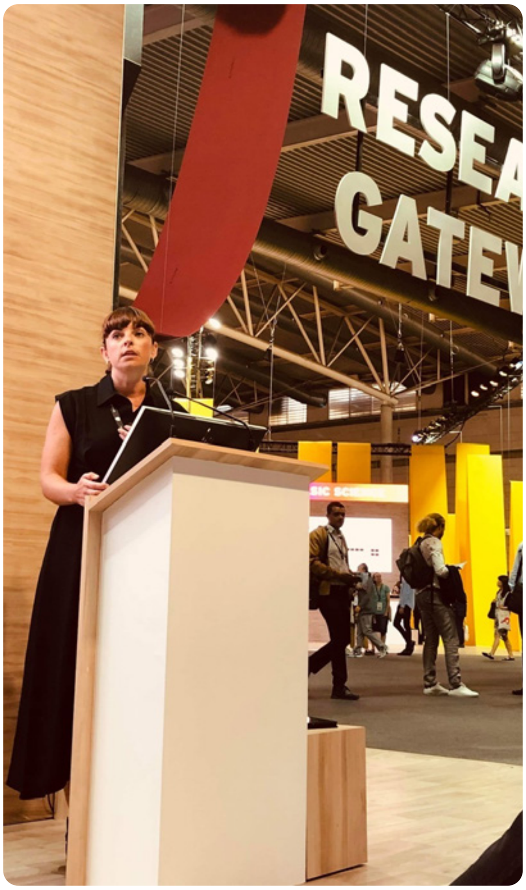
- Technical development and clinical feasibility of using pocket-sized ultrasound.
- Clinical use, automated methods for navigational aid and (semi)automatic measurements (e.g. organ size, displacements).

Methods will be adapted for non-expert personnel but will also find use in high-end systems when successful. The work in this WP is relevant for the development of novel technology within the field, as well as for scientific evaluation of novel technology and clinical impact.

At NTNU / Levanger Hospital, general practitioners (GPs) that provided services in nursing homes were trained in simplified use of ultrasound to detect heart failure and fluid overload. They assessed and scanned patients with pocket-sized ultrasound in a heart failure outpatient clinic and transferred the recordings to a cardiologist with a telemedicine system. Our industrial partner GEVU has provided Vscan Extend devices for the clinical GP study at NTNU. Software for automatic analyses of left ventricular function on the handheld devices were further provided by GEVU and NTNU. Decision-support software for telemedical support were provided by GEVU.

Project Updates

- Feasibility and accuracy study of automatic tools for quantitative analysis by hand-held ultrasound systems and the use of telemedicine: Completed 2020.
- The clinical GP study includes evaluation of: 1) Standardised education of GPs for assessment of LV function; 2) Automatic software for LV analyses integrated in pocket-sized ultrasound device; and 3) Support of inexperienced users by telemedicine.
- PhD candidate Hjorth-Hansen published two manuscripts in 2022 and will submit her PhD thesis early 2023.
- PhD candidate Magelssen had her second manuscript accepted late 2022. Her last manuscript and the thesis will be submitted in 2023.
- "Real-time evaluation of AI algorithms for improved image quality during scanning." This is the first clinical step towards real-time guidance of the operator during scanning and we have developed the methodology ready to be tested in next generation hand-held ultrasound scanners.
- "Pocket-sized ultrasound by residents for quick diagnosis in patients with stroke and TIA." This is a study conducted at Levanger Hospital with Vscan with Dual probe. There has been some delay in this project due to the clinical workload caused by the coronavirus pandemic. PhD candidate Saxhaug had his second manuscript published in 2022 and is about to submit his third paper and the PhD thesis.



PhD-candidate Malgorzata Magelssen presenting at the ESC congress in Barcelona August 2022. Photo: Erik Madsen/NTNU and St. Olavs

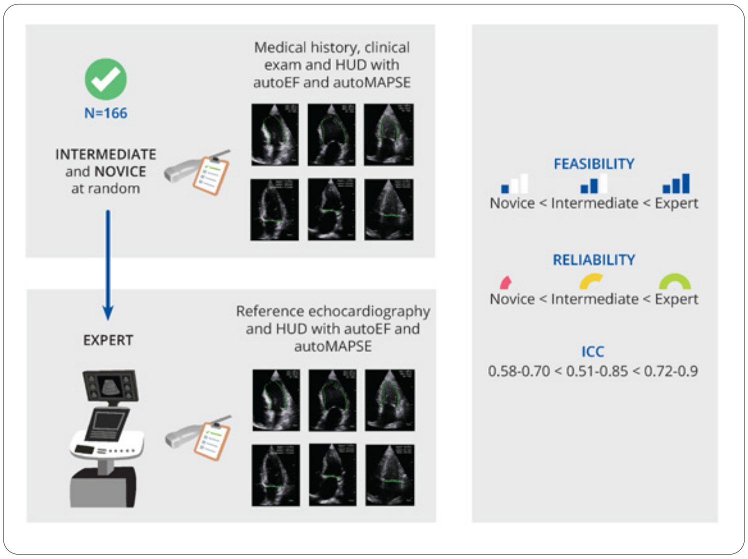


Illustration: Real-time automatic quantification of left ventricular function by hand-held ultrasound devices in patients with suspected heart failure: A feasibility study of a diagnostic test with data from general practitioners, nurses, and cardiologists. HUD: Handheld Ultrasound device. EF: Ejection Fraction. MAPSE: Mitral Annular Plane Systolic Excursion. Illustration: Anna Hjort Hansen/NTNU

WP6-2 Clinical Benefit of use of Pocket-Sized Ultrasound Imaging in Nursing Homes

As discussed in previous reports, this part was merged into WP 6-1 as the physicians at the nursing homes at our partners, the municipalities of Levanger and Verdal, were the same as those selected to join the clinical GP study.

WP6-3 Automatic Detection of Signs of Rheumatic Heart Disease

The collaboration with Brisbane, Australia was postponed for years due to lack of feedback from our partners and was finally cancelled in 2021 as it was no longer realistic due to the pandemic.

Going Forward in 2023

PhD student David Pasdeloup will continue with machine learning and AI in cooperation with Professor Lasse Løvstakken (NTNU) and Sigmund Frigstad (GEHC) to develop technology for quality assurance of echo images and computer-assisted guiding for cardiac applications. PhD students Magelssen and Hjorth-Hansen will finalise the submission of manuscripts and have their PhD-defences in 2023. They are ahead of their planned 6-year schedule. PhD student Saxhaug is in the process of publishing his work. PhD candidate and research student Sæbø has ended data collection and will publish his first manuscripts in 2023. We will plan for the evaluation of real-time guiding on the hand-held platform when the next generation hand-held scanners are introduced to the market.

7

Asbjørn Støylen, Professor, NTNU
WP Leader

Clinical Feasibility

This work package focuses on clinical assessment of new technical ultrasound modalities for the evaluation of coronary disease and congenital heart disease.

Clinical Assessment of New Technical Ultrasound Modalities for Evaluation of Coronary Disease

Coronary heart disease is still the largest single cause of death, as well as being treatment cost intensive. Early invasive treatment in the acute phase of an infarct is the main cause for treatment-related reduced mortality. The challenge is both to develop more effective diagnostic modalities to assess infarcts, both in the acute and late phase, to select patients to the appropriate treatment in the acute phase to minimise organ damage, and at the same time reduce the number of unnecessary procedures. The emphasis is on quantitative ultrasound methods, using new technology, especially 3/4D ultrasound for deformation and flow. This has significant development potential and can present a paradigm shift for quicker pre- and early in-hospital assessment and selection. In addition, the identification of viable myocardium after an infarct is of importance for maintaining optimal heart function, while at the same time identifying patients who will not profit from invasive treatment to avoid unnecessary treatment. Clinical research, however, depends on the establishment of the new methods, primary development is technical, while clinicians enter at later stages of testing in vivo, as well as evaluating findings in terms of function.

WP7-1 Ultrasound Coronary Angiography and Cardiac Flow – Feasibility and Validation

The WP resources have been diverted to flow vector imaging (clinical).

- The physiology of intraventricular flow in normal subjects. 2 papers published 2021.
- Retrospective tissue Doppler and Doppler in normal subjects. Submitted.
- The clinical data on the patient population is collected and will be analysed and published in 2023.

Since the WP resources have been diverted to flow vector imaging, the primary objective of 3D ultrasound coronary imaging has thus not been started. However, in collaboration with a project centring on CT anatomical and functional assessment of coronary arteries, a stress echo study utilising new high-end scanners with increased resolution and frame rate, has been started to evaluate speckle tracking stress echocardiography as a functional test for coronary perfusion. This has not been feasible by any previous scanner generation and thus lacks clinical data. The analysis is underway. Financing is outside of CIUS, and the project will continue.

WP7-2 and 7-3 Ultrasound Based Markers of Ischemia and Viability in Patients with Myocardial Infarction

Acute ischemia and viability. Originally in two work packages, the projects have been merged. In the acute phase, acute infarcts may present without characteristic ECG changes, although research have shown that at least 1/3 of patients without these

Photo: Kari Williamson/NTNU

changes have an occluded infarct related artery. Due to the lack of specific ECG changes, they will miss early invasive treatment, which will lead to larger infarcts and worse prognosis. Using newer physiological markers of ischemia, in combination with 3D deformation imaging, will make it possible to quantitate "myocardial area at risk", to select these patients for early treatment. The same parameters can be used to evaluate the extent of myocardial scarring, where extensive scarring in the late phase precludes effect of invasive treatment.

The aim of this WP is to validate the assessment of acute ischemia and scarring in 3D reconstructed images against references (coronary angiography and MR scar imaging). The project has one PhD student full time. The analysis tool is finished for the reconstruction of a 3D plane model from 2D tissue Doppler echocardiography. Analysis is finished in the chronic infarct population and the acute study, and both papers have been submitted.

The analysis tool based on high framerate 3D tissue Doppler acquisition has been developed. Old data has shown low feasibility for 3D measurement. HFR 3D tissue Doppler is being developed, and will be useful for measuring both contraction, stiffness and elasticity in acute infarcts. The third project is in the process of acquiring clinical data.

Additional Projects in WP7

Prehospital diagnosis and risk stratification of Acute Coronary Syndrome: In cooperation with Sørlandet Sykehus. The project has suffered from the fact that the PhD candidates have left their positions, but patients have still been included, and the project is now finished with 250 patients included. One manuscript is under review. Data has been analysed and interpreted at NTNU (CIUS research fellow Bjørnar Grenne).

In this clinical WP, an additional project based on 2D and 3D vector flow imaging (CF. WP 3.1) to visualise abnormal intracardiac flow in children has been started under WP7 (3D flow quantification congenital). The project on congenital heart disease has one PhD student and one part time guest researcher. The inclusion of patients at SickKids Hospital in Toronto is ongoing. A new PhD has been employed in the same field with external funding. In addition, the technique is being tested for feasibility in adults, in a cooperative project with the Department for circulation and medical imaging (ISB, NTNU) (3D flow quantification acquired). The project on intracardiac flow in adults has included healthy volunteers in the pilot study, and analysis is ongoing.

Going Forward in 2023

Finalizing clinical analysis and PhD's in all the ongoing projects is the main task in 2023 as the centre is approaching its end.

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Svein-Erik Måsøy, NTNU
WP Leader

Piloting in the Maritime and Oil & Gas Fields

This work package follows feasibility, piloting, and validation of CIUS developed innovations in the maritime and oil & gas sector. In these fields, field trials, demos, equipment, and systems are very expensive and require the partners to take the lead with support from CIUS researchers.

Activities in 2022

This year has seen advancements in all our projects, and some are now finalised. As CIUS is approaching its end, we see great collaboration efforts between our partners and researchers in this domain.

Oil & Gas

The project on assisted interpretation of cement evaluation logs using machine learning started in 2021 and was finalised this year. Equinor has funded the project through a framework agreement with NTNU, providing 50% funding for CIUS researcher Erlend Magnus Viggen to collaborate with Equinor personnel on building a tool to assist well log interpreters. The prototype assisted cement log interpretation tool has been deployed as planned and is currently benefitting Equinor's cased hole logging group in their day-to-day operations. Equinor is currently continuing the maintenance and development of the tool as an internal R&D project.

The engagement from Equinor has been the key to the success of this project. In particular, two members of Equinor's cased hole logging group (the target user group) have been part of the core team. They made extensive contributions, including building a high-quality training set, integrating the tool into the software they use, and applying their domain expertise to benefit the project. Software developers in Equinor were involved to help ensure high-quality code. The project has also received important feedback from stakeholders in Equinor, including the cased hole logging group and chief engineers. Equinor is planning to make this tool open source so the entire oil & gas industry may benefit from this innovation.

In another project, Equinor has funded a fit-for-purpose flow-rig system for simulating drilling fluid circulation, including the possibility to simulate fluid influx or efflux through fractures of various shapes and areas. This flow-rig is currently functional, located at an HSE approved laboratory at SINTEF in Trondheim where the experiments are ongoing using various types of drilling muds, provided by major well fluid service companies.

A new machine learning project has also been started in collaboration with Archer in Bergen.

Maritime

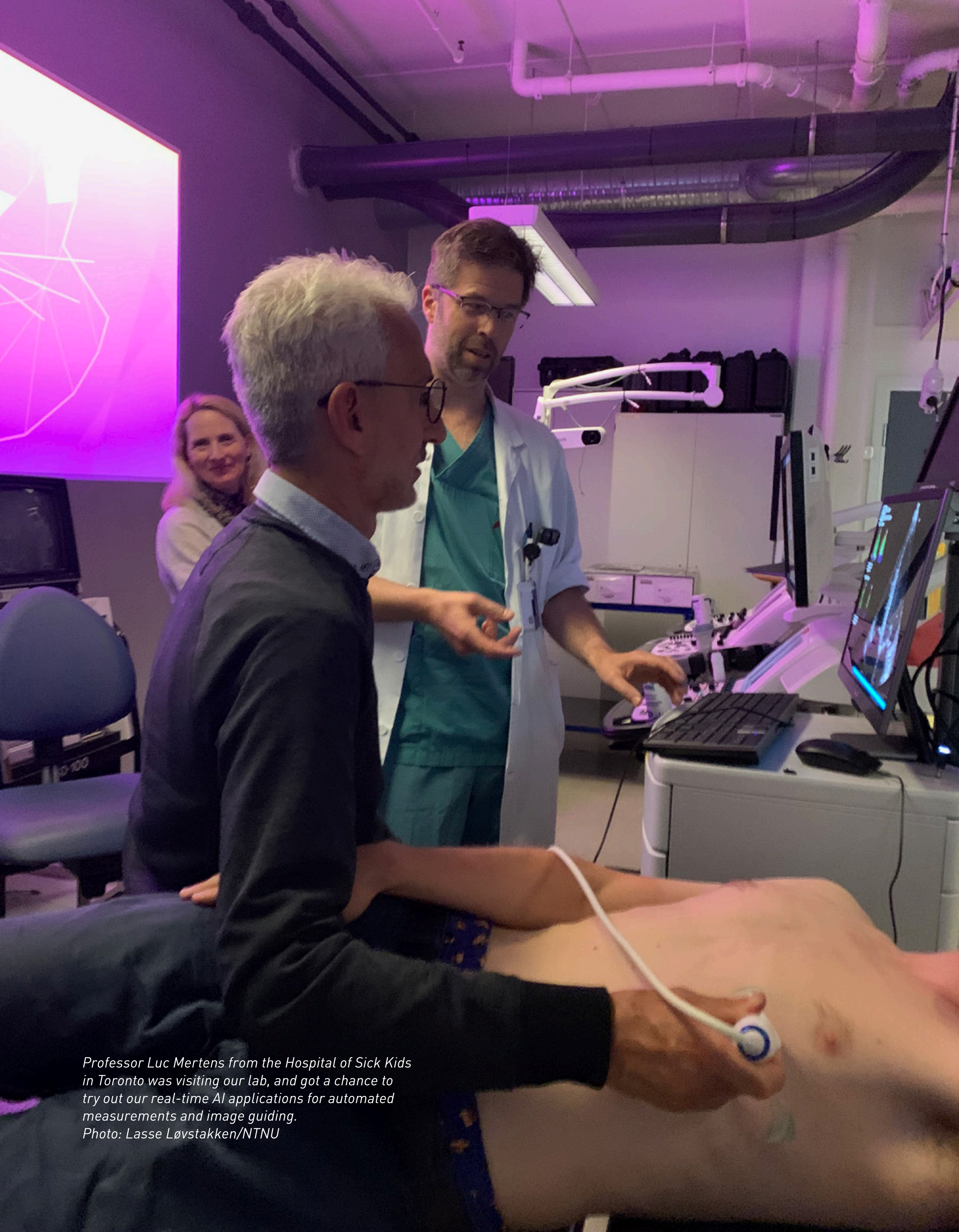
Ellen Sagaas Røed, an Industrial PhD candidate at USN, submitted her thesis in September 2022. Ellen has successfully fabricated a new single crystal piezocomposite transducer at Kongsberg Martime in Horten. The transducer has a usable bandwidth of 132% relative to the centre frequency, which represents a significant improvement

Eirik Time (Equinor) and Erlend Magnus Viggen presented the results from the Equinor-CIUS collaboration at the CIUS Fall Conference 2022. Photo: Kari Williamson/NTNU.

in bandwidth compared to conventional transducers. This is a great achievement and will potentially lead to increased sensitivity and resolution of future sonars.

In a collaboration between CIUS, Kongsberg Maritime and The Geological Survey of Norway (NGU), a project on piloting seabed classification using machine learning on simulated and realistic data is ongoing. In 2021, the first large dataset was collected and prepared. PhD candidate Rosa Virginia Garone has in 2022 trained a Convolutional Neural Network (CNN) classifier on data from Søre Sunnmøre and achieved good match with expert classification. These results are promising, and the project moves forward with the aim of significantly reducing the workload on seabed classification.

In a joint project between CIUS, CIUS partners InPhase Solutions, Aquagen and Mowi a large dataset for ultrasound machine learning based monitoring of maturation states of Atlantic Salmon was collected in 2021. PhD candidate Yasin Yari has successfully developed a machine learning algorithm capable of segmenting the ovaries of salmon, allowing for automatic length and volume estimates. The work was presented at the IEEE International Ultrasonics Symposium in Venice, Italy, in October 2022. The project continues in 2023 with further development and validation of the methods.



Professor Luc Mertens from the Hospital of Sick Kids in Toronto was visiting our lab, and got a chance to try out our real-time AI applications for automated measurements and image guiding.
Photo: Lasse Løvstakken/NTNU

Stories

Part of CIUS' success in innovation stems from our ability to work across subject fields, and across the professional 'barriers' between industry, academia and medicine.

With CIUS entering its final stages, we have chosen to focus our Stories from 2022 on industry-collaboration. This is to show that our research "makes it" into the "real-world", but also to highlight how a research-background from CIUS can lead to careers within R&D – also outside of academia.

The Heat is on – Transducer Design
At the heart of all ultrasound is the probe – or transducer. One thing is its capabilities in terms of sending and receiving signals, another thing is for the probe itself to be able to handle the environment in which it is being used. PhD Candidate Josh Hoi Yi Siu, USN, is working together with Sensorlink on designing and testing a transducer that can take higher temperatures than the industry standards. A project beneficial both to Sensorlink and Siu.

Real-Time Project and Real-Life Experience
Kongsberg Maritime announces summer projects every year to solve specific problems. In 2022, our PhD Candidate Rosa Virginia Garone, NTNU, was selected to work on automating sediment mapping of the seabed. Is it possible to automate the process – and make it real-time? Garone says she enjoyed stepping out of her PhD project (also with Kongsberg Maritime), to work on a "real-time, real case problem".

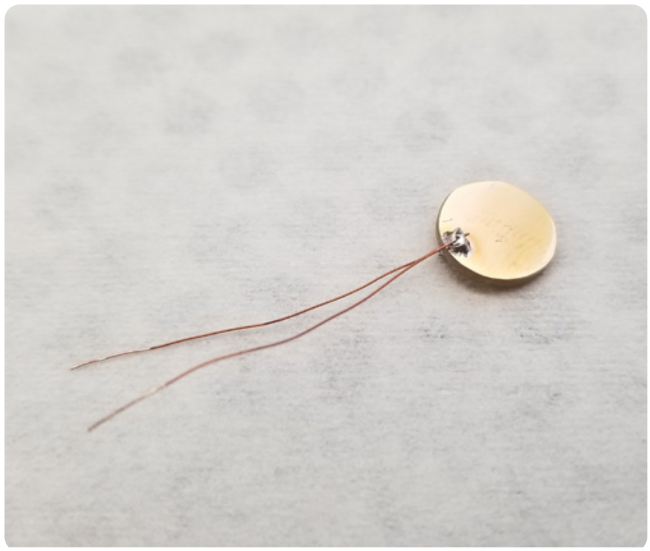
Crack-Detecting Waves
Detecting and then assessing cracks in pipes can be challenging – especially when it has to be done on pipes that are in use. CIUS partner NDT Global specialises in non-destructive testing using ultrasound and other methods. Co-supervising our PhD Candidate Simen Hammervold Midtbø, NDT Global and CIUS are getting closer to measuring cracks using Lamb waves.

In Sharper Focus
In this story, we look at a 40-year-old problem of 'unfocused' ultrasound images. The breakthrough came through the CIUS collaboration, resulting in the Adapt technology – which has already been incorporated into GE ultrasound scanners. The game-changer? More powerful computers thanks to the gaming industry, alongside an intensive team effort between industry and academia.

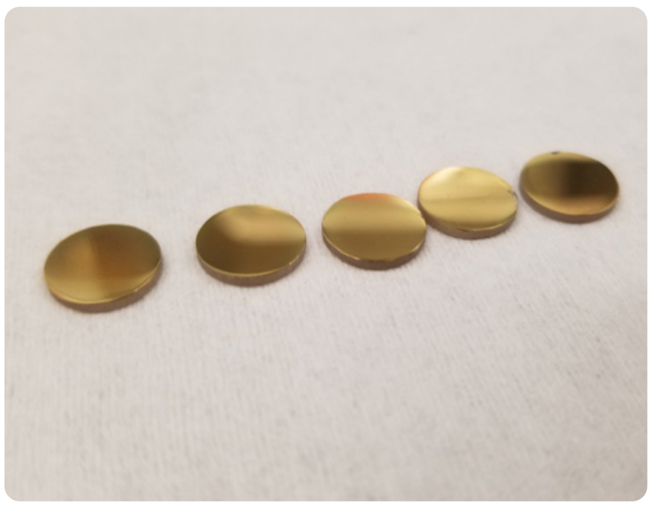
THE HEAT IS ON – TRANSDUCER DESIGN

To inspect and test oil pipelines is crucial – both for health and safety, and for the environment. But the harsh conditions mean specialised equipment is imperative. When using ultrasound to perform non-destructive testing, this translates into a need for transducers that can withstand extremely high temperatures.

Josh Hoi Yi Siu, PhD Candidate, USN and Sensorlink



Crystals with soldered cables for room temperature testing. Photo: Hoi Yi Siu/USN



Crystals with electrodes. Photo: Hoi Yi Siu/USN

CIUS partner Sensorlink, which offers non-intrusive topside and subsea erosion and corrosion monitoring, needs to solve the challenge of producing transducers that can withstand even greater temperatures than those now available on the market. They have therefore teamed up with CIUS and the University of South-Eastern Norway (USN) on a PhD.

Josh Hoi Yi Siu, with a background from physics at the Hong Kong University of Science and Technology, and a master's thesis on fabrication and characterisation of piezocomposites from USN, is now working on solving the problem.

He has visited Sensorlink's plant and seen the current NDT equipment for onshore and subsea applications:
"It was incredibly fascinating to see transducers used on such a massive scale while silently maintaining the health of the infrastructure," Siu says.

Taking the Heat
To design and later produce transducers that can withstand temperatures of several hundred degrees, is challenging and labour-intensive: "Due to de-poling (when high heat destroys the transducer), most typical transducer probe materials are incompatible with the temperature specifications," Siu says. Furthermore, the improved transducers also have to be compatible with Sensorlink's systems.

"For the transducer to withstand the heat and harsh environment, the crystal itself has to be able to withstand the heat while the other passive materials (matching, backing, housing), have to be thermally stable, having similar thermal expansion and not melting," he explains.

Despite only being one year into his PhD, Siu is starting to see results: "I have managed to characterise the crystals, and they fit with simulation results, and are now getting ready for high-temperature testing. I am hoping to assemble the transducer and test it under heat for my first publication."

The Secret Nature of Industrial Competition
Academia although not a complete stranger to competition and certain levels of secrecy about research and development, is generally about being open and enabling reproducibility – at least after publication. But in industry, some types of secrecy are vital to stay in business. This can pose a challenge when doing a PhD.

One thing is all the details about this project that cannot yet be revealed – another problem is getting information about other transducers already on the market:

"Challenges are the secretive nature of these types of transducers as the manufacturers usually hide their recipes as well as their publications, and thus it takes more experience from supervisors, PhD colleagues, Sensorlink, etc., to make things viable," Siu says.

However, as CIUS is funded by the Norwegian Research Council, part of the consortium agreement deals with these challenges to ensure the ability to publish PhD-articles – although sometimes with a slight delay to secure patents and intellectual property rights.

Multidisciplinary Benefits
The broad range of topics and disciplines involved in transducer design, and the wider ultrasound subject field, poses its challenges, but also its benefits:

"Academically, I see myself benefiting from knowing the actual industrial setting for the transducers – also gained from attending CIUS events about cardiac imaging, sonars, etc. – as well as the interdisciplinary nature of ultrasound – from physics and electronics, to signal processing, product development, customer service, and so on.

"The synergy and networking opportunities I've had with other seasoned engineers, technicians, and management in the ultrasound sector in Norway have been invaluable to my professional development. Being a part of this field has been a fantastic learning experience for me."

The collaboration is also seen as beneficial for the industry partner: «The collaboration with CIUS has made it possible for Sensorlink to connect with the ultrasound research community in Norway. This is a very valuable opportunity for Sensorlink to benefit from the knowledge and experience of both professors and researchers in the field," Siu's co-supervisor Ali Fatemi at Sensorlink says.

What Next
If all challenges of making the different layers in a transducer and the electrodes to withstand higher temperatures than the industry standards are overcome, the possibilities extend beyond oil pipelines:

"Upon successful manufacturing, we want to broaden the applications in the future to downhole inspection in geothermal wells, a renewable energy source of increasing interest, inspection of aluminium furnaces and more," Siu says.

Piezocomposites
Piezocomposites are materials made up of piezoelectric materials and so-called 'passive' polymers or epoxy compounds.

Piezoelectric materials are found in for example loudspeakers and microphones, where they 'translate' electric signals into sound waves, and vice versa.

By Kari Williamson/NTNU

REAL-TIME PROJECT AND REAL-LIFE EXPERIENCE

When building a house, it is crucial to know whether the ground consists of rock, gravel, sand, or clay. The same goes for underwater installations, but it is not so easy to determine as on dry land.

CIUS partner Kongsberg Maritime wished to explore whether deep learning could assist in real-time seabed classification, and our PhD Candidate Rosa Virginia Garone stepped up to the challenge.

"The knowledge helps the scientific community to make important decisions about the management of marine resources, ecosystem preservation, offshore installations (both for the oil & gas and the renewable energy industries), offshore structural monitoring and hazard control," Garone explains about the motivation for the project.

Seabed sediment classification is usually a manual process involving expert operators merging geological, geophysical, and geotechnical data to infer information about the distribution of the sediments. This can be very time-consuming and subjective.

"With the use of deep learning we aim to automate or partially automate the process of sediment mapping by letting the neural network predict the sediment classes, thus reducing the subjectivity and increasing speed. So far, we hadn't the opportunity to conduct these experiments in real-time" Garone says.

A Real(-Time) Problem
To investigate the potentials of a deep learning network to solve a seabed classification problem in a real-time setting, Kongsberg Maritime announced a summer project where Garone and other students with different technical backgrounds were chosen to work on these problems. Garone's background made her particularly qualified for this.

She has a bachelor in geology and a master's degree in geophysics, and has experience as a geophysicist/geologist and processing geophysicist before she started her PhD in CIUS. Her PhD project is on multibeam echosounders (MBES) seabed imagery consisting of high-resolution bathymetry grids and backscatter mosaics from Søre Sunnmøre. It is a collaboration with Kongsberg Maritime and NGU.

She heard about the summer project via her co-supervisor at Kongsberg Maritime Tor Inge Birkenes Lønmo. The two-month summer project spanned across different topics and different engineering disciplines.

"I was immediately thrilled about it and interested in answering two main questions. 1) Is my algorithm able to generalise its predictions in a different geological setting without any need for re-training the neural network? And 2) What about real-time context? What are the factors affecting the quality of sediment class prediction then?"

For her initial experiment, Garone used deep learning to discriminate between hard substrate (mainly bedrock) and soft sediments (mud or sand or mixed sediments). To do this, the neural network has been shown expert interpretation of the bathymetry and backscatter so that it can learn to predict and discriminate different sediment classes.

"My main task consisted in adapting my PhD work to MBES data from a different geological background and geographical location. Thus pre-processing and processing of the new data, together with the deep learning algorithm integration into the real-time pipeline had a huge impact on the positive outcome of the experiment," Garone says.

"Results looked encouraging despite the biggest challenge was related to obtaining MBES data without artifacts and with a low signal to noise ratio," she adds. "In fact real-time

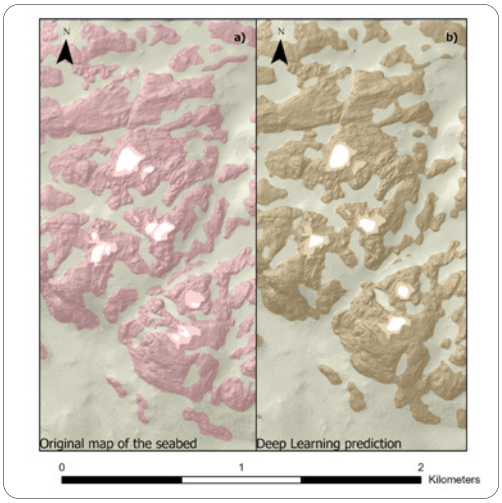


*Image showing:
a) Example of the original map for the study area;
b) Deep Learning prediction. This shows the similarity between the original annotations and the predictions confirming the suitability of Deep Learning to perform automatic classification of the seabed.
Image: Rosa Virginia Garone/NTNU.*

data don't undergo all the necessary pre-processing steps necessary to make them ideally clean from artifacts and noise".

A Step Toward Automated Classification
Obtaining high quality MBES data is not just a question of equipment. External factors also play a major role: Ocean depth and weather conditions affect the quality of the MBES data and images, which again affect the performance of the deep learning algorithms:

"Ultimately our final results looked encouraging. The algorithm provided a plausible map of the seabed sediments. However, due to the scarcity of good quality images and missing ground truth we were not able to do a rigorous comparison."

"It is very encouraging to see that Rosa and the students were able to integrate the algorithm in real time during this summer project. Something like this would be very valuable for many users of multibeam systems, and this shows that a real time implementation could be feasible," comments Birkenes Lønmo.

Real-Life Experience
The summer project had more than just scientific benefits:

"This collaboration gave me the opportunity to step out of my comfort-PhD-project-zone, challenging me to find a solution to a real-time, real case problem," Garone reflects.

"It was extremely interesting to come out with different solutions to different problems together with the other students participating in the summer project. This experience has benefitted me academically by pushing me to keep in mind how important it is being able to make the results of research available for use in a real-case scenario. This will for sure also help me careerwise," she concludes.

Multibeam Echo Sounder (MBES)
Multibeam echo sounder is type of sonar system used to map the seabed. These instruments have the capability to map the seafloor by emitting narrow acoustic beams allowing for a 100% coverage of the ocean bottom.

Backscatter Mosaic
The backscatter mosaic is a product of the MBES systems. Backscatter data provide the users with a reflectivity seabed map. In fact, different seabed sediments have distinct acoustic characteristics, as a consequence, the acoustic wave emitted form the MBES instrument will be reflected from the seabed accordingly to the seafloor sediments characteristics.

Bathymetry Grid
The bathymetry grid is an additional product of the MBES systems. Bathymetry data provide the users with information about the seafloor depth and its spatial variability. Depth data are acquired by measuring the time necessary to the MBES instrument's acoustic wave to hit the seafloor and to be reflected back to it.

By Kari Williamson/NTNU

CRACK-DETECTING WAVES

Whether they transport oil, gas, water, or other substances – you do not want them to leak. But if a pipe is in an inaccessible area, how do you then check for cracks? And if there are any – are they critical, or not?

Simen Hammervold Midtbø, PhD-Candidate, NTNU and NDT Global
Photo: Karl Jørgen Marthinsen/NTNU

These are important questions for health and safety, and for the environment – especially in the oil and gas industry. Simen Hammervold Midtbø is now finalising his PhD on crack detection and assessment using Lamb waves and has already been employed by CIUS partner NDT Global, which specialises in ultrasonic and non-ultrasonic inspection of, amongst other things, pipelines.

How Deep is the Crack?
"The overall goal of crack detection technologies in pipelines is to find cracks of certain sizes and notify the pipeline operators of critical cracks. Critical cracks are defined by their shape and depth," Midtbø explains. "A crack that is going through the entire pipe wall is very critical to detect, whereas a crack that is only 1% of the wall thickness is non-critical – though it would still be necessary to monitor that crack and its potential development."

This is why crack depth is one of the more important variables that have to be accurately identified. Midtbø has chosen to use Lamb waves for this:

"The measurement of a Lamb wave that travels in a pipe wall will change if there is a crack in its path, and the change will vary with crack depth. However, this change can be subtle, depending on the measurement system and method, which can be modelled. This is where my work comes in, as I am working with a model that can be used for optimisation for such a measurement system to detect as much change as possible."

Lamb Waves Modelling
To create Lamb waves one can set a transmitter to radiate sound waves towards, for example, a metal plate – like a loudspeaker facing a wall. The sound waves will generate a

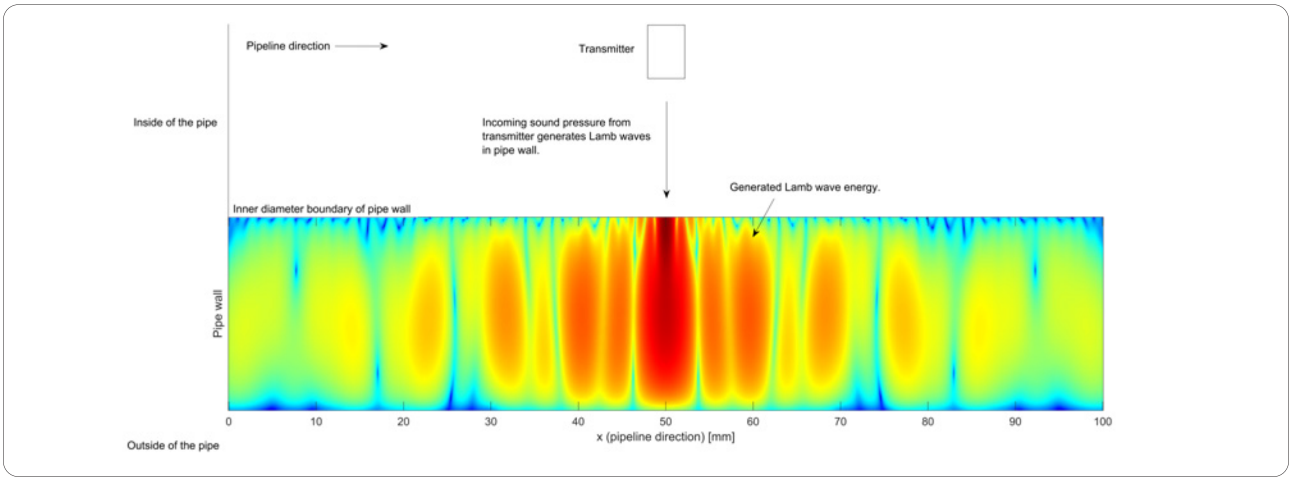


Illustration of the measurement principle in a pipewall. The tool is inside the pipe as it is moving along the pipe and radiating sound towards the wall. The transmitted sound generates Lamb waves in the pipe wall, which will change and be distorted if there is a crack. Illustration: Simen Hammervold Midtbø/ NTNU and NDT Global

Lamb wave inside the plate, and it travels along it. The wave energy can be measured using a receiver at a certain distance from the transmitter – a bit like placing a microphone along the plate a certain distance away from the loudspeaker.

If there is a crack between the transmitter and the receiver, the wave energy will change and can thereby be measured – in theory...

The size of the transmitter, the thickness of the plate, the distance between the transmitter and the receiver – they all affect the outcome. The proposed solution is therefore to use modelling:

"The first step of such a model is to develop a description that can account for a transmitter and plate, without cracks. This is described in my first PhD article "ASM and finite beam description of the excited leaky Lamb waves in a fluid-immersed plate" (Ultrasonics, 2022).

The second step is to perform measurements of cracks and use the model to analyse how the measurement-response is related to the different parameters, and how one can exploit that information to optimise the measurement system," Midtbø says.

It may sound straight forward, but theories do not always correspond with the 'real world':

"The biggest challenge is perhaps being able to compare theory with measurements – or vice versa. Theory in physics/ acoustics are often limited by assumptions, so to understand what those assumptions mean for an actual, physical, real setup can sometimes be challenging," he explains.

Already a Fulltime Employee
Midtbø is now in the process of finishing his second PhD article but has already started fulltime work for NDT Global. They are currently developing a crack detection tool, for which Midtbø's expertise comes in useful.

Doing a PhD with an industrial partner has been a positive experience – also academically:

"As a researcher, I had access to tools and laboratory equipment necessary to do my studies. I was also fortunate enough to be stationed at NDT Global's location in Bergen, so that I had an office and close contact with the technology, people, and challenges.

"Obviously this also put me in a good position when ending my time at CIUS and was offered a position within the research & development department at NDT Global," Midtbø concludes.

Lamb Waves
Lamb waves are waves generated within a thin layer of solid material such as a metal plate or pipe wall. They exhibit different properties depending on the material, but also depending on changes within that material – like cracks. The trick is to interpret the changing properties correctly – to correctly identify and measure cracks.

By Kari Williamson/NTNU

IN SHARPER FOCUS

Take a 40-year-old problem of 'unfocused' ultrasound images, add dedicated researchers at a centre for research-based innovation, and the result? Sharper, clearer images regardless of the patient's anatomy – a vitally important improvement for diagnosing heart attacks and their severity.

When diagnosing heart attacks, subtle changes in movement in the heart muscle can give information on the size of the attack and the extent of muscular damage. In most cases, this can be seen by an experienced sonographer, but in 10-15% of patients, image quality is suboptimal. Not a high percentage you think? Add then that more than 100 million ultrasound heart examinations are carried out globally every year, and the magnitude of the challenge can be overwhelming.

"Having ultrasound pass through the body wall can be compared to light travelling through a layer of Vaseline on your camera lens – it results in a blurred image with poor contrast. The image is said to be aberrated," CIUS centre director and researcher Svein-Erik Måsøy explains.

A Window in the Wall

The challenge lies in the fact that the human body consists of various substances such as fat, muscles, tissue and bones, that the sonographer and the soundwaves from the ultrasound probe have to navigate. And no two human beings are identical.

This is why in 2017, CIUS researchers at GE Healthcare, NTNU, University of Oslo and St. Olavs hospital came together to solve the 40-year-old issue of aberration. The result is the Adapt technology:

"Adapt is an algorithm that uses the recorded ultrasound data to estimate and compensate for the effect of the body wall in each individual patient. It adapts itself to the patient making more than 100 corrections to each image pixel per second," Måsøy says.

It was tested in a pilot study with four clinicians at St. Olavs hospital, and the result was that Adapt was preferred in 97% of cases compared with ultrasound scans without the new technology, and it has already been made available on the GE Vingmed Vivid E95 scanners worldwide.

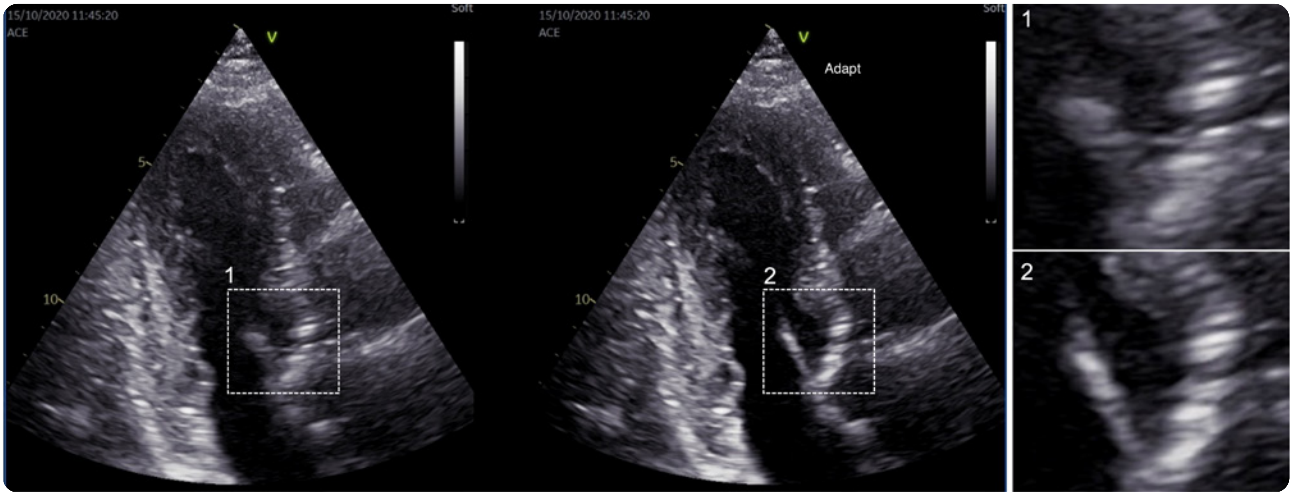
"Adapt sharpens images, increasing contrast resolution and improving diagnostic confidence," says Echo technician Lill Merete Skretteberg Lindøe at Oslo University Hospital. "The imaging enhancements reduce non-diagnostic images and improve productivity and workload by reducing scan time and improving ergonomics."

A Gam(ing)-Changer

So how come it suddenly only took five years of dedicated CIUS research to solve the 40-year-old problem? Well, that is something we can thank the gaming industry for – at least partially!

"Advancements in GPU processing power over the past decade, brought to the fore by the gaming industry and recent improvements in 3D ultrasound probes, have been instrumental for the success of Adapt," Måsøy says.

"Modern ultrasound systems have moved ultrasound image reconstruction from dedicated hardware chips to software using GPUs, allowing for storage of so-called raw-unprocessed ultrasound data. This data can be used to recreate images by testing variations of algorithms over and over again on realistic, clinical data. This was simply not possible before, and therefore represented a game-changer in the possibilities for making Adapt work."



The case example shows an ultrasound image of the left heart chamber using the GE Vivid E95 ultrasound system. Left: State-of-the-art imaging, without cSound Adapt. Right: Same image with cSound Adapt processing. The data are processed from exactly the same recording. Notice improved resolution and sharpness in the cSound Adapt processed image. See detailed results in boxes 1 and 2, where it can be seen that the heart valve and heart wall is much more clearly visualised using cSound Adapt.

But to create the algorithm, the research team consisting of 10 core members and many more contributors, started studying more than 40 000 ultrasound images of the heart. This was to understand the fundamental mechanisms needed to make the algorithm work – regardless of the great variations in patients' body walls.

Unlike traditional methods, which rely on a mathematical model of how ultrasound waves move at a constant speed through the body, the Adapt algorithm optimises the image reconstruction process for each individual patient. This adaptive approach takes into account the unique anatomy of each patient, allowing for real-time adjustments to the ultrasound image formation process.

"At GE HealthCare, we are committed to creating a world where healthcare has no limits, and the development of the Adapt technology serves as a shining example of this mission in action," explains Bastien Dénarié, Manager of External Imaging research at GE HealthCare.

"This innovative technology, developed in partnership with the CIUS team, improves ultrasound image quality to an industry-leading level. This would not have been possible without the excellent cross-disciplinary collaboration between researchers and clinicians that is so unique to CIUS. The Adapt technology's ability to adapt to the unique characteristics of each patient's anatomy is a game-changer for the diagnosis and treatment of heart attacks. We are proud to have been a part of this breakthrough and look forward to continuing our collaboration with CIUS to push the boundaries of medical technology and improve patient care."

The Adapt Technology

Ultrasound images are formed by sending a concentrated ultrasound wave into the body and recording the returning echoes. This is done by using a probe acting simultaneously as a speaker and microphone. The probe has many elements (thousands) which allow the system to locate precisely where the echoes are returning from by logging the arrival times of each ultrasound signal at each element. By comparing arrival time differences across all elements, the exact position of each individual echo can be found.

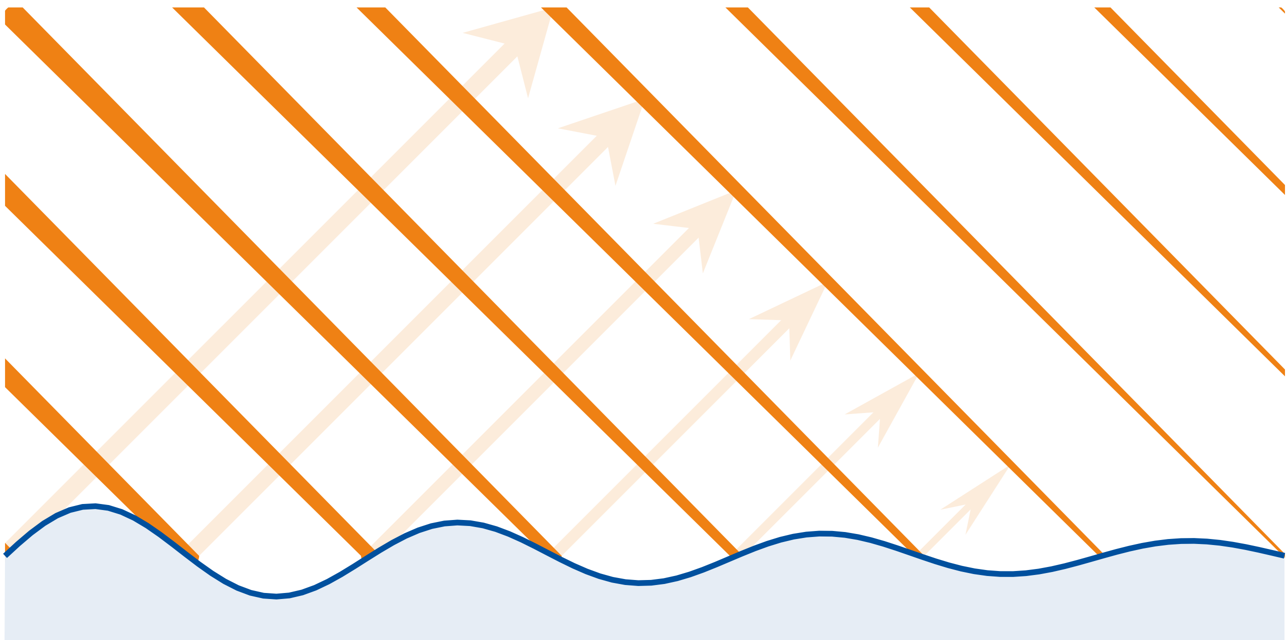
This process works perfectly if tissue is even. But the body wall is not even creating additional unknown varying arrival times across the probe's elements. This is the basic mechanism for reduced image resolution and contrast. The system can no longer work out the exact location of each echo.

Adapt works by estimating the change in arrival times for all the elements of the probe and compensates for this in the image reconstruction process, thereby improving the echo localisation process and consequently providing better images.

By Kari Williamson/NTNU

BLUE SKIES
INNOVATION

Basic research (or blue skies research) may be defined as research to understand the basic mechanisms of nature. Such research is often regarded as curiosity driven and defined by scientists.



A central point of Erlend and Håvard's insights is that a surface vibration (blue) is weakened as it loses energy into the sound wave. It therefore radiates a so-called inhomogeneous sound wave (orange), which has some unique properties that allow subsonic radiation. Image: Erlend Viggen/NTNU

Having worked more than 20 years with research and development, mostly in academia, I have always been taught that this is the best way to do science as the findings of such work can lead to unforeseen gains to society in the form of new knowledge and innovations.

Innovation can, on the other hand, be defined as gathering a group of people to solve real-world problems. This is almost the opposite of blue skies research, as here, a known problem is addressed specifically.

Personally, I have always felt that parts of the academic community have looked in disdain at innovation, as this seemingly betrays the notion of academic freedom and the knowledge-driven researcher. On the other hand, innovators may think academics are not focused enough on solving the problems of the real world, and that they are more interested in figuring out nitty gritty details. Over the years, my view on this has changed, and being the leader of a centre for research-based innovation, the world does not appear black or white.

Regardless of the polemic discussion above, my experience from working in CIUS is that a tight focus on innovation in many cases also leads to the development of fundamental new knowledge. In other words, in CIUS we see that a focus on innovation leads to basic research. I will illuminate this with some recent examples from the fantastic researchers working at our centre:

CIUS researcher Erlend Viggen has been working on ultrasonic logging in oil and gas wells for many years. These ultrasonic measurements are analysed by log interpreters to verify that these wells are hydraulically sealed by cement or rock. Such seals control the flow of oil and gas, preventing catastrophes where large amounts of hydrocarbons leak out into the environment. While building an efficient computer model for propagation for an important logging application, Viggen and his MSc student Håvard Arnestad (now a PhD candidate at UiO) realised how important a phenomenon called subsonic radiation was for this application.

Simply put, subsonic radiation is when a vibrating surface produces a sound wave even though the vibration moves slower than the speed of sound – a phenomenon that every acoustics textbook Viggen and Arnestad could find considered to be impossible. Only a handful of research articles had observed the phenomenon, but a fundamental understanding of it was missing. After digging into it, Viggen and Arnestad now have a research article on the way that provides the missing understanding of this quite fundamental acoustics phenomenon. You can read more about it in this preprint of the article: https://s.ntnu.no/Viggen_article.

PhD candidate Annichen Søyland Daae is a medical doctor and has used a new ultrasound method called Blood Speckle Tracking (BST) to investigate the complex blood flow inside the heart. A version of BST called Blood Speckle Imaging (BSI) was launched commercially by CIUS partner GE Vingmed Ultrasound in 2017 based on work prior to CIUS.

BST allows for visualisation of the complex blood flow inside the body with very high time resolution, and in all directions. In her project, Daae has used BST to describe the normal physiology and the coupling between the blood flow and the geometry of the heart, and is currently working on describing the differences in blood flow between the healthy and the sick heart. She has basically described unknown physiology in the heart, with complex vortex flow changing shape and form with different diseases and shapes of the heart.

The start of both these projects was with a goal of solving real-world problems: How to help log interpreters analyse ultrasonic data from oil and gas wells more efficiently and robustly; and how a new commercially available technology could help describe new features of heart disease, potentially providing new diagnostic methods for clinicians. Both projects ended up with beneficial side-effects: new basic knowledge that may be translated into more use and understanding of the complex phenomena of subsonic radiation and the blood flow in hearts.

To me, it is very clear that innovation is also a path to fundamental research, and we see this happening in almost all CIUS projects. As stated above, the world of basic research and innovation does not appear black or white to me anymore, it is more like blue skies in all directions...

By: Svein-Erik Måsøy, Centre Director

International
Collaboration

Sheffield University, UK
Kings College, London, UK
University of Twente, Netherlands
Århus University, Denmark
Rigshospitalet, København, Denmark
University of Bath, UK
Linköping University, Sverige
Technical University of Denmark, Lyngby, Denmark
Charité Hospital, Berlin, Tyskland
Medical University of Vienna, Austria
Creatis Insa de Lyon, France
GE Parallell design, Sophia Antipolis, France
TDK Invense, Italy
University of Craiova, Romania
University of Rome, Italy
Genth University,Belgium
University of Rennes, France
KU Leuven, Belgium
INSERM, Paris, France
Institute of Cancer Research, London, UK
Ho Chi Minh International University, Vietnam
University of Queensland, Australia

PhD Candidates

Erik Andreas Berg (WP5)
Multimodality and interventional imaging
We refine and validate a computerised algorithm for 3D transthoracic and transoesophageal echocardiographic measures for reconstruction of aortic root morphology. We also work on a semi-automatic computerised algorithm for semi-quantification of aortic and mitral valve regurgitations based on ultrasound data, the clinical value of an algorithm for continuous ultrasound monitoring of LV function during major surgery, and an application for 3D echocardiography of coronary arteries.

Per Kristian Bolstad (WP1)
Transducer design
Central topics of the PhD-project is to develop and investigate new bonding methods for ultrasound transducers, using metal alloys to replace polymers. Single element and arrays will be designed, fabricated and characterised. The stability and robustness of the new structures will be investigated, such as long-time stability, aging, mechanical strength, and behaviour under high temperatures and pressures.

Gerard Clarke (WP5)
Mild traumatic brain injury research
Mild traumatic brain injury (also known as concussion) often leads to long-lasting emotional, memory, psychological and physical consequences, known as post-concussion syndrome. The aim of this project is to develop – using state-of-the-art machine learning – objective biomarkers of this persistent syndrome, in order to facilitate improved treatment protocols. Candidate biomarkers investigated are markers of inflammation and central nervous system damage obtained from the blood, along with neural metabolic activity of glucose, tau and amyloid beta, as measured using positron emission tomography.

Mikael Estuariwinarno (WP4)
Cement log processing algorithms
Many oil service companies offer ultrasonic pulse-echo cement logging tools of similar design. These tools record similar waveforms, which are then processed to help determine the state of the well. However, different tools typically process waveforms using different algorithms that have never been comprehensively compared with each other. This project will quantitatively compare the performance of these processing algorithms and publish their implementations in an open-source library. Furthermore, it will seek to design a new processing algorithm that improves on existing algorithms by extracting additional information that is known to be contained in the waveforms.

Ali Fatemi (WP2)
Acoustics and beamforming
State-of-the-art echocardiography allows us to correctly diagnose most cardiovascular diseases. An unknown source of clutter, however, hinders the visualisation of the heart in some cases. The aim of this project is to study the cause of this clutter noise in the current echocardiograms and to propose new processing methods to improve the image quality.

Rosa Garone (WP4)
Deep learning for seabed classification in SONAR
Maps of seabed sediments can be obtained by classifying data recorded by sonar systems such as multibeam echosounders (MBES). Although automatic methods for seabed sediments mapping are already in use, map production in geological surveys is still often a manual process. In collaboration with Kongsberg Maritime and NGU, I am studying the applicability and potential of CNNs for the purpose of classifying acoustic seabed imagery into sediment classes. Starting from MBES data, as source dataset, and ground truth data, we aim to help automate the seafloor mapping process in future applications.

Marlene Halvorsrød (WP7)
Clinical feasibility and validation – ischemic heart disease
In our project, we want to find new ultrasound methods to predict who will benefit from revascularisation in heart attacks. We take advantage of ultrasound methods developed in CIUS for detection of fibrosis to decide whether the myocardium is viable. In addition, 1/3 of non-ST-elevation myocardial infarctions have a totally blocked artery and will need treatment immediately. Our aim is to better detect these patients and quantify the myocardial tissue at risk. We use tissue Doppler, strain rate and 3D high frame rate imaging.

Mailys Hau (WP5)
Automated leaflets tracking
Ultrasound analysis is a time-consuming process and is submitted to inter-operator variability. The aim of this PhD is to enhance automated leaflets detection and segmentation by adding a time series point of view. Tracking leaflets on complete acquisition will allow more precise 3D modelling of the valve and follow-up of patients.

Aslak Lykre Holen (WP1)
Transmitters and receivers for ultrasound systems
This project is to develop transmitter and receiver hardware for low power and high integration targeting medical ultrasound. The aim of this project is to study low power adaptive solutions for integrated high voltage ultrasound pulse generators with harmonic suppression, and low power digital hardware beam formers for ultrasound receivers.

Thong Tuan Huyhn (WP1)
Non-ideal effects in transducers
Novel medical ultrasound imaging utilises the nonlinear properties of the tissue. This requires good control of the nonlinear behaviour of the transmit system. The aim of this project is to develop methods to explore and model the nonideal effects in this system, defined as any effect that cannot be described by an impulse response. The ultimate goal is to develop methods to compensate for such effects by shaping the transmit pulses. The project uses our 3D scanning hydrophone measurement tank, connected to a GE Vingmed Ultrasound scanner.

Shivanandan Indimath (WP3)
Identification of influx/efflux in oil and gas boreholes using doppler ultrasound while drilling for early kick detection
Drilling of boreholes in the earth's crust is standard practice for the extraction of oil and gas. The drilling process is an extremely complex and expensive process and the hydraulic pressure balance in the borehole is constantly maintained within certain limits. There are instances when this pressure balance is disturbed due to influx/efflux of formation fluids into/out of the borehole, and this results in "kicks" which can escalate into catastrophic events called "blowouts". Such events pose severe consequences from ecological, economic and safety perspectives. It is the objective of my PhD project to evaluate the applicability of Doppler ultrasound for characterisation of these influx/efflux events while drilling a borehole so that such catastrophic incidents are averted.

Jessica Lage (WP5)
Targeted drug delivery
Acoustic Cluster Therapy (ACT) is found to improve the delivery of drugs and nanoparticles (NPs) to tumours and across the blood-brain barrier. The overall aim of the project is to bring light to the underlying mechanisms ACT, a method that is based on the use of ultrasound in combination with large microbubbles to improve the delivery of NPs to tumour tissue. Of special interest is clarifying the cause and mechanism of the enhanced tissue extravasation and flow through the Extracellular Matrix (ECM), especially on infiltrating ductal adenocarcinoma of the pancreas (PDAC). The project also aims to evaluate the application of ACT mediated delivery in brain diseases, especially on a glioma model. Moreover, we will evaluate the response of the immune system.

Duy Hoang Le (WP1)
New generation cardiovascular ultrasound probe based on a hybrid CMUT-piezoelectric transducer
Motivation of the project is a new type of ultrasound probe which gives higher quality of medical imaging by utilising harmonic imaging technique. The probe consists of a piezoelectric transducer array (as transmitter) and a capacitive micromachined ultrasonic transducer (CMUT) array (as receiver) on the same footprint. The hybrid transducer generates ultrasound beam at frequency f_C and acquires reflected beam at frequency 2 f_C (second harmonic). The advantages of the new technology are lower reverberation noise and improved axial and lateral resolution.

Malgorzata Magelssen (WP6)
Diagnostic accuracy of handheld ultrasound
Significant efforts are being made to improve the diagnostic accuracy of handheld ultrasound devices (HUDs). This can enhance the art of clinical examination by revealing disease at an earlier stage and help to better identify patients in need of specialised care. The focus of our scientific work is to study the feasibility, accuracy and reliability of HUDs when used by less experienced healthcare professionals such as general practitioners (GPs) and specialised nurses after a period of focused training. We want to evaluate the usefulness of using HUDs as a supplement to clinical diagnostics in patients with suspected heart failure. Further, we want to evaluate the use of automatic analysis of heart function and telemedical support from cardiologists.

Amirfereydoon Mansoori (WP1)
Wideband solutions for Piezoelectric MEMS Ultrasonic Transducers (PMUTs)
Piezoelectric MEMS Ultrasonic Transducers (PMUTs) are promising alternatives to conventional bulk piezoelectric transducers, particularly in applications where miniaturisation, cost, ease of fabrication and integration to the front-end circuitry are of critical importance. Unlike its capacitive counterpart (CMUT), PMUT does not require a DC bias voltage and operates linearly, however the performance of conventional PMUTs have been limited by their narrow bandwidth. The aim of this project is to first identify the theoretical as well as practical limits of PMUTs and then propose novel solutions to enhance the bandwidth of such devices enabling new ultrasonic imaging applications.

Wadi Mawad (WP7)
Cardiac blood flow and blood speckle tracking
The use of high frame rate ultrasound and blood speckle tracking allows the visualisation of cardiac blood flow patterns and quantification of flow characteristics such as vorticity and energy losses. Changes in flow characteristics are thought to precede overt cardiac remodelling which makes them potential early biomarkers of adverse cardiac remodelling. This project focuses on the application of this imaging technology to multiple congenital cardiac conditions in children to assess its feasibility, reproducibility and to demonstrate differences in flow characteristics.

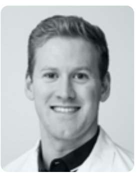
Simen Hammervold Midtbø (WP4)
Crack detection
Cracks and defects in oil- and gas pipelines are a major concern to operators across the globe today. NDT Global is a company that is developing a tool that can detect and quantify the severity of the cracks, using ultrasound and tomography methods. By exciting and recording the resonances in the pipewalls using an array of ultrasound transmitters and receivers, tomography methods can be used to detect irregularities within the pipewall. The challenge, however, lies in differentiating actual cracks from more general irregularities, such as corrosion, within the pipe. It is our objective to contribute to this task by optimising an inverse tomography technique that combines theory and measurement, while simultaneously increasing knowledge on how waves interact with cracks to improve analysis results.

Olivia Mirea (WP1)
In-probe receivers for medical ultrasound systems
The purpose of this research is to improve the quality of ultrasound heart imaging by developing new integrated in-probe electronics using dual frequency hybrid CMUT technology. Different topologies of LNA (low noise amplifier), TGC (time gain compensation amplifier) and ADC (analogue to digital converter) will be studied/compared, the aim of the project being to find new ideas of improving the current state-of-the-art of the circuits.

Danial (Mohammad) Mohajery (WP3)
Mechanical wave propagation in LV
Underlying pathologies and deficiencies of the heart often lead to characteristics changes of the cardiac tissue. Knowing that mechanical wave propagation in the myocardium is connected to tissue properties, I aim to study naturally produced waves during a cardiac cycle as a tool for pathology diagnosis. Combining high-frame-rate ultrasound volumes with AI-based processing, I plan to evaluate wave velocity and to construct a 3D velocity map of the left ventricle. In addition, in collaboration with medical PhDs, I conduct large cohort studies to verify the validity of my tool.

David Pasdeloup (WP4)
Image analyses
With the availability of portable ultrasound devices, the number of examinations carried out by non-expert users will increase. The aim of the project is to use state-of-the-art machine learning to develop tools that aid the non-expert user when acquiring images, performing image measurements, and for proposing an initial diagnosis. All steps in the echocardiography workflow can benefit from these tools. Challenges in image acquisition will initially be approached by developing a probe guidance system. Further focus will be placed on automatic interpretation of ultrasound images.

Josh Hoi Yi Siu (WP1)
High temperature transducers for applications in the oil and gas industry
Non-destructive testing and monitoring in the oil and gas industry in some cases require the use of transducers that can operate at very high temperatures, e.g., above 500°C. High temperature piezoelectric ultrasound transducers have been a prime candidate in such applications, due to their simplicity and ease of integration. The goal of this project is to investigate, develop, fabricate, and characterise piezoelectric transducer elements for use at such high temperatures. Evaluation of long-term stability and reliability are central parts of the project.



Andreas Sørbrøden Talberg (WP2)
Acoustics and beamforming
The focus is on using ultrasonic non-destructive testing methods in applications related to the oil & gas industry. Current work is being conducted with WP3 to combine the knowledge related to the propagation of waves in solids and the use of Doppler methods to inspect flow behind a solid layer through numerical and experimental work.

Anders Emil Vrålstad (WP2)
AI beamforming
In collaboration with GE Healthcare Women's Health Ultrasound, I work on improving image quality in medical ultrasound using artificial intelligence (AI). The aim is to correct the delay model in the beamformer by estimating the speed of sound of the imaging tissue. My research is based on image quality metrics, advanced beamforming techniques and machine learning. Improvement in image quality will hopefully result in more precise medical diagnosis and faster ultrasound examinations.

Magnus Wangensteen (WP2)
Increased sensitivity and detailed diagnosis of corroded oil and gas pipes using ultrasound
Some of the challenges with the current corrosion monitoring is inexact sound speed temperature compensation and undetermined pitting developments on the inner pipe wall. The objective of this project is to investigate improved transducer technology and algorithms to address these challenges. This may be achieved by using annular arrays for detection of pitting or by taking advantage of guided waves for advanced diagnosis between sensors.

Sigurd Vangen Wifstad (WP3)
3D Doppler and Machine Learning to evaluate mitral valve disease
Mitral valve disease is one of the most common heart diseases, with an estimated prevalence of 2-3% globally. Diagnosis of mitral valve disease is commonly performed with ultrasound, but providing accurate quantitative measures is difficult because of physical and technological limitations. In this project we wish to improve the quantitative metrics for valve disease severity grading to aid doctors provide correct treatment to patients. We will explore the use of 3D Doppler ultrasound and machine learning to measure regurgitant orifice areas and flow volumes.

Yasin Yari (WP4)
Machine learning and ultrasound to predict Atlantic salmon maturation
The goal of my PhD project is to research and develop state-of-the-art machine learning methods for determining various important maturation states of Atlantic salmon with the aim of predicting the optimal timing of egg stripping for breeding purposes. This includes performing tasks like real-time segmentation and classification in the ultrasound image of the fish ovary in combination with using peripheral sensors for having an autonomous prediction. This may result in a set of methods that can be applied to the daily operations of the Atlantic salmon farming companies.

Postdocs

Stefano Fiorentini (WP3)
Valve insufficiency quantification
My main research field is the quantification and imaging of blood flow using Doppler ultrasound. The aim of my current research project is to develop new methods and acquisition sequences to quantify the severity of mitral and aortic valve insufficiency. We have developed a method that combines 3D ultrasound technology and high frame-rate acquisitions to measure the regurgitant volume, an important parameter in the assessment of valve insufficiency. The method passed the technical validation stage and is currently undergoing preliminary clinical validation.

Jahn Frederik Grue (WP6)
Improved diagnostics of cardiotoxicity and valvular disease
Novel methods based on artificial intelligence and machine learning can improve analysis in echocardiography. My research is on using such methods for more sensitive detection of heart disease. In this project, the focus is on cardiotoxicity caused by chemotherapy for breast cancer, mitral regurgitation, and aortic stenosis. The aim is to develop and validate methods for automatic echocardiographic detection and grading of these diseases.

Mansoor Khan (WP 1)
Acoustic Characterization of Dual Hybrid Ultrasound Transducer
My work involves acoustic characterisation of hybrid transducer architecture that can operate at distinct frequencies. I have developed fast analytic circuit models matching the accuracy of FEMs. To reduce the computational complexity, a shorter periodic segment of an infinitely large array is usually modelled in FEMs. The predictions of these periodic boundary conditions are not exact as they ignore the mutual coupling between CMUT elements, coupled through local media and backing. Acoustic measurements like electrical impedance and receive transfer function of large a CMUT array in a pulse echo water tank setup, are easily benchmarked and understood in terms of these analytic circuit models.

Ole Marius Hoel Rindal (WP2)
Advanced beamforming
My postdoc research is on beamforming for medical ultrasound imaging, more specifically on advanced beamforming techniques to improve image quality. Improved image quality will lead to images that are easier to interpret for the clinicians, resulting in more correct and precise medical diagnosis. Part of my research is on the metrics and the development of more relevant and useful metrics to evaluate the image quality improvements. Most of my work is centred around the development and maintenance of the UltraSound ToolBox (http://www.USTB.no)

Erik Smistad (WP4 and WP5)
Image processing, analysis and visualisation
I am primarily working on image segmentation and exploring new developments in the field of machine learning and neural networks. The work has so far been on classification of images, as well as identifying structures, such as blood vessels and the left ventricle. I have also developed software tools for easy annotation of ultrasound image data (Annotationweb), and tools for processing ultrasound images with a trained neural network in real-time.

Erlend Viggen (WP4)
Ultrasonic petroleum well logging
The integrity of a petroleum well can be evaluated with the help of measurements in the well, including ultrasonic ones. Equinor has released a large set of well measurement data to CIUS, and I am working on developing techniques to draw new information about the well status from this data. The aim is to provide more certainty about the status of the well, so that expensive operations such as plug-and-abandonment can be carried out in more cost-effective ways.

Jahn Frederik Grue testing Dolphitech's non-destructive testing (NDT) scanner at the CIUS 2022 Spring Conference.

Scientific Personnel

Tore Bjåstad
Scientific programmer
The main purpose of Bjåstad's work is to accelerate the process of getting new methods and algorithms into a product. Primarily, the product will be a GE Vingmed Ultrasound scanner intended for cardiovascular imaging. This work will typically involve further development of scanner code to make it capable of executing new methods in real-time, or to collect data for offline processing, or in some cases just assistance in how to set up and use existing functionality of the scanner.

Vincent Bryon
Researcher
The goal of my research is to improve the accuracy of colour flow imaging in the heart by implementing computational fluid dynamics (CFD) to simulate blood flow. By using CFD, I aim to provide new flow features that cannot be accurately depicted by traditional colour flow imaging methods. These new features could help to identify abnormal blood flow patterns in the heart, which can be indicative of cardiovascular disorders. Overall, my research aims to investigate the potential of using CFD to enhance the accuracy and reliability of colour flow imaging in detecting cardiovascular disorders.

Karin Deibele
Senior Consultant
Senior Consultant at the Centre for Foetal Medicine, St. Olavs hospital, Trondheim

Ingvild Kinn Ekroll
Associate Professor and Researcher
Ingvild Kinn Ekroll is an associate professor and researcher at NTNU with a background in biophysics. She has been working with ultrasound technology for medical applications since 2009, with imaging of blood flow and clutter filtering as specific research topics of interest.

Solveig Fadnes
Researcher
Fadnes is a researcher at NTNU with background in applied physics. She has worked with research within medical ultrasound technology since 2010. Research interests include cardiac blood flow imaging, especially for foetal and paediatric applications.

Erlend Løland Gundersen
Researcher
Gundersen is a researcher at NTNU with a background in electronics. His research aims to enhance image quality in medical ultrasound imaging, in order to facilitate more accurate diagnoses. He is utilising deep learning techniques to replicate advanced signal processing methods. Currently, he is particularly focused on the state-of-the-art cardiac ultrasound system from GE Vingmed Ultrasound.

Magnus Kvalevåg
Researcher
Magnus Dalen Kvalevåg is a researcher at NTNU. His work includes creating tools that integrate beamforming into machine learning pipelines. The goal of this work is to better utilise data and prior knowledge in cardiac ultrasound. The output will be an open-source software library for high performance beamforming that supports machine learning.

Martijn Frijlink
Associate Professor
The Department of Micro- and Nanosystem Technology (USN) are developing and investigating different aspects of ultrasound transducers for applications in both medical, maritime, and industrial fields. With Frijlink's background in different medical and nonmedical ultrasound applications, and having experience from the field of medical transducer design and manufacturing, his contribution mainly consists of supporting different ultrasound transducer related projects.

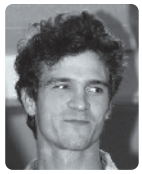
Bjørnar Grenne
Researcher
Grenne is a researcher at NTNU and a Cardiologist at St. Olavs Hospital. His main research areas are advanced echocardiography, valvular disease, coronary artery disease and echocardiography in valve interventions.

Espen Holte
Researcher
Holte is a researcher and Section head, Echocardiography at the Clinic of Cardiology, St. Olavs hospital. His main research areas are advanced echocardiography, machine learning, valvular disease, and coronary artery disease.

Tonni Franke Johansen
Researcher
Tonni Franke Johansen is a researcher at SINTEF and NTNU. His research interests are simulation and instrumentation for ultrasonic measurement systems. He contributes to research and supervision at USN with piezoelectric transducers, and at NTNU with wave propagation in layered media.

Spiros Kotopoulis
Associate Professor
Dr Kotopoulis' research focuses on the use of ultrasound to enhance targeted drug-delivery with an aim of increasing therapeutic benefit. Dr Kotopoulis' research ranges from understanding the microbubble-cell-ultrasound interactions to developing novel ultrasound transducers that accelerate and improve pre-clinical research and improve clinical translation. He is also involved with image-based data analysis and validation techniques.

Ole Christian Mjølstad
Researcher
Mjølstad has worked with the development of pocket-sized ultrasound technology since 2009, trying to improve physical examination and to increase diagnostic precision. Mjølstad and his colleagues work continuously to establish the position of pocket-sized ultrasound in daily clinical care. An important part is the development and clinical evaluation of applications that increase the usability among non-experts.



Sebastien Salles
Researcher
Sébastien Salles is a researcher at the laboratory of medical imaging (LIB) in Paris. He is currently developing new echocardiography techniques to improve the detection of cardiovascular diseases. His research focuses on creating and developing novel methods for tissue characterisation thanks to the propagation of mechanical waves produced by the Heart itself.

Lars Valderhaug
Staff Engineer
I am coordinating the 10-year testing of the Generation 100 study at NTNU. The Generation 100 study started in 2012 and is an ongoing study where the aim is to find out if exercise gives older adults a longer and healthier life. In the 10-year testing CIUS obtains echocardiography from approximately 600 adults above 80 years from Trondheim making this one of the biggest echocardiography materials in this age-group. In addition to echocardiography the Generation 100 study collects clinical data of cardiorespiratory fitness, cognitive function, blood pressure, blood samples, muscular function, ergospirometry, short-physical-performance-battery, MRI scanning of the brain and anthropometrics.

Andreas Østvik
Researcher
Østvik is a researcher at NTNU and SINTEF. His main research areas are quantitative echocardiography and artificial intelligence, currently focused on improving automatic methods for assessing regional myocardial function.

Researchers with External Financing in CIUS-projects

Postdoctoral Researchers

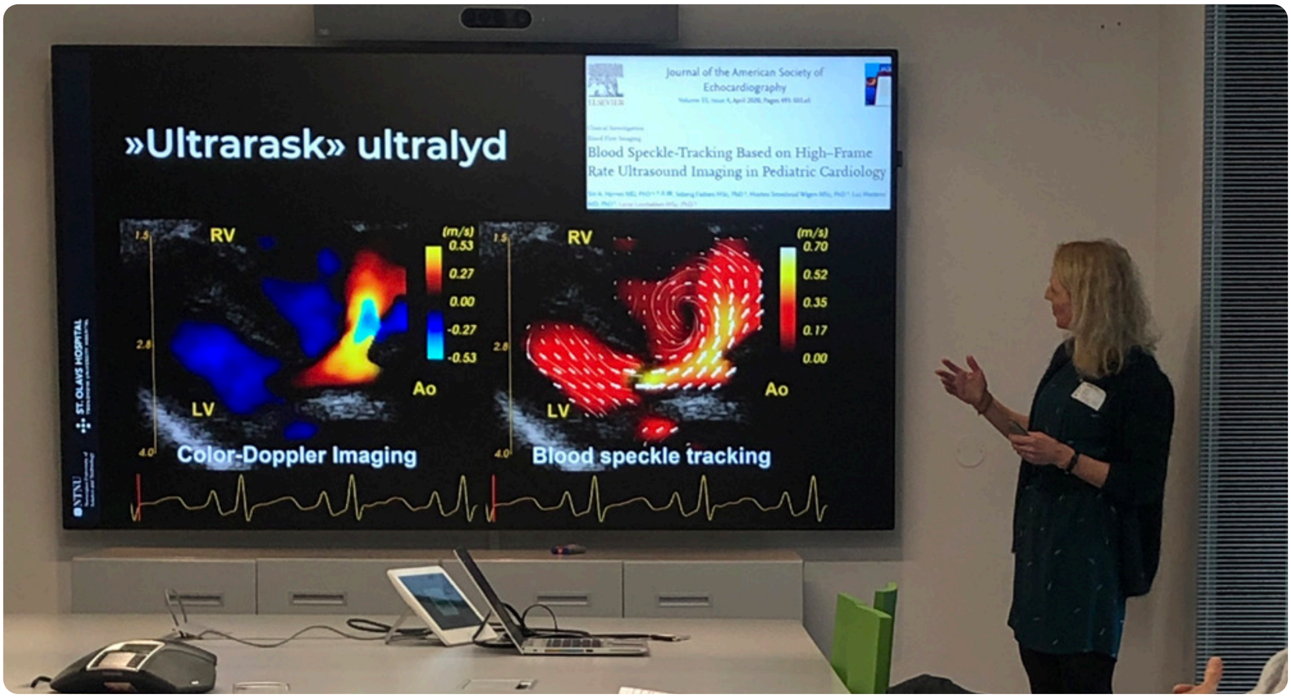
Anna Karlberg, NTNU
Sofie Snipstad, NTNU

PhD Candidates

Håvard Kjellmo Arnestad, UiO
Anders Tjellhaug Braathen, NTNU
Sri Nivas Chadrasekaran, UiO
Artem Chernyshov, NTNU/UiO
Annichen Søyland Daae, NTNU
Caroline Einen, NTNU
Torvald Espeland, NTNU
Henrik Fon, NTNU
Harald Garvik, NTNU
Gabor Gereb, UiO
Thomas Grønli, NTNU
Anna Hjort Hanssen, NTNU
Vegard Holmstrøm, NTNU
Matthew Henry, SickKids Toronto
Margrete Haram, NTNU, St. Olavs hospital
Jieyu Hu, NTNU
Trine Husby, NTNU
Henrik Kildahl, NTNU
Ole Jacob Lorentzen, UiO/FFI
Daniela Melichova, SSHF
Melina Mühlenpfordt, NTNU
John Nyberg, NTNU
Sindre Hellum Olaisen, NTNU
Håkon Pettersen, NTNU
Sebastian Price, NTNU
Ellen Sagaas Røed, USN
Ivar Salte, SSHF
Lars Saxhaug, NTNU
Peter W Strandhagen, NTNU
Sigbjørn Sæbø, NTNU
Kristian Sørensen, NTNU
Anders Austlid Tasken
Sander Bøe Thygesen, UiO
Benedikte Vindstad, NTNU
Gilles Van De Vyer, NTNU
Silje Kjærnes Øen, NTNU

CIUS Faculty

Svend Aakhus, Professor, NTNU
Andreas Austeng, Professor, UiO
Sigrid Berg, Research Scientist, SINTEF
David Bouget, Research Scientist, SINTEF
Håvard Dalen, Associate Professor, NTNU
Live Eikenes, Associate Professor, NTNU
Ingvild Kinn Ekroll, Researcher, NTNU
Roy Edgar Hansen, Professor II, FFI/UiO
Rune Hansen, Senior Research Scientist, SINTEF
Erlend Fagertun Hofstad, Research scientist, SINTEF
Gabriel Hansen Kiss, Associate Professor, NTNU
Thomas Langø, Research scientist, SINTEF
Torgrim Lie, Research scientist, SINTEF
Tung Mahn, Associate Professor, USN
Luc Mertens, Professor, Sick Kids, Toronto, Canada
Sebastien Muller, Research scientist, SINTEF
Sven-Peter Näsholm, Associate Professor, UiO
Siri Ann Nyrnes, Researcher, NTNU
Andre Pedersen, Research Scientist, SINTEF
Erik Smistad, Research Scientist, SINTEF
Ole Vegard Solberg, Senior Research Scientist, SINTEF
Karen Helene Støverud, Research scientist, SINTEF
Geir Arne Tangen, Research scientist, SINTEF
Ingrid Tvete, Research scientist, SINTEF
Andreas Østvik, Research Scientist, SINTEF



Siri Ann Nyrnes presenting at the Norwegian Ministry of Health and Care Services on 1. June 2022, in connection with a report on innovation in Norwegian health services.Photo: May Britt Melandsø Kjelsaas/Helse-Midt. Report: https://helse-midt.no/Documents/2022/Nasjonal%20rapport%20for%20forskning%20og%20innovasjon%202021.pdf

The 2022 CIUS Fall Conference was well attended. Photo: Kari Williamson/NTNU

Dissemination, Media Coverage and Outreach

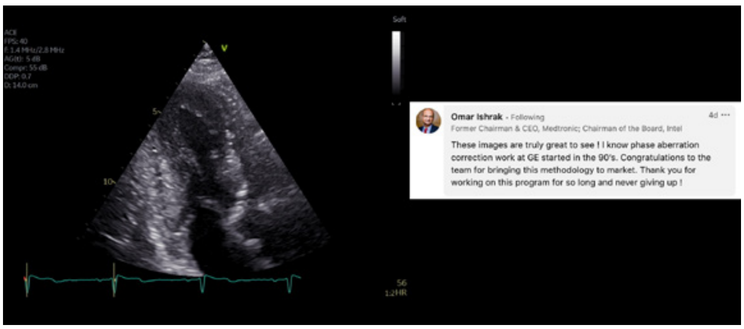
CIUS acknowledges the importance of communicating our research to the public. In 2022 we continued our focus on social media, including running a course for our PhD students.

Our dissemination efforts in 2022 were in some ways taken both to a new level, and back in time, when our partner Exact Therapeutics TX commissioned a journalist to explore Norwegian ultrasound history to be published in the online magazine The Explorer. We quickly showed our support and have since co-financed the effort. You can find the 'Spotlight on Norwegian ultrasound history' stories in our media list, but also on our History and Timeline page: ntnu.edu/cius/timeline.

We also decided to make better use of the stories that we publish in the annual reports, and throughout 2022, we therefore published these on the CIUS Blog to increase the reach. We have also slowly managed to get blogging back on the agenda with more 'original' posts appearing.

This effort was greatly improved after we held a blog and social-media lunch-time course in the autumn. Anyone interested, but primarily aimed at PhD and PostDocs, we held a short course on how to blog, and how to use social media. As can be seen from our "People to follow" list in Twitter, it certainly seems to have worked – the list has nearly doubled from last year!

One of the greatest success stories on social media this year, was not directly via the CIUS accounts, but through our Director, Svein-Erik Måsøy. He posed the success story of the Adapt Technology on his personal LinkedIn profile, and on the profile for the American Society of Echocardiography. The posts had nearly 9000 and 4500 impressions respectively. And – as an added bonus – had a comment from Omar Ishrak, Chairman of the Board, Intel. It turns out he used to work at GE in the 90s.



When it comes to Twitter, we have steadily built an increasing following and traffic, but things took a noticeable dip when Mr. Elon Musk took charge. For the time being, we have decided to remain on the platform as it is a great way of teaching young researchers to share their research in a short, succinct way, but we will monitor the situation and evaluate our presence if things take a turn for the worse.

In other news, one can see the effect of Exact Therapeutic's listing on the stock market, as they frequently feature in financial news. We have only recorded the main stories and left out ordinary 'stock market announcements'. There has also been a few news stories out there about Cimon Medical and the NeoDoppler technology, which is bringing in substantial investments.

We are looking forward to more blog posts, hopefully more media coverage, and an increased presence of our researchers in social media promoting their work in 2023!

CIUS PEOPLE TO FOLLOW

TWITTER

@sveinmas (Svein-Erik Måsøy)
@olemjolstad (Ole Christian Mjølstad)
@ErlendViggen (Erlend Viggen)
@alfonso_molares (Alfonso Molares)
@Larshoff1 (Lars Hoff)
@annichendaae (Annichen Søyland Daae)
@strain_rate (Asbjørn Støylen)
@ErikSmistad (Erik Smistad)
@bgrenne (Bjørnar Grenne)
@load_dependent (Lars Mølgaard Saxhaug)
@Sverre_Holm (Sverre Holm)
@Håvard Arnestad (Håvard Arnestad)
@annakhjh (Anna Hjort-Hansen)
@MalgosiaM3 (Malgorzata Izabela Magelssen)
@john_nyb (John Nyberg)
@dritsyk (Jingyang Yu)
@AndersTasken (Anders Austlid Tasken)

BLOGS

ntnu.no/blogger/cius
erlend-viggen.no
eriksmistad.no
dritsyk.no

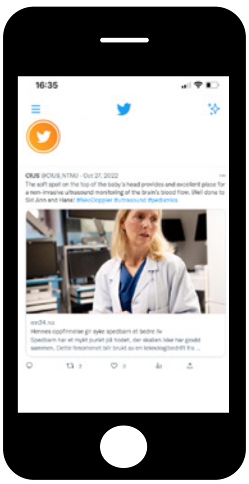
CIUS IN SOCIAL MEDIA 2022

Twitter: @ CIUS_NTNU — 235 followers — 51 tweets

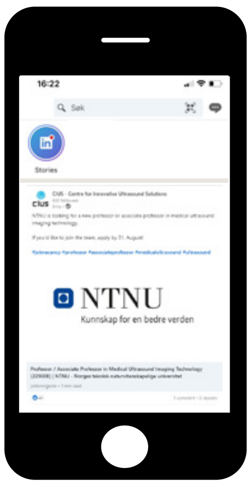
LinkedIn: @ CIUS — 587 followers — 54 updates

Facebook: @ NTNUhelse — 8500 followers — 13 updates

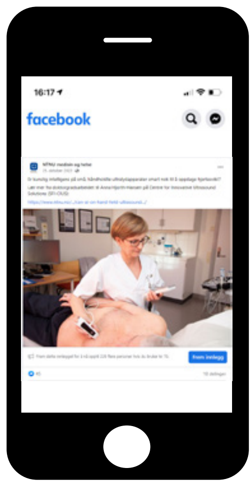
TOP CIUS POSTS 2022



3 LIKES
13 CLICKS
384 IMPRESSIONS
2 SHARES



40 LIKES
84 CLICKS
1600 IMPRESSIONS
2 SHARES

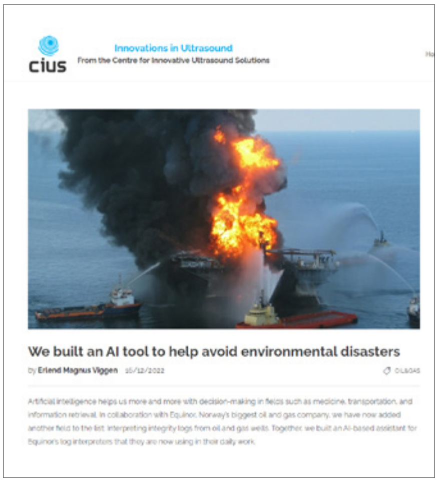


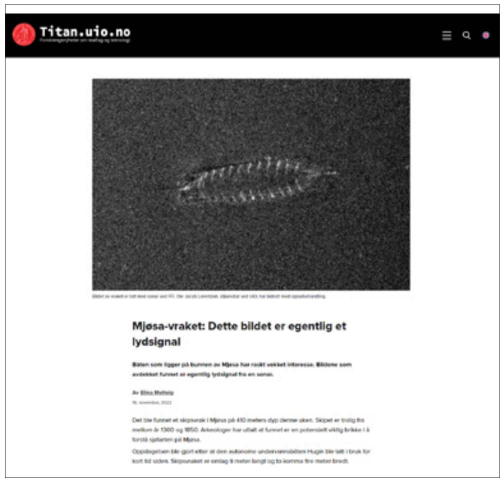
45 LIKES
9668 REACH
468 ENGAGEMENTS
18 SHARES


Finansavisen
Tips oss
Nyheter
Børs
Forum
TV
Aksjeanalyse
Academy
Podcast
Kjøp
Skal hente 60 millioner før påske
Et kobbel norske og internasjonale venture-fond har satset tungt på dette gründerselskapet, som bygger på norsk spisskompetanse. Nå er ett viktig mål nådd.
Publisert 22. nov. 2022 kl. 10.50
Lesetid: 3 minutter


MN24
Teknobedrift utnytter spedbarns myke skalle
Spedbarn har et mykt punkt på hodet, der skallen ikke har grodd sammen. Dette fenomenet blir brukt av en teknologibedrift fra Trondheim for å kunne gi for tidlig fødte barn et bedre liv.


blogg.forskning.no
cius
Alt om Ultralyd
- en blogg om forskning hos SFI CIUS
MV 0.86
LA 0.92
Kunstig intelligens er til stor hjelp ved ultralydavbildning av hjertet


cius
Innovations in Ultrasound
From the Centre for Innovative Ultrasound Solutions
We built an AI tool to help environmental disasters
by Erlend Magnus Viggen 10/12/2022


Titan.uio.no
Mjøsa-vraket: Dette bildet er egentlig et lydsignal


MN24
Må ha grønn profil for å vokse
Sammen med 14 andre midtnorske bedrifter går Sensorlink på kurs, for å komme i gang med det grønne skiftet. Slik kan de bidra til å redde verden, og samtidig tjene mer penger.


HELSE MIDT-NORGE
Forside > Nyheter > 2022 > Utvikler ultralydløsninger tilpasset barn og unge
Utvikler ultralydløsninger tilpasset barn og unge
Dagens ultralydløsninger for hjerte og hjerne er ikke godt nok tilpasset barns behov. UNG-prosjektet vil gi bedre diagnostiske verktøy, som på et tidligere tidspunkt kan finne markører for sykdom hos unge.
Ultralyd tilpasset barn og unge
– UNG-prosjektet handler om å utvikle ultralydløsninger spesielt tilpasset barn, med søkelys på hjerte og hjerne.


Sofie forskar på korleis medisin kan leverast meir presist i kroppen

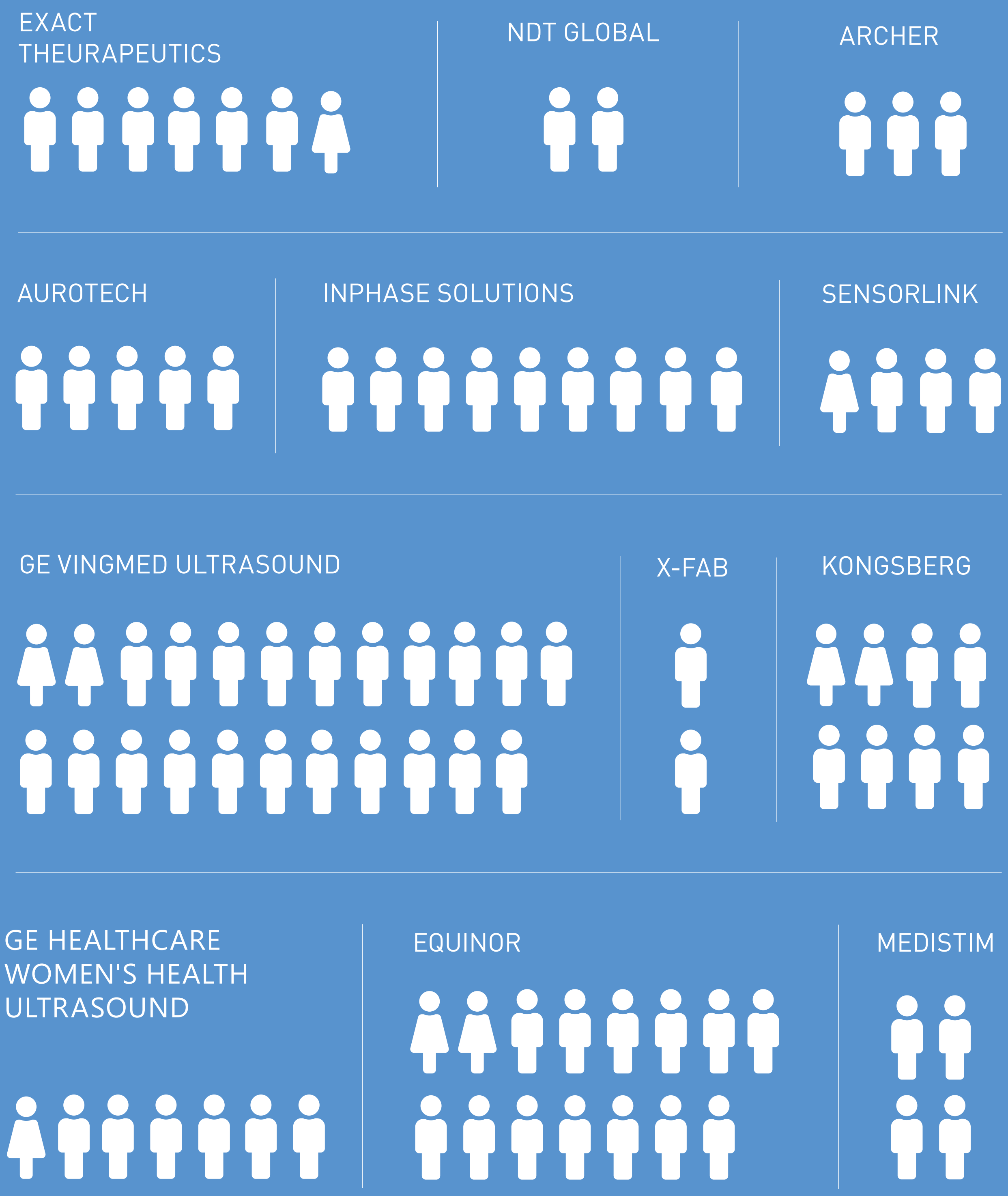
TITLE	MEDIUM
Sofie forskar på korleis medisin kan leverast meir presist i kroppen	Framtidajunior.no
In-probe receivers for medical utlrasound systems	CIUS Blogg
Dr Liv Hatle's pioneering work in ultrasound saves lives 40 years on	TheExplorer.no
The biased inventor - when an innovation fails	CIUS Blogg
How Bjørn Angelsen's innovation spearheaded a medical ultrasound industry	TheExplorer.no
Ultrasound on a chip	CIUS Blogg
Må ha grønn profil for å vokse	Mn24.no
From startup to global brand: a medical ultrasound success	TheExplorer.no
Spring Conference 2022 - imaging in more ways than one	CIUS Blogg
Utvikler ultralydløsninger tilpasset barn og unge	Helse-Midt.no
From medical innovation to commercialisation: a translational success	TheExplorer.no
Ultrasound and AI improve salmon breeding and welfare	CIUS Blogg
Ultralyd og bobler hjelper medisiner inn i hjernen	Gemini.no
Spotting small objects on the seafloor	CIUS Blogg
Taking heart imaging out of th ehospital with AI	CIUS Blogg
New adventures in assisted well log interpretation	Erlend-viggen.no Blogg
Combination of ultrasound and microbubbles helps medicines pass through the blood-brain barrier	News-medical.net
Automating heart monitoring	CIUS Blogg
Detecting issues in the foetal heart	CIUS Blogg
Uncovering stiff or leaky heart valves	CIUS Blogg
Putting microbubbles to work in medical ultrasound imaging	TheExplorer.no
Aminig at lifelong partnerships in North America	CIUS Blogg
Can AI on hand-held ultrasound help diagnose heart failure?	CIUS Blogg
Teknobedrift utnytter spedbarns myke skalle	MN24.no
Sir William Castell: championing Norway's pioneers of ultrasound contrast media	TheExplorer.no
Kunstig intelligens er til stor hjelp ved ultralydavbildning av hjertet	Forskning.no
Mjøsa-vraket: Dette bildet er egentlig et lydsignal	Titan.uio.no
EXACT: Gode resultater i prekliniske data	finansavisen.no
Skal hente 60 millioner før påske	finansavisen.no
We built an AI tool to help avoid environmental disasters	CIUS Blogg
EXACT Therapeutics for millioner fra Norges Forskningsråd	Finansavisen.no

Innovation Prize

Researcher Sindre Olaisen, Professor Lasse Løvstakken, PhD Candidate David Pasdeloup and Researcher Andreas Østvik received the 2022 Declaration of Innovation (DOFI) Prize of NOK 25 000 for their work on "Real-time Image Guiding in Echocardiography using Deep-Learning".

Photo: Kari Williamson/NTNU

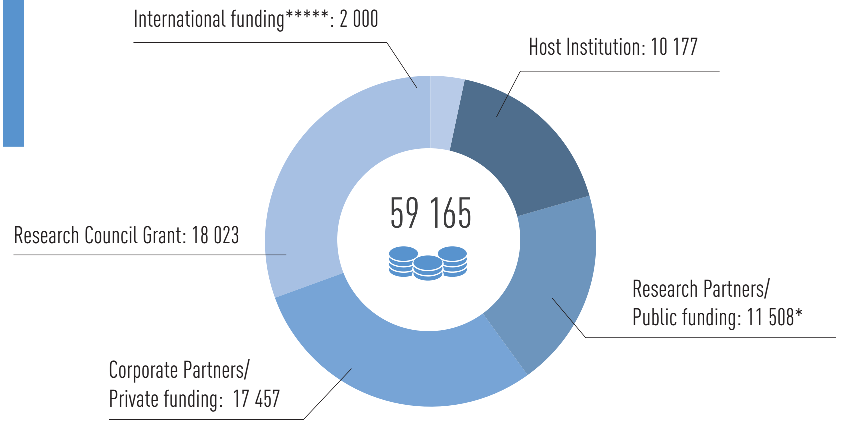
Industry Partner R&D Staff



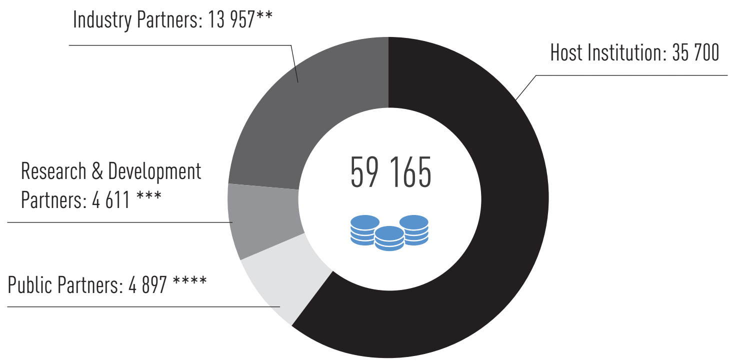
CIUS and the NTNU Ultrasound Research Group participated at NTNU's Researchers' Night 2022 as part of the Norwegian National Science Week. Photo: Invild Kinn Ekroll/NTNU

Annual Accounts for 2022

FUNDING
(in 1000 NOK)



COSTS
(in 1000 NOK)



*SINTEF, University of Oslo, University of South-Eastern Norway, Helse Midt-Norge RHF, St. Olavs University Hospital HF, Nord-Trøndelag Hospital Trust, Levanger municipality, Verdal municipality , Sørlandet Sykehus

**Equinor, GE Vingmed Ultrasound AS, Archer Bergen Technology Center AS, Sensorlink Subsea AS, Exact Therapeutics AS, InPhase Solutions AS, Kongsberg Maritime AS, NDT Global, Aurotech Ultrasound AS, X-Fab Semiconductor Foundries AG, Medistim ASA

*** SINTEF, University of Oslo, University of South-Eastern Norway

****St. Olavs University Hospital HF, Nord-Trøndelag Hospital Trust, Levanger municipality, Verdal municipality , Sørlandet Sykehus

*****GE Healthcare Women's Health Ultrasound (GEWHUS)

Journal Articles and Conference Proceedings - CIUS

AUTHOR/AUTHORS	TITLE	JOURNAL
Røed ES, Bring M, Tichy F, Henriksen A, Åsjord E-M, Hoff L	Optimization of matching layers to extend the usable frequency band for underwater single crystal piezocomposite transducers	IEEE Transactions on Ultrasonics, Ferroelectrics, and Frequency Control
Røed ES, Bring M, Frijlink M, Henriksen A, Tichy F, Åsjord EM, Hoff L	Underwater single crystal piezocomposite transducer with extended usable frequency band	Ultrasonics
Liu X, Ytterdal T, Shur M	Multi-Segment TFT Compact Model for THz Applications	Nanomaterials
Bolstad PK, Frijlink M, Manh T, Hoff L	Estimating Effective Material Parameters of Inhomogeneous Layers Using Finite Element Method	IEEE Transactions on Ultrasonics, Ferroelectrics, and Frequency Control
Shur M, Liu X, Ytterdal T	Plasmonic Si CMOS TeraFETs for detection, mixing, and processing sub-THz radiation	Proceedings of Spie
Shur M, Liu X, Ytterdal T	Improved Thin Film Transistor Model Predicts TFT Operation in the THz Range	ECS Transactions
Masoori A, Hoff L, Salmani H, Halvorsen E	An Efficient Electrode Optimization Method for Multi-Frequency PMUTs	Proceedings - IEEE International Ultrasonics Symposium
Bolstad PK, Frijlink M, Hoff L	Metallurgical AuSn Bonding of Piezoelectric Layers	Proceedings - IEEE International Ultrasonics Symposium
Chandrasekaran SN, Näsholm SP, Holm S	Wave equations for porous media described by the Biot model	The Journal of the Acoustical Society of America
Indimath S, Fiorentini S, Bøklepp BR, Avdal J, Måsøy S-E	Optimization of pulsed-wave Doppler ultrasound for estimation of influx/efflux in oil and gas boreholes while drilling using conventional LWD transducers	Journal of Petroleum Science and Engineering
Wifstad SV, Løvstakken L, Avdal J, Berg EAR, Torp H, Grenne B, Fiorentini S	Quantifying Valve Regurgitation using 3-D Doppler Ultrasound Images and Deep Learning	IEEE Transactions on Ultrasonics, Ferroelectrics, and Frequency Control
Pasdeloup D, Olaisen SH, Østvik A, Sabo S, Pettersen HN, Holte E, Grenne B, Stølen SB, Smistad E, Aase SA, Dalen H, Løvstakken L	Real-Time Echocardiography Guidance for Optimized Apical Standard Views	Ultrasound in Medicine & Biology
Smistad E, Østvik A, Grue JF, Dalen H, Løvstakken L	Tracking-based mitral annular plane systolic excursion (MAPSE) measurement using deep learning in B-mode ultrasound	Proceedings - IEEE International Ultrasonics Symposium
Smistad E, Dalen H, Grenne B, Løvstakken L	Segmentation of parasternal long axis views using deep learning	Proceedings - IEEE International Ultrasonics Symposium
Saxhaug LM, Graven T, Olsen Ø, Kleinau JO, Skjetne K, Ellekjær H, Dalen H	Reliability and agreement of point-of-care carotid artery examinations by experts using hand-held ultrasound devices in patients with ischaemic stroke or transitory ischaemic attack	Open Heart
Dalen H, Graven T, Slagsvold KH, Krogstad LEB, Saxhaug LM, Tannvik TD, Holte E, Nordhaug DO, Karlsen Ø, Thorstensen A, Wahba A, Winnerkvist AM	Complete embolization of a mechanical aortic valve during trail running - a case report with a lucky ending	European Heart Journal - Case Reports
Ness HO, Ljones K, Gjelsvik RH, Tjønna AE, Malmo V, Nilsen HO, Hollekim-Strand SM, Dalen H, Høydal MA	Acute effects of high intensity training on cardiac function: a pilot study comparing subjects with type 2 diabetes to healthy controls	Scientific Reports
Dalen H, Letnes JM	Rethinking Left Atrial Enlargement: Identifying Individuals at Risk by Appropriate Scaling	JACC: Cardiovascular Imaging
Ingul CB, Grimsmo J, Mecinaj A, Trebinjac D, Nossen MB, Andrup S, Grenne B, Dalen H, Einvik G, Stavem K, Follestad T, Josefsen T, Omland T, Jensen T	Cardiac Dysfunction and Arrhythmias 3 Months After Hospitalization for COVID-19	Journal of American Heart Association
Ingul CB, Edvardsen A, Follestad T, Trebinjac D, Ankerstjerne OAW, Brønstad E, Rasch-Halvorsen Ø, Aarli B, Dalen H, Nes BM, Lerum TV, Einvik G, Stavem K, Skjørten I	Changes in cardiopulmonary exercise capacity and limitations 3 to 12 months after COVID-19	European respiratory journal
Hjorth-Hansen AK, Magelssen MI, Andersen GN, Graven T, Kleinau JO, Landstad B, Løvstakken L, Skjetne K, Mjølstad OC, Dalen H	Real-time automatic quantification of left ventricular function by hand-held ultrasound devices in patients with suspected heart failure: a feasibility study of a diagnostic test with data from general practitioners, nurses and cardiologists	BMJ Open
Hjorth-Hansen AK, Magelssen MI, Andersen GN, Graven T, Kleinau JO, Landstad B, Løvstakken L, Skjetne K, Mjølstad OC, Dalen H	User experience and image quality influence on performance of automated real-time quantification of left ventricular function by handheld ultrasound devices: a diagnostic accuracy study with data from general practitioners, nurses and cardiologists	Open Heart
Viggen EM, Singstad B-J, Time E, Mishra S, Berg E	Assisted Cement Log Interpretation Using Machine Learning	SPE Drilling & Completion
Yadhav A, Rizkalla M, Ytterdal T, Lee JJ, Balasubramanian LS, Gopinath A	Evaluation of FinFET in Ultra Low Power ALU	IEEE International Conference on Design & Test of Integrated Micro & Nano-Systems (DTS)
Liu X, Shur M, Ytterdal T	Optimization of Si CMOS TeraFETs for 300 GHz band operation	Proceedings of the 47th International Conference on Infrared, Millimeter and Terahertz Waves
Viggen EM, Arnestad H	Inhomogeneous P- and S-wavefields radiated into isotropic elastic solids	Proceedings of the 45th Scandinavian Symposium on Physical Acoustics

AUTHOR/AUTHORS	TITLE	JOURNAL
Feyling F, Malmberg H, Wulff C, Loeliger H-A, Ytterdal T	High-level Comparison of Control-Bounded A/D Converters and Continuous- Time Sigma-Delta Modulators	IEEE Nordic Circuits and Systems Conference
Måsøy S-E. Denarie B, Sørnes A, Holte E, Grenne B, Espeland T, Berg EAR, Rindal OMH, Rigby W, Bjåstad T	Aberration correction in 2D echocardiography	TechRxiv
Rindal OMH, Vrålstad A, Bjåstad TG, Austeng A, Måsøy S-E	Coherence from Refocus Compared to Retrospective Transmit Beamforming	Proceedings - IEEE International Ultrasonics Symposium
Arnestad HK, Austeng A, Näsholm SP, Rindal OMH	The Effect of Retrospective Transmit Focusing on Minimum Variance Beamforming	Proceedings - IEEE International Ultrasonics Symposium
Arnestad H, Gereb G, Lønmo TIB, Kirkebø JE, Austeng A, Näsholm SP	Sonar array beampattern bounds and an interval arithmetic toolbox	Proceedings of Meetings on Acoustics
Leinan PR, Grønli T, Skjetne P, Wigen MS, Urheim S, Løvstakken L, Dahl SK	Comparison of ultrasound vector flow imaging and CFD simulations with PIV measurements of flow in a left ventricular outflow trackt phantom - Implications for clinical use and in silico studies	Computers in Biology and Medicine
Hu J, Smistad E, Olaisen SH, Dalen H, Løvstakken L	Exploiting temporal information in echocardiography for improved image segmentation	Proceedings - IEEE International Ultrasonics Symposium
Chernyshov A, Østvik A, Smistad E, Løvstakken L	Segmentation of 2D Cardiac Ultrasound with Deep Learning: Simpler Models for a Simple Task	Proceedings - IEEE Ultrasonics Symposium
Pani J, Eikenes L, Reitlo LS, Stensvold D, Wisløff U, Håberg AK	Effects of a 5-Year Exercise Intervention on White Matter Microstructural Organization in Older Adults. A Generation 100 Substudy	Frontiers in Aging Neuroscience
Aamodt EB, Lydersen S, Alnæs D, Schellhorn T, Saltvedt I, Beyer MK, Håberg A	Longitudinal Brain Changes After Stroke and the Association With Cognitive Decline	Frontiers in Neurology
Poon C, Mühlenpfordt M, Olsman M, Kotopoulis S, de Lange Davies C, Hynynen K	Real-Time Intravital Multiphoton Microscopy to Visualize Focused Ultrasound and Microbubble Treatments to Increase Blood-Brain Barrier Permeability	Bioengineering
Arild A, Vangberg TR, Nikkels H, Lydersen S, Wisløff U, Stensvold D, Håberg AK	Five years of exercise intervention at different intensities and development of white matter hyperintensities in community dwelling older adults, a Generation 100 sub-study	Aging
Eikenes L, Visser E, Vangberg TR, Håberg AK	Both brain size and biological sex contribute to variation in white matter microstructure in middle-aged healthy adults	Human Brain mapping
Øen SK, Johannessen K, Pedersen LK, Berntsen EM, Totland JA, Johansen H, Bogsrud TV, Solheim TS, Karlberg A, Eikenes L	Diagnostic Value of ^{18}F-FACBC PET/MRI in Brain Metastases	Clinical Nuclear Medicine
Stenberg J, Skandsen T, Moen KG, Vik A, Eikenes L, Håberg AK	Diffusion Tensor and Kurtosis Imaging Findings the First Year Following Mild Traumatic Brain Injury	Journal of Neurotrauma
Husby T, Johansen H, Bogsrud TV, Hustad KV, Evensen BV, Boellaard R, Giskeødegård GF, Fagerli UM, Eikenes L	Prognostic value of combined MTV and ADC derived from baseline FDG PET/MRI in aggressive non-Hodgkins lymphoma	BMC Cancer
Husby T, Johansen H, Bogsrud T, Hustad KV, Evensen BV, Boellard R, Giskeødegård GF, Fagerli UM, Eikenes L	A comparison of FDG PET/MR and PET/CT for staging, response assessment, and prognostic imaging biomarkers in lymphoma	Annals of Hematology
van Wamel A, Mühlenpfordt M, Hansen R, Healey A, Villanueva FS, Kotopoulis S, Davies C, Chen X	Ultrafast microscopy imaging of Acoustic Cluster Therapy (ACT®) bubbles: Activation and Oscillation	Ultrasound in Medicine & Biology
Mawad W, Fadnes S, Løvstakken L, Henry M, Mertens L, Nyrnes SA	Pulmonary Hypertension in Children is associated with Abnormal Flow patterns in the Main Pulmonary Artery as demonstrated by Blood Speckle Tracking	CJC Pediatric and Congenital Heart Disease
Jacobsen L, Grenne B, Olsen RB, Jortveit J	Feasibility of prehospital identification of non-ST-elevation myocardial infarction by ECG, troponin and echocardiography	Emergency Medicine Journal
Karlsen S, Melichova D, Dahlslett T, Grenne B, Sjøli B, Smiseth O, Edvardsen T, Brunvand H	Increased deformation of the left ventricle during exercise test measured by global longitudinal strain can rule out significant coronary artery disease in patients with suspected unstable angina pectoris	Echocardiography
Midtbø SH, Aanes M, Talberg AS, Måsøy SE	ASM and finite beam description of the excited leaky Lamb wave fields in a fluid-immersed plate	Ultrasonics
Grande M, Bjørnsen LP, Næss-Pleym LE, Laugsand LE, Grenne B	Observational study on chest pain during the Covid-19 pandemic: changes and characteristics of visits to a Norwegian emergency department during the lockdown	BMC Emergency Medicine
Pettersen EM, Avdal J, Fiorentini S, Salvesen Ø, Hisdal J, Torp H, Seternes A	Validation of a novel ultrasound Doppler monitoring device (earlybird) for measurements of volume flow rate in arteriovenous fistulas for hemodialysis	The Journal of Vascular Access
Zotcheva E, Håberg AK, Wisløff U, Salvesen Ø, Selbæk G, Stensvold D, Ernstsen L	Effects of 5 Years Aerobic Exercise on Cognition in Older Adults: The Generation 100 Study: A Randomized Controlled Trial	Sports Medicine
Aker K, Thomas N, Adde L, Koshy B, Martinez-Biarge M, Nakken I, Padankatti CS, Støen R	Prediction of outcome from MRI and general movements assessment after hypoxic-ischaemic encephalopathy in low-income and middle-income countries: data from a randomised controlled trial	Archives of Disease in Childhood: Fetal and Neonatal Edition

Journal articles and Conference Proceedings - CIUS related

AUTHOR/AUTHORS	TITLE	JOURNAL
Pani J, Marzi C, Stensvold D, Wisløff U, Håberga AK, Diciotti S	Longitudinal study of the effect of a 5-year exercise intervention on structural brain complexity in older adults. A Generation 100 substudy	NeuroImage
Leth-Olsen M, Døhlen G, Torp H, Nyrnes SA	Detection of Cerebral High-Intensity Transient Signals by NeoDoppler during Cardiac Catheterization and Cardiac Surgery in Infants	Ultrasound in Medicine & Biology
Langlo KAR, Lundgren KM, Zanaboni P, Mo R, Ellingsen Ø, Hallan SI, Aksetøy ILA, Dalen H	Cardiorenal syndrome and the association with fitness: Data from a telerehabilitation randomized clinical trial	ESC Heart Failure
Øygard SH, Audoin M, Austeng A, Thomsen EV, Stuart MB, Jensen JA	Accurate prediction of transmission through a lensed row-column addressed array	The Journal of the Acoustical Society of America
Massey RJ, Myrdal OH, Diep PP, Burman MM, Brinch L, Gullestad LL, Ruud E, Aakhus S, Beitnes JO	Reduced exercise capacity is associated with left ventricular systolic dysfunction in long-term survivors of allogeneic hematopoietic stem-cell transplantation	Journal of Clinical Ultrasound
Brørs G, Dalen H, Allore H, Deaton C, Fridlund B, Osborne RH, Palm P, Wentzel-Larsen T, Norekvål TM, CONCARD investigators	Health Literacy and Risk Factors for Coronary Artery Disease (From the CONCARD PCI Study)	The American Journal of Cardiology
Halle M, Prescott E, Van Craenenbroeck EM, Beckers P, Videm V, Karlsen T, Feiereisen P, Winzer EB, Mangner N, Snoer M, Christle JW, Dalen H, Støylen A, Esefeld K, Heitkamp M, Spanier B, Linke A, Ellingsen Ø, Delagardelle C, SMARTEX-HF Study Group	Moderate continuous or high intensity interval exercise in heart failure with reduced ejection fraction: Differences between ischemic and non-ischemic etiology	American Heart Journal Plus: Cardiology Research and Practice
Fraser A, Markovitz AR, Haug EB, Horn J, Romundstad PR, Dalen H, Rich-Edwards J, Åsvold BO	Ten-Year Cardiovascular Disease Risk Trajectories by Obstetric History: A Longitudinal Study in the Norwegian HUNT Study	Journal of the American Heart Association
Fredriksen V, Sevle SOM, Pedersen A, Langø T, Kiss G, Lindseth F	Teacher-student approach for lung tumor segmentation from mixed-supervised datasets	PlosOne
Kirkebø JE, Austeng A	Amplitude tolerance analysis of curved sonar arrays	OCEANS 2021: San Diego – Porto
Gustad LT, Myklebust TÅ, Bjerkeset O, Williams LJ, Laugsand LE, Dalen H, Berk M, Romundstad S	Anxiety and depression symptoms, albuminuria and risk of acute myocardial infarction in the Norwegian HUNT cohort study	BMC Cardiocasvular Disorders
Tauschek L, Røsbjørgen REN, Dalen H, Larsen T, Karlsen T	No Effect of Calanus Oil on Maximal Oxygen Uptake in Healthy Participants: A Randomized Controlled Study	International Journal of Sport Nutrition and Exercise Metabolism
Svensson SF, Fuster-Garcia E, Latysheva A, Fraser-Green J, Nordhøy W, Darwish OI, Hovden IT, Holm S, Vik-Mo EO, Sinkus R, Emblem KE	Decreased tissue stiffness in glioblastoma by MR elastography is associated with increased cerebral blood flow	European Journal of Radiology

Presentations - CIUS

AUTHOR/AUTHORS	TITLE	LOCATION
Rindal OMH, Nasholm SP, Hansen RE, Austeng A	Image Enhancement Using Capon Minimum Variance Adaptive Beamforming in Synthetic Aperture Sonar	International Conference of Underwater Acoustics
Rindal OMH, Nasholm SP, Hansen RE, Austeng A	Compensating Dynamic Range Alterations from Adaptive Beamforming using Histogram Matching	International Conference of Underwater Acoustics
Austeng A, Nasholm SP, Hansen RE, Rindal OLM	Spatial Aperture Coherence with Synthetic Transmit Focusing in SAS	International Conference of Underwater Acoustics
Rindal OMH, Bjåstad TG, Espeland T, Berg EAR, Måsøy S-E	Global Image Coherence (GIC) – an in-vivo Image Quality Metric	IEEE International Ultrasonics Symposium
Måsøy S-E, Denarie B, Sørnes A, Holte E, Grenne B, Espeland T, Berg EAR, Rindal OMH, Rigby W, Bjåstad TG	Aberration Correction in the Echo Lab - A Clinical Pilot	IEEE International Ultrasonics Symposium
Austeng A, Arnestad H, Bjåstad TG, Måsøy S-E, Rindal OMH	Issues with Histogram Matching for Fair Evaluation of Image Quality Metrics	IEEE international Ultrasonics Symposium
Smistad E, Østvik A, Grue JF, Dalen H, Løvstakken L	Tracking-based mitral annular plane systolic excursion (MAPSE) measurement using deep learning in B-mode ultrasound	IEEE Internatiional Ultrasonics Symposium
Wifstad SV, Hauge SW, Seljelv SJ, Saebo S, Mekonnen D, Nega B, Abebe S, Estensen ME, Haaverstad R, Dalen H, Lovstakken L	Tracking heart valve motion from transthoracic echocardiography using deep learning	IEEE International Ultrasonics Symposium
Hu J, Smistad E, Olaisen SH, Dalen H, Lovstakken L	Exploiting temporal information in echocardiography for improved image segmentation	IEEE International Ultrasonics Symposoum
Sæbø S, Pettersen HN, Østvik A, Pasdeloup D, Smistad E, Stoelen S, Grenne B, Løvstakken L, Holte E, Dalen H	Automated analyses and real-time guiding by deep learning to reduce test-retest variability of global longitudinal strain	ESC 2022
Wifstad SV, Hauge SW, Seljelv SJ, Saebo S, Mekonnen D, Nega B, Abebe S, Estensen ME, Haaverstad R, Dalen H, Lovstakken L	Tracking heart valve motion from transthoracic echocardiography using deep learning	Autumn Research School in Artificial Intelligence Methods in Medical Imaging 2022
Sæbø S, Pettersen HN, Østvik A, Smistad E, Pasdeloup DFP, Grenne B, Stølen SB, Løvstakken L, Holte E, Dalen H	Automated analyses and real-time guiding by deep learning to reduce variability of global longitudinal strain	CIUS fall conference 2022
Måsøy S-E	Aberration correction in medical ultrasound imaging	Johann Radon institute for computaional and applied mathema - inveted talk
Viggen EM, Arnestad H	Intensity of inhomogeneous waves in simple solids	45th Scandinavian Symposium on Physical Acoustics
Time E, Viggen EM	Implementation of an assisted cement log interpretation system in Equinor	CIUS Fall Conference 2022
Rindal OMH	Transition of advanced techniques from medical ultrasound to sonar imaging using the UltraSound ToolBox	CIUS Spring Conference 2022
Dalen H	Rekruttering i kardiologi	Kardiologisk høstmøte
Dalen H	Fenotyping ved hjertesvikt	Keep Learning Webinar for spesialister
Løvstakken L	Automatiserte målinger - hvordan gjør maskinen det?	Norsk Cardiologisk Selskap (NCS) høstmøte
Dalen H	Improved cardiac imaging at the patients' point-of-care	Helse Møre og Romsdals forskersamling
Dalen H	Improved cardiac diagnostic imaging at the patients point-of-care	Helse Mift-Norges forskningskonferanse
Feyling F, Malmberg H, Wulff C, Loeliger HA, Ytterdal T	High-level Comparison of Control-Bounded A/D Converters and Continuous- Time Sigma-Delta Modulators	2022 IEEE Nordic Circuits and Systems Conference
Arnestad HK, Gereb G, Lønmo TIB, Kirkebø JE, Austeng A, Näsholm SP	Sonar array beampattern bounds: tolerance analysis using interval arithmetic	International Conference on Underwater Acoustics
Arnestad HK, Austeng A, Näsholm SP, Rindal OMH	The Effect of Retrospective Transmit Focusing on Minimum Variance Beamforming	IEEE International Ultrasonics Symposium
Mohajery M, Fadnes S, Espeland T, Salles S, Løvstakken L	Three-dimensional velocity estimation of natural mechanical waves in the myocardium	IEEE International ultrasonics symposium
Indimath S, Fiorentini S, Bøklepp BR, Avdal J, Måsøy S-E	3D Flow Velocity Estimation of Influx from Fractures in Borehole Wall and Estimation of Fracture Area Using Pulsed-Wave Doppler Ultrasound for Logging-While-Drilling	IEEE International ultrasonics symposium
Yari Y, Næve I, Voormolen MM, Bergtun PH, Måsøy S-E, Løvstakken L	Ultrasound and Deep Learning for automated maturation prediction of Atlantic salmon	IEEE International Ultrasonics Symposium
Garone RV, Lønmo TIB, Tichy F, Diesing M, Thorsnes T, Schimel ACG, Løvstakken L	Deep Learning for seafloor sediment mapping: a preliminary investigation using U-Net	EGU General Assembly 2022
Rindal OMH	The Myriad of metrics in medical ultrasound imaging; Which should we use?	Acoustical Society of America, 183rd Meeting

Presentations - CIUS related

AUTHOR/AUTHORS	TITLE	LOCATION
Shur M, Liu X, Ytterdal T	Plasmonic Si CMOS TeraFETs for detection, mixing, and processing sub-THz radiation	SPIE Photonics West Terahertz, RF, Millimeter, and Submillimeter-Wave Technology and Applications XV
Shur M, Liu X, Ytterdal T	Improved Thin Film Transistor Model Predicts TFT Operation in the THz Range	242nd ECS Meeting
Yadhav A, Rizkalla M, Ytterdal T, Lee JH, Balasubramanian LS, Gopinath A	Evaluation of FinFET in Ultra Low Power ALU	4th IEEE International Conference on Design & Test of Integrated Micro & Nano-Systems

Posters - CIUS

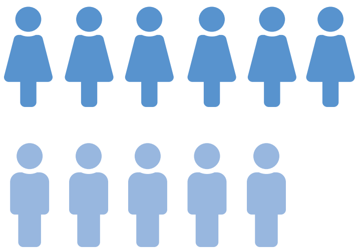
AUTHOR/AUTHORS	TITLE	LOCATION
Mansoori A, Hoff L, Salmani H, Halvorsen E	An Efficient Electrode Optimization Method for Multi-Frequency PMUTs	IEEE International Ultrasonics Symposium
Boltad PK, Frijlink M, Hoff L	Metallurgical AuSn Bonding of Piezoelectric Layers	IEEE International Ultrasonics Symposium
Vrålstad AE, Rindal OMH, Bjåstad TG, Måsøy S-E	Sound Speed Correction for Virtual Source Retrospective Transmit Beamforming	IEEE International Ultrasonic Symposium
Rindal OMH, Vrålstad AE, Bjåstad TG, Austeng A, Måsøy S-E	Coherence from REFoCUS compared to Retrospective Transmit Beamforming	IEEE international Ultrasonics Symposium
Smistad E, Dalen H, Grenne B, Løvstakken L	Segmentation of parasternal long axis views in echocardiography using deep learning	IEEE International Ultrasonics Symposium
Pasdeloup D, Sæbø S, Olaisen SH, Pettersen HN, Østvik A, Holte E, Grenne B, Stølen SB, Smistad E, Dalen H, Løvstakken L	Real-time Echocardiography Guidance for Optimized Apical Standard Views	IEEE International Ultrasonics Symposium
Pasdeloup D, Sæbø S, Olaisen SH, Pettersen HN, Østvik A, Holte E, Grenne B, Stølen SB, Smistad E, Dalen H, Løvstakken L	Real-time Echocardiography Guidance for Optimized Apical Standard Views	PRESIMAL Autumn Research School
Viggen EM, Arnestad	An explanatory model for sound radiation from subsonic surface vibrations	IEEE International ultrasounics Symposium
Arnestad H, Viggen EM	A Fast Simulation Method for Lamb Wave Propagation in Coupled Non-Parallel Plates	IEEE international Ultrasonics Symposium
Chernyshov A, Østvik A, Smistad E, Løvstakken L	Segmentation of 2D Cardiac Ultrasound with Deep Learning: Simpler Models for a Simple Task	IEEE International Ultrasonics Symposium
Fermann BS, Aase SA, Nyberg J, Grue JF, Grenne B, Dalen H, Løvstakken L, Østvik Ø	Cardiac event detection in echocardiography with triplane data and deep learning	IEEE International Ultrasonics Symposium
Fernandes JF, Loncaric F, Marciniak M, Gilbert A, Smistad E, Løvstakken L, Mcleod K, Sitges M, Lamata P	Automatic measurement of LV wall thickness from 2D cardiac echocardiography	EuroEcho

Posters - CIUS related

AUTHOR/AUTHORS	TITLE	LOCATION
Liu X, Shur MS, Ytterdal T	Optimization of Si CMOS TeraFETs for 300 GHz band operation	47th international Conference on Infrared, Millimeter, and Terahertz Waves
Gerèb G, Ravn AWR, Hansen REH, Lønmo TIB, Näsholm SP, Rindal OMH, Austeng A	Improving Sonar Surveying of Subsea Cables and Pipelines with Adaptive Beamforming,	IEEE International Ultrasonics Symposium

Degrees 2022

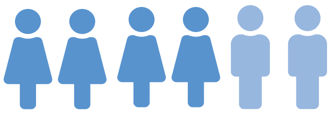
MASTER THESES



MASTER STUDENTS OBTAINING THEIR DEGREE IN 2022 ON A CIUS TOPIC AND SUPERVISER

Erlend Løland Gundersen	Patient Adaptive Imaging in Echocardiography	S-E Måsøy, E Smistad
Nina Edvardsdal	Comparisons of Image Quality and Aperture Blockage Caused by the Ribs for Male and Female Patients in Echocardiography	S-E Måsøy
Andreas Fagerland Haavik	Development of an FPGA echo sounder system	H Balk
Charlotte Årseth	Effects of ultrasound and microbubbles on vasculature and extracellular matrix components in murine breast cancer tumors	C Davies
Sara Beate Stjern Årbogen	Acoustic Cluster Therapy and induced immune response	C Davies
Camilla Bang	Using atomic force microscopy and second harmonic generation to investigate the effects of ultrasound and microbubbles on the extracellular matrix in 4T1 breast tumors	C Davies
Heidi Hammer Eriksen	Risk factors for cerebral infarction in a general population aged 50-66 years	A Håberg
Vilde Wøien	Supervised Deep Learning for Perioperative Cardiovascular Monitoring	J Vatn, G Kiss, A Tasken
Kåre Fosli Obrestad	Aortic Valve Localisation in 3D Transesophageal Echocardiography Volumes using Deep Learning	G Kiss, F Lindseth
Bendik Nilsen Brunvoll	Implementing Volume Rendering Optimizations for Real-Time Performance Directly on Microsoft's HoloLens 2	G Kiss
Sigbjørn Sæbø	Artificial intelligence for improved ultrasound diagnostics	JM Letnes, H Dalen

PHD THESES



PHD CANDIDATES 2022 - CIUS FINANCED

Ali Fatemi	On the origin of clutter in echocardiography and possible solutions	A Molares, S-E Måsøy

PHD CANDIDATES 2022 - CIUS RELATED

Silje K Øen	PET/MRI – Towards clinical use in the brain	L Eikenes
Jasmine Pani	Exercise and cardiorespiratory fitness in the aging brain: evidence from the Generation 100 brain MR substudy	A Håberg
Eva Aamodt	Brain Imaging Markers of Decline in Cognitive Ability After Stroke	M Beyer, A Håberg
Karoline Aker	Perinatal asphyxia in a global perspective: how can we improve outcomes?	R Støen, A Håberg
Erik Mulder Pettersen	Early bird: A new approach to vascular assessment	A Seternes

Director Svein-Erik Måsøy presenting at the 2022 CIUS Spring Conference. Photo: Stefano Fiorentini/NTNU

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Location
NTNU Fred Kavli Building and ISB, located at Øya,
St. Olavs hospital in Trondheim

CIUS NTNU, Faculty of Medicine and Health Sciences,
Department of Medical Imaging and Circulation,
PO Box 8905, 7491 Trondheim, Norway

Contact
Svein-Erik Måsøy (Industry Liaison)
+47 926 25 082 / svein-erik.masoy@ntnu.no

Line Skarsem Reitlo (CIUS Coordinator)
+47 917 21 190 / line.reitlo@ntnu.no

Kari Williamson (Web & Communication)
+47 986 66 928 / kari.williamson@ntnu.no

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