2020 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

GE Vingmed Ultrasound

InPhase Solutions

KONGSBERG

HALFWAVE

MEDISTIM

XFAB
MIXED-SIGNAL FOUNDRY EXPERTS

Re{Lab}

EXACT THERAPEUTICS

Sensorlink

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

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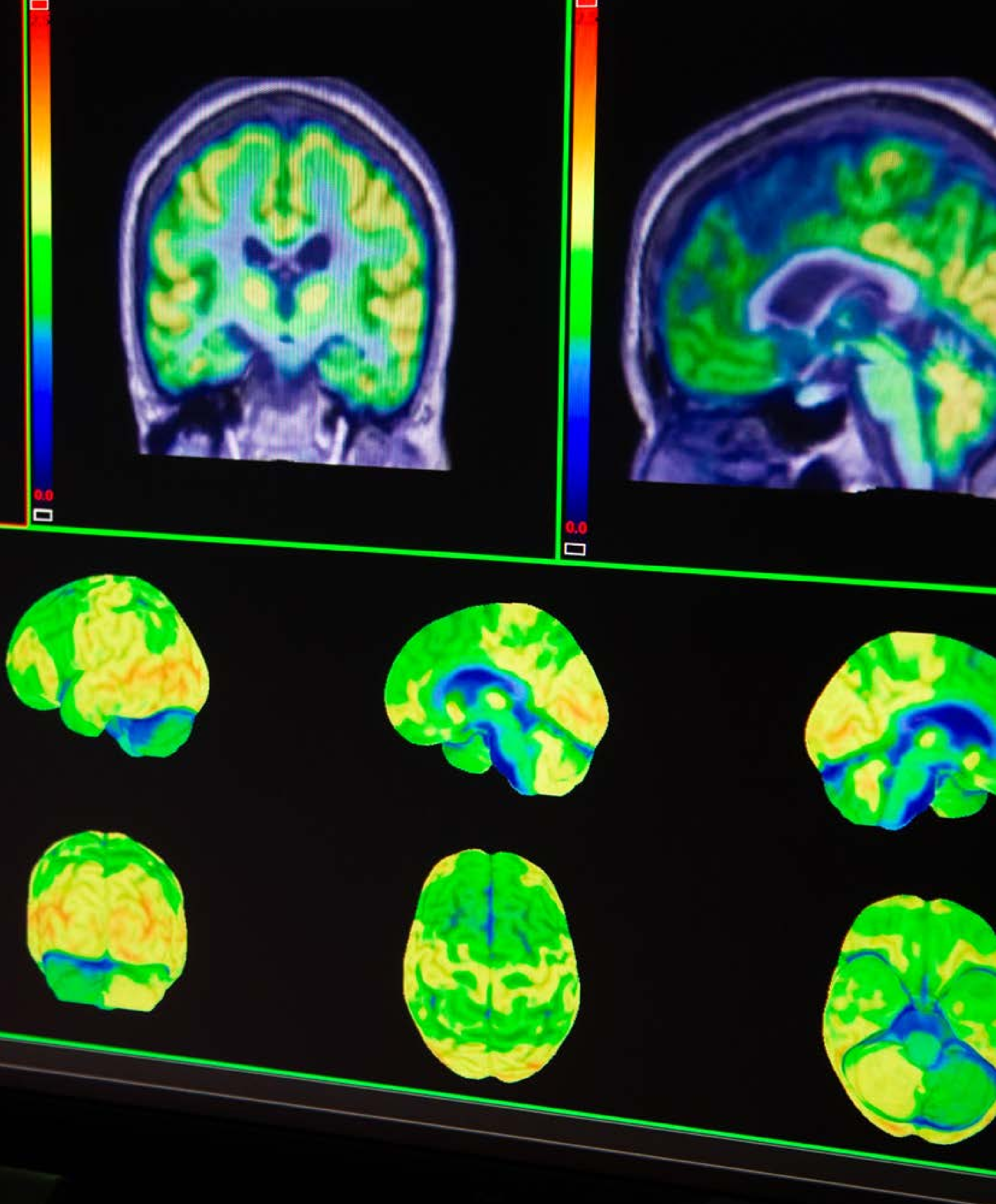


PET-MRI to uncover dementia. Photo: Karl Jørgen Marthinsen

Asta Håberg
Centre Director

Dear CIUS family and friends

I am not going to tell you what a shock the 2020 Covid-19 pandemic was, how it took us by complete surprise and left us working from home in single isolation or surrounded by family or roommates. Instead, I will commend the resilience and creativity which allowed much of the research activity in CIUS to continue.

In 2020, the activity was comparable to previous years with 74 journal- and proceedings publications, which you can access using the hyperlinks under Publications in this report. Supervisors and master students displayed inventive use of already collected data to finalise their master's project on time during the spring lock-down (see here for more details about the 14 master students graduating in 2020). 7 CIUS PhD candidates had their PhD defence, most of them online. The online defences allow for participation of a broader audience, enabling all interested CIUS family members to take part irrespective of geographical location. This advantageous side-effect of online PhD defences will be continued post-pandemic. To keep abreast on PhD defences in CIUS, please follow the upcoming event calendar on the CIUS homepage www.ntnu.edu/cius.

CIUS got a new industry partner in 2020, ReLab, a start-up company emerging from CIUS activity at USN. CIUS´ partners reported one new product, 27 new methods or processes, and six new services as a result of the collaboration within the SFI in 2020. The innovation team has worked with the NTNU Technology Transfer office (TTO) to ensure appropriate handling of IPR. A total of six declarations of innovations (DOFIs) were submitted in 2020. Licensing is an important mechanism for transfer of technological solutions from academia to industry partners. In this annual report you can read about how the licensing process is handled in CIUS.

A new generation of CIUS PhD and Postdocs started out as CIUS passed half-term early in 2020. Onboarding in COIVD19-times is not easy and will continue to present a challenge for the scientific and innovative processes until the return of social interaction and the hive mind setting. To get an overview of where CIUS´ research is heading in its last period, see the short project descriptions for the new CIUS PhD and Postdoc candidates.

The CIUS academics would like to thank the Research Council of Norway and our health and industry partners for funding, in-kind, being supportive and creating a community. I thank the PhD and Postdoc candidates, the supervisors and senior researchers for their academic and innovation contributions, the innovation team for following up and ensuring proper handling of innovations, the industry liaison for keeping up with the industry partners, and the CIUS administrative team for taking care of the economy, media and outreach, organising of all kinds of events, and keeping tabs on CIUS activities and reporting.

"We are aiming for a physical 2-day CIUS conference in November/December 2021 and hope to finally meet in person."

Brita Pukstad
Vice Dean

Greetings from the Vice Dean

The Faculty of Medicine and Health Sciences (MH) at NTNU is proud to be host for CIUS and follows their excellent scientific and innovative achievements with great excitement.

2020 was a challenging year for the Faculty, as it was for everybody else, with the Covid-19-pandemic. Our students and employees have struggled, but found solutions to cope with teaching, research, mentoring, grant writing and fulfilling publications. We still have popular study programmes with a high number of applicants and good evaluations. During the crisis, we have learned new skills in digital teaching, and we have managed to fulfil all scheduled PhD-defences on digital platforms. Some of our researchers have even launched new initiatives and forged new career directions in this year of upheaval. We are especially proud of the newly developed Covid-19 test method developed at our Faculty in collaboration with researchers at the Department of Chemical Engineering at NTNU, using NTNU-crafted magnetic nanoparticles. This new sensitive test has gained publicity both on a national and international level.

With NTNU's strategy "Knowledge for a better world", the MH Faculty is continuing to strive towards its own ambitious, strategic vision "Health for a better world". Our aim is to develop knowledge, skills and solutions that contribute to good health from a regional, national and global perspective. The vision also expresses our aim to enable a fairer distribution of knowledge and resources, and we have strengthened our commitment to research, innovation and education for better global health. During the pandemic, we have travelled less, and with fewer flights and a reduced carbon footprint we contribute to the UN Sustainable Development Goals and to the Paris Agreement. We have learned that it is possible to collaborate through digital platforms. Although virtual networking cannot fully replace the opportunities that arise in actual face-to-face meetings, we will continue to travel less in the future when the pandemic hopefully comes under control.

An increased focus on innovation and collaboration between academia, industry and the public sectors, is central for MH. We are pursuing these goals at every level in the organisation, and our student-lead health innovation lab, DRIV, was successfully active with workshops and hackathons until Covid-19 slowed this down. DRIV is established for all students interested in health innovation in order to facilitate innovative activity for our future health workers, and academic colleagues and collaborators. 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 and Postdoctoral fellows.

The centres for research-based innovation, such as CIUS, embody the culture NTNU aspires to in its strategy. CIUS has managed to uphold scientific and innovative activity throughout the pandemic and has demonstrated the great value of working on ultrasound technologies across different academic fields in collaboration with industrial partners.

"We look forward to a continued fruitful and engaging collaboration with CIUS in 2021!"

Eva Nilssen
Board Leader

Greetings from the CIUS Board

"Of course, new partners and partner constellations need to be included as well; they will benefit from our existing experience, bringing at the same time new perspectives to the table."

At the start of CIUS in 2016, the Industry partners had different starting points: for the Healthcare partners who had participated in the MiLab SFI, CIUS was more of a continuation project, whilst the Oil & Gas and Maritime partners started from scratch. Improvements identified in the MiLab, such as early tests for proof of clinical value, were able to be addressed by CIUS from the start. This has worked very well, with great engagement and involvement of the clinicians from St. Olavs hospital, actively prioritising the clinical testing of CIUS research results. This engagement and iterative process provides early feedback, and guides research in the right direction for true value realisation.

For Oil & Gas and Maritime, it took some time to get to know the structure and the organisation of the SFI, but gradually CIUS has proved quite useful to the non-healthcare partners too. The CIUS consortium is ideal for network building, both with academic institutions and with ultrasound businesses in Norway, enabling the partners to discuss technology and business models, and to find new collaborators inside and outside the core of CIUS' research.

In addition, now that we are in the second half of CIUS, collaboration upon specific PhD/Postdoc projects is working very well for most industry partners. One of the key success factors in CIUS is the excellent researchers, who are "annoyingly good", as Petter Nordlie in Halfwave puts it. This illustrates the importance of attracting good candidates. It all starts with the professors and the academic environment. It is incredibly important that this environment is stable over time and continues to grow competence and scope, i.e. that there are more professors and scientific staff at the academic institutions. Just having the possibility to contact these world-class experts directly and obtain their insights is of great value for the industry partners.

CIUS is also an excellent place for recruitment. Through the close collaboration within CIUS, the industry gets to know potential candidates for employment, whilst the candidates get to know the industry and potential future colleagues. This collaboration is very motivating for both the industry experts and the academics: researchers in industry are able to work on longer term research to the benefit of their products, whilst academic researchers are exposed to local and global market realities, and learn to make the right trade-offs identifying those solutions with the greatest impact in real-life situations.

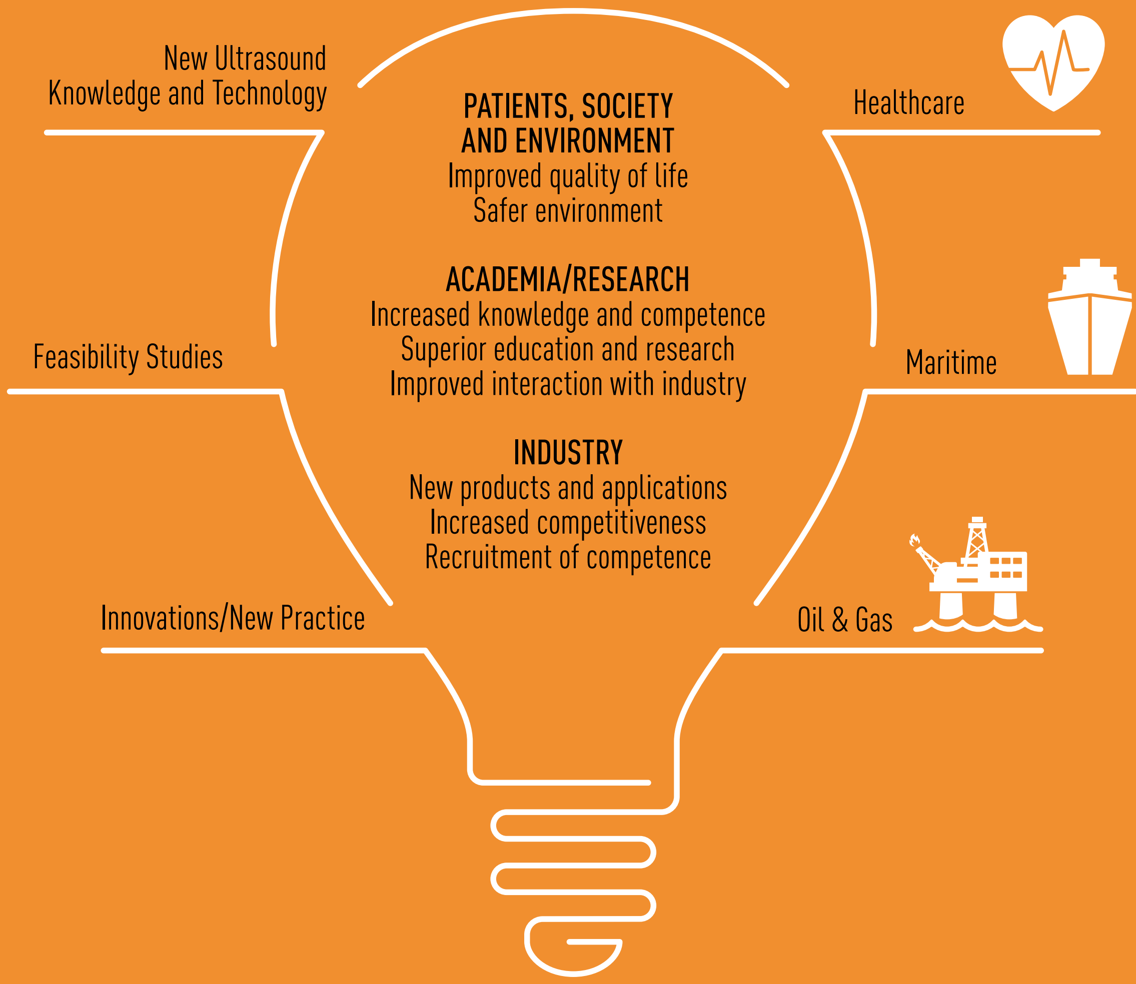
Several CIUS researchers have already been hired in industry from academia. This illustrates that research from the CIUS project and competency more generally acquired through the CIUS project, is of great value to the industry partners. These researchers also form a bridge between academia and industry, which lays a foundation for continued cooperation within CIUS, and for research projects in the future.

The socioeconomic value of trust is a frequent topic of discussion these days. We operate in Norway, a country with a high degree of trust, so we have a good starting point. But this aspect needs continued attention and is not trivial. We must all strive to ensure that the partners in a project understand and respect that there may be different needs in academia compared to in industry, and that sometimes these needs are conflicting. These conflicts need to be discussed and resolved, for the mutual benefit of the CIUS collaboration. It is my experience that though these discussions may be difficult, they often bring us to a new level of understanding and respect, if carried out in an atmosphere of trust and respect.

It does take time to understand and realise the value of the cooperative environment in an SFI. The level of collaboration achieved in CIUS is of great value for a possible next round of SFI application from the CIUS family.

CIUS Idea

CIUS will deliver 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: Fisheries and seabed mapping; Oil & gas: Monitoring the integrity and safety of wells and pipelines.

The potential impact of CIUS innovations within these areas will be described by three examples from CIUS`largest 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 200 000 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.

- 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 will be 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, 12 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 will ensure that all initiated projects are based on future needs in the different sectors. A large multidisciplinary research environment is now 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 12 corporate partners: GE Vingmed Ultrasound, Medistim, Aurotech and EXACT Therapeutics within the medical sector; and Equinor, Halfwave, Sensorlink, InPhase Solutions and Archer BTC within the oil & gas sector: Kongsberg Maritime within the martime 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, 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 Professor Asta Håberg. Further, the CIUS administration includes Industry Liaison Svein-Erik Måsøy, the Project Coordinator and Administrator Line Skarsem Reitlo, Communication and Web Officers Kari Williamson and Karl Jørgen Marthinsen and Financial Advisor/ Project Economists Vegard Nyhus and Aleksandra Skorobogataia. Innovation in CIUS has been further strenghtened by Innovation manager Tormod Njølstad.

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 Chair is Eva Nilssen, Director of R&D, GE Vingmed Ultrasound.

MANAGEMENT

Board Leader Eva Nilssen, GE Vingmed Ultrasound

Dean, Project Owner and Board Member Brita Solveig Pukstad, NTNU

Centre Director Asta Håberg, NTNU

Industry Liason Svein-Erik Måsøy, NTNU

CIUS

BOARD

ELECTED BOARD REPRESENTATIVES AMONG THE CORPORATE PARTNERS

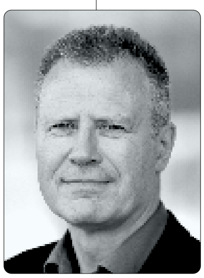
Erik Swensen, Medistim

Petter Norli, Halfwave

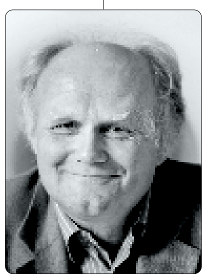
APPOINTED BOARD REPRESENTATIVES

Pål Hemmingsen, Equinor

Frank Tichy, Kongsberg Maritime



Gunnar Morken, St. Olavs hospital



Olav Haraldseth, NTNU

Berit L. Strand, NTNU

SCIENTIFIC ADVISORY BOARD

Dr. Iacob Mathiesen, CSO, Otivio, Oslo

Professor Jenny Dankelman, MISIT Group, Delft University of Technology

Dr. Philippe Blondel, Senior Lecturer, University of Bath

Anna Shaughnessy, previous Director of Earth Resources Laboratory, MIT

WORK PACKAGE LEADERS


Professor Lars Hoff, USN


Professor Sverre Holm , UiO


Professor Hans Torp, NTNU


Professor Lasse Løvstakken, NTNU


Professor Asta Håberg, NTNU


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


Professor Asbjørn Støylen, NTNU

INNOVATION TEAM


Industry Liason
Svein-Erik Måsøy, NTNU


Innovation Manager
Tormod Njølstad, NTNU

WORK PACKAGE SUPERVISORS


Hefeng Dong, NTNU


Trond Ytterdal, NTNU


Tonni Franke Johansen, NTNU/Sintef


Catharina de Lange Davies, NTNU

ADMINISTRATION


Kari Williamson


Karl Jørgen Marthinsen


Vegard Nyhus


Aleksandra Skorobogataia


Line Skarsem Reitlo

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
Archer – Bergen Technology Center
Aurotech ultrasound AS
Equinor ASA
EXACT Therapauthics
GE Vingmed Ultrasound AS
Halfwave
InPhase Solutions AS
Kongsberg Maritime Subsea AS
Medistim ASA
ReLab
Sensorlink AS
X-Fab Semiconductor Foundries GmbH

Health Sector Partners
Helse Midt-Norge (Central Norway Regional Health Authority)
Helse Nord-Trøndelag (Nord-Trøndelag Health Trust, Levanger Hospital)
Levanger and Verdal Municipalities
St. Olavs hospital (Trondheim University Hospital)
Sørlandet sykehus HF (Sørlandet Hospital Health Authoirty)

Associated Partner
Forsvarets forskningsinstitutt (Norwegian Defence Research Establishment)

Centre for Innovative Ultrasound Solutions

CIUS 2020

INNOVATION STATISTICS

- 1 NEW PRODUCT
- 27 NEW METHODS/PROCESSES
- 6 NEW SERVICES
- 0 PATENT APPLICATIONS
- 6 DISCLOSURE OF INVENTIONS
- 74 JOURNAL AND PROCEEDINGS ATRICLES

CONFERENCE CONTRIBUTIONS: 34

1 NEW INDUSTRY PARTNER

Re{Lab}

Photo: Medistim ASA

The Medistim MiraQ system is used during both cardiac and peripheral vascular surgical procedures to measure blood flow in vessels and acquiring high-resolution ultrasound images of the blood vessels.

1

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

Transducer and Electronics

WP1 covers joint research for the design, fabrication, characterisation and modelling of 1D and 2D transducer arrays, integration of high-density arrays with electronics, ultrasound transducers for high pressure and high temperature environments, and multi frequency band transducers. These tasks are fundamental and highly overlapping for all applications and CIUS partners.

WP1-1: Acoustic Source Characterisation and Optimisation

Good theoretical models are essential for designing optimal ultrasound transducers. We base our work on analytical 1D equivalent circuit models and FEM simulation models. Building on existing software, we have developed an extensive software library for a variety of transducer designs, and integrated these into other software, such as optimisation algorithms. Likewise, good experimental characterisation methods are essential to investigate the designs and determine unknown parameters. The facilities of USN MST-lab provide equipment for classic material characterisation. Through CIUS, we continue to develop dedicated systems to characterise ultrasound transducers, such as acoustic material parameters, electro-acoustic transfer function, beam pattern, and pulse shape.

WP1-2: Integrated High-performance Transducer Array Electronics

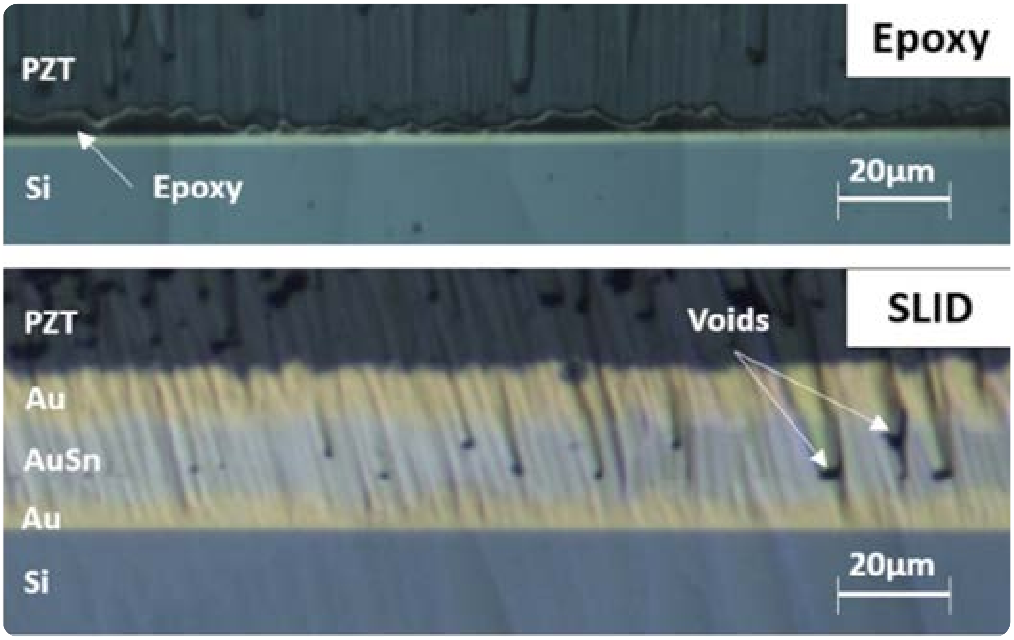
New high-density ultrasound arrays require electronics to be moved closer to the transducer. In maritime acoustics, this means moving electronics to the sonar head, while in medical ultrasound, from the scanner to the probe. A purely digital interface between the system and the transducer is preferred. 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 can withstand the harsh environments found in oil wells, i.e. high pressure and temperatures. We explore new materials and fabrication methods to ensure reliable operation under these conditions. The resulting improved robustness and reliability will also be beneficial for other application areas.

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

Combined therapeutic and diagnostic ultrasound applications require transducers covering a wider frequency range than conventional ultrasound imaging applications. The same applies to novel imaging methods based on nonlinear acoustics. We have developed new design and modelling methods for multi-band transducers and use these to develop piezoelectric transducer structures covering several frequency bands. Micromachining is another approach to achieve this performance, i.e. CMUT and PMUT technology. This can be combined with a conventional piezoelectric stack to cover several frequency bands. The resulting transducers can lead to new opportunities for combined ultrasound imaging and drug-delivery systems.



The micrographs show the cross-section of two transducers with 250x magnification. Two different bonding techniques have been utilised. The conventional epoxy bonding technique (top) and a novel metallurgical bonding technique (bottom), known as solid-liquid interdiffusion (SLID). The metallurgical bonding technique offers advantages in terms of high-temperature stability, robustness and increased acoustic impedance. Photo: Per Kristian Bolstad/USN.

Activities in 2020

The last year has seen a generation shift among the PhD-students in WP1. Two PhD-candidates who started in 2016 have successfully defended their PhDs. Three projects that started in 2018 are progressing well, but Covid-19 restrictions on lab access have led to challenges. The consequences of Covid-19 for the PhD students' progress are not yet fully known. The two last PhD-positions were announced early 2020 but finding qualified candidates has been challenging. Eventually one position was filled, and we are actively searching for a candidate for the last PhD-position. The two-year Postdoc-position in transducer technology is expected to be filled early 2021.

In addition to the CIUS-positions, USN has received funding for one industrial PhD working with a Norwegian ultrasound technology company outside of CIUS, creating good synergy with the CIUS students. Three PhD students at IES NTNU are working together with GE Vingmed Ultrasound on integrated circuit design for in-probe electronics. The work involves both transmitters and receivers. Other PhD-students have worked with the industry partners Kongsberg Maritime, Exact TX, GE Vingmed Ultrasound and BTC Archer. During 2020, three PhD-graduates in ultrasound technology from USN were hired by CIUS industry partners, and two more by Norwegian ultrasound companies outside of CIUS. This demonstrates the high demand for the competence we offer. No ultrasound transducers master's students finished in 2020, but three new projects were started. All new master's students work on projects related to CIUS activities, either directly with CIUS industry partners or by expanding the capabilities of our transducer lab and exploring new fabrication methods.

USN is a partner in two new ultrasound projects granted by the Norwegian Research Council. One is an INTPART project funding staff and student exchange with leading US universities, the other is an IPN industry project with the CIUS partner GE Vingmed Ultrasound. Both these projects are linked with our activities in CIUS and contribute to strengthening our competence and industrial relevance.

ReLab, a start-up company founded by CIUS PhD-students from USN, has received funding from the Research Council for a STUDENT commercialisation project. ReLab was admitted as a CIUS industry partner in 2020.

Activity in the ultrasound transducer lab is still high, but was strongly reduced for a period due to Covid-19 restrictions. Some expansion of the lab is planned for 2021. The activity causes some wear and damage to the equipment, requiring funds for replacements and maintenance. The main challenge remains as for previous years: High activity poses challenges in lab maintenance and student supervision. The CIUS-funded researchers are invaluable for our activity. Employees at industry partners contribute to supervision of the PhD-students, which is essential to ensure industry relevance.

Going Forward in 2021

Two PhD-students are planning to defend their theses in 2021. Development of a hybrid CMUT-piezoelectric array transducer aimed at GE Vingmed Ultrasound scanners start in 2021. A prototype transducer for speed of sound measurements in both oil and gas shall be tested with BTC Archer.

2

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

Acoustics and Beamforming

This work package covers fundamental research on acoustic wave propagation and image formation (beamforming) common to applications in oil & gas, maritime and medicine. Knowledge and simulation tools are developed for improved algorithms in all applications to achieve improved image resolution and contrast, higher frame rates, and improved measurement accuracy (e.g. in Doppler imaging). Research systems at academic laboratories as well as computer simulations will be used to investigate next-generation imaging based on channel data processing that will provide a strong basis for innovation for the user partners.

WP2-1. UltraSound Toolbox (USTB)

This project focuses on joint development of the UltraSound Toolbox (USTB), which is an open source software toolbox for processing ultrasonic signals. It aims to facilitate the comparison of imaging techniques and thereby generalisability and dissemination of research results. USTB covers processing techniques for tissue and flow visualisation, as well as other image reconstruction techniques. Please visit USTB here: www.ustb.no. The development of USTB has continued in 2020 and release v2.2 is available. This toolbox is central in many beamforming projects in CIUS, with applications ranging from simulation and visualisation of fundamental beamforming to processing of in-vivo data used in clinical projects, as well as potential commercial projects. It is also highly useful in teaching and in the projects of master's students, PhDs and Postdocs. It was featured in an invited talk in 2020 at the American Institute of Ultrasound in Medicine (AIUM) meeting by Marius Hoel Rindal.

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

Here we use ultrasonic NDT methods to solve various problems relevant to the CIUS partners. These problems will be to detect and give information about 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. During the spring of 2020, a set of measurements for detecting and measuring flow in a channel on the far side of a steel plate was conducted at Department of Circulation and Medical Imaging (ISB), NTNU. This was done in collaboration with colleagues in WP3, and it proved to be successful. An improvement of the Doppler power was observed when employing our transmit and receive focusing algorithms. During the summer, an extensive experimental study was conducted to further investigate transmit and receive beamforming for imaging through a steel layer.

WP2-3: Multibeam Sonar Imaging with Nonlinear Acoustics

As stated in our 2012 IEEE Oceanic Eng. paper: "We investigate the feasibility of utilising the part of the signal generated around the second harmonic frequency band by nonlinear propagation of sound in water. The combined use of the signal components in the second harmonic and fundamental frequency bands provides a high-resolution image at short range and a long-range imaging capability at a lower resolution as well as a multifrequency characterisation of targets."This project takes this research further. No activity has taken place in 2020, according to plan.

WP2-4: Adaptive Image Formation for Improved Image Quality

This work focuses on developing a method for adaptively improving image quality

Sensorlink continues to improve their monitoring technology, with important input from CIUS. Photo: Sensorlink

in echocardiography. This means using patient-dependent processing in the ultrasound system, adapting the image quality and processing in the ultrasound scanner to each individual patient. The goal is to improve image quality with the potential of improving diagnosis and patient follow-up.

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

Recent development of sonar technology allows for more flexible sonar array design, and for greater frequency agility. The development of high-performance computing in small form-factors also allows for using substantially more complex signal processing. Taking these factors into account, a re-visit of the fundamentals in signal processing in certain advanced sonar applications is studied. This activity is near its end, but two papers have been submitted this year to IEEE Journal of Oceanic Engineering. A thesis was also submitted at the University of Oslo on 22 Sept 2020: Antoine Blachet, "Advanced waveform modulation and associated signal processing techniques".

WP2-6: Suppression of Reverberation Artifacts in Ultrasound Imaging

The image quality of echocardiograms has increased greatly in the last 20 years, making it possible to correctly diagnose the occurrence of cardiovascular disease in about 80% of patients. In the remaining 20%, a number of physical factors hinder good visualisation of the heart and assessment of its function. Patients with a high body mass index (BMI) often have an impaired acoustic window that is translated into aberration and reverberation artifacts. This project aims to understand and correct the factors that lead to reverberation artifacts, such as secondary out-of-plane reflections from ribs/lungs. CIUS PhD candidate Ali Fatemi is about to submit his PhD thesis. An MSc student is following up the work carried out by Ali Fatemi and is developing a new coherence imaging method for 2D matrix arrays. The method has been tested using USTB and shows promising results.

WP2-7: Ultrasound Elastography with Harmonic Source for Cardiology

Commercial ultrasound elastography is either static elastography or acoustic radiation force elastography. MR elastography is, however, based on an external vibration source. Here we explore the potential of the MR approach for ultrasound elastography, as it has the potential for e.g. deeper penetration and more accurate reconstruction. Since elastography of the heart is a tough challenge due to the motion, the project will progress from imaging of static phantoms, to stationary organs (e.g. thyroid gland), to the heart. The activity in this project only took place for two months as the CIUS Postdoc at UiO (Karabiyik) started a new job as an engineer in the DSB group at UiO on 1 March 2020. The work attempted to image a static organ like the thyroid. The status was that there were unresolved synchronisation problems with the 4V probe between sub volumes. A team at the University of British Columbia has, however, recently demonstrated that the method gives excellent results on the liver, which correlates well with MR elastography.

Going Forward in 2021

In WP2-1 we will continue the development of the USTB and aim to involve more people. The USTB will be used in several planned publications. In WP 2-4 and 2-6 MSc students will follow up the work of former PhDs related to these projects. Three PhD theses will be defended in 2021: Andreas Sørbrøden Talberg (WP2-1), Antoine Blachet (WP2-5) and Ali Fatemi (WP2-6).

3

Doppler and Deformation Imaging

Technology to improve methods for detecting and measuring flow and displacements in ultrasound images. This ability is considered one of the main strengths of US compared to other image modalities and is fundamental to several of CIUS' innovation goals.

Hans Torp, Professor, NTNU
WP leader

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 focus will be on achieving real-time 3D (full velocity vector) imaging of blood velocities, based on spectral- and colour-Doppler imaging.

Flow quantification of mitral and aortic valve insufficiency by 3D Doppler ultrasound: The project was started in 2018, aiming to develop automated quantitative measurements of jet flow in the heart. In 2020, methods for improving quantification of effective leakage area and flow volume have been improved using simulations and in vitro measurements. A first round of clinical measurements is concluded, resulting in data from 86 insufficiencies. Analysis of these data sets are ongoing.

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. Fredrik Fossan defended his PhD on 24 November 2020. The thesis contains fluid dynamic modelling and flow estimation in coronary blood flow.

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 using 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). The method "Clutter wave imaging" to quantify myocardial stiffness has made substantial progress in 2020, in collaboration with the former Postdoc Sebastien Salles. Two more journal papers on the method have been published in 2020. A new SW tool for analysis has been developed and applied to patients with myocardial fibrosis. Some results have been presented at a meeting in Leuven; and a journal paper with a large number of patients is in progress.

The jet flow phantom for heart valve leakage quantification operated by Postdoctor Stefano Fiorentini. The fluid chamber is shown in the lower left corner, receiving hydrostatic pressure from an elevated bucket. Photo: Hans Torp/NTNU.

WP3-4: Doppler Imaging of Flow in Cement behind Steel Casing

For the oil & gas well integrity logging operations, detecting flow in the cemented zonal isolation layers is of vital interest. Currently this is not possible with state-of-the-art US logging tools. This project will use lab models of cemented wells and develop new ultrasound Doppler techniques for flow detection in the cement behind steel casing. Extensive lab experiments with Doppler acquisitions, based on wave propagation simulations, have been continued in 2020. Techniques have been developed to improve the sensitivity of Doppler methods. Results have been published in the PhD thesis of Cristiana Golfetto.

Going Forward in 2021

Most of the activities in WP3 will continue in 2021, but with a focus on WP3-1, and WP3-3. 3D flow quantification of valve leakage (WP3-1) has top priority by GE-Vingmed, and the activity now has a new PhD student, Sigurd Vangen Wifstad, who started in August 2020.

Postdoc Stefano Fiorentini will continue his efforts on this project, but he will also conduct a study on aortic stenosis (see below). There are several technical challenges in this project, where a joint effort by CIUS researchers, our Scientific programmer, and engineers in GE Vingmed is necessary to be successful. The focus in 2021 will be further trials and lab experiments to optimise data acquisition, the improvement of methods for automated quantification of effective orifice area and flow volume, and facilitating the implementation of the method on clinical scanners. Clinical testing will continue in collaboration with WP7 personnel.

Postdoc Stefano Fiorentini has received an innovation grant from NTNU to further develop his method on aortic stenosis quantification, and he will therefore be on a six-month leave from his Postdoc position in 2021.

The project "Clutter filter wave imaging" (WP3-3) has shown very promising results and received significant international attention. Analysis of data from 100 patients with myocardial fibrosis is in progress and will result in a journal paper in 2021. Software analysis tools will be further developed in the framework of the GE Vingmed plugin analysis tools, to make a smoother transition to future product implementations. A new PhD student, Danial Mohajery, has recently started, with the project "Quantification of mechanical waves in the myocardium, unravelling the relation between tissue characteristics and elastic wave propagation, with application to tissue fibrosis detection and infarct detection."

The newly hired PhD candidate Shivanandan Indimath will start working at the beginning of January 2021. The plan for 2021 is for the candidate to build an experimental setup emulating realistic influx/efflux velocities in a simplified setup using only water/scatterer emulsion. The setup will be used to tune and find the Doppler processing requirements for a sudden influx/efflux event with varying conditions of vibration of the transducer. When results are satisfactory the project will move to the second stage using a new experimental setup with real drilling fluids at SINTEF in Trondheim.

4

Lasse Løvstakken, Professor, NTNU
WP leader

Image Analysis and Visualisation

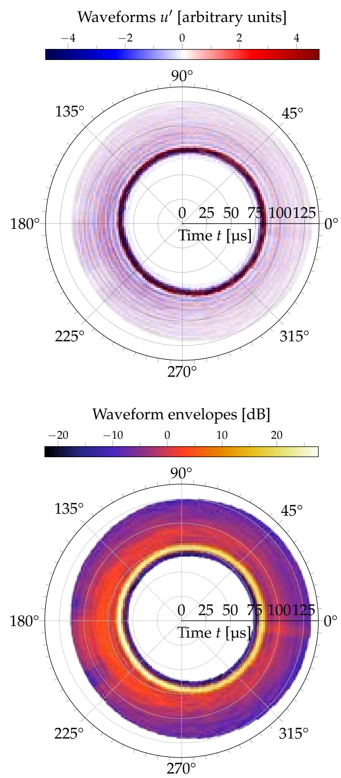
This work package covers the development of image processing and analysis methods to extract relevant contextual information from ultrasound image data, to improve measurement quality, and to provide a more efficient workflow to reduce the time to decision. These tasks are also coupled to enhanced data 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 to 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, topics of high relevance for WP6.

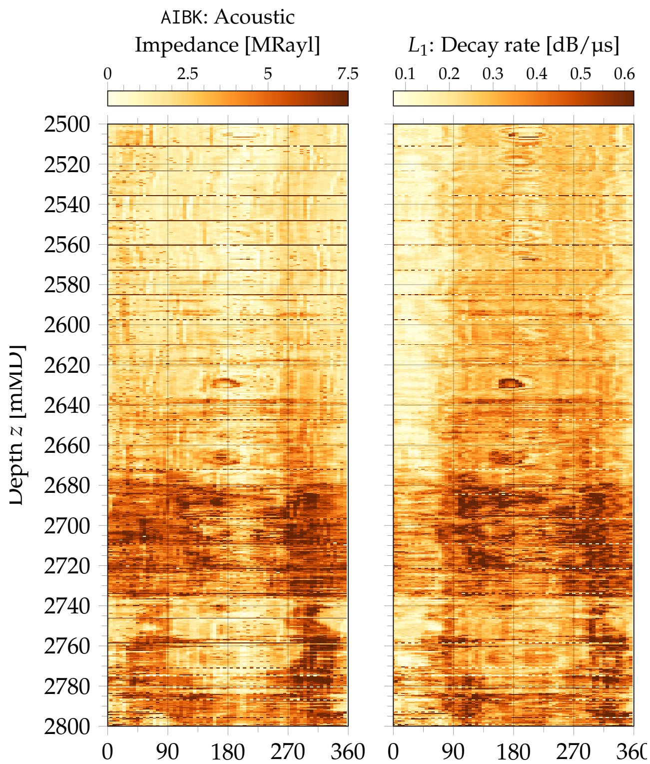
The Initial Work Package Tasks were as Follows:

- WP4-1: Real-time 3D image segmentation of all heart chambers
- WP4-2: Patient and image registration for improved workflow and ease-of-use
- WP4-3: Improved processing of corrosion pittings in external pipe inspection
- WP4-4: Improved detection of pores and cracks in downhole logging
- WP4-5: Model-based acquisition for high frame-rate medical ultrasound imaging

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 recognise and segment relevant image or data features. Further, we aim to develop a model-based estimation framework for regularisation and reconstruction of noisy and potentially missing image information based on physical models, a pathway towards more robust



Ultrasonic waveforms (top) measured by a pulse-echo logging tool for different angles at the same well depth, and the envelopes of these waveforms (bottom). Illustration: Erlend Magnus Viggen. Data source: Volve Data Village from Equinor.



Two evaluations of what is behind the steel casing in an oil well, both calculated from the same ultrasonic waveforms. Light colours represent fluids, while dark colours represent solids. On the left is a reference evaluation from the service company, and on the right is another evaluation calculated using a simple method from the literature. Illustration: Erlend Magnus Viggen/NTNU. Data source: Volve Data Village from Equinor.

measurements. Finally, to explore how these methods can provide context for improved data acquisition and measurements.

We have tuned our efforts somewhat differently since the initial task list, focusing now mostly on WP4-1, WP4-3 and WP4-4, as well as including seabed classification, a challenge that was initially moved from WP4 to WP2. We have also in collaboration with an industry partner chosen to focus on the practical use of the methods developed. For instance, in medical applications we focus on using real-time segmentation (WP4-1) for the automation of clinical measurements. In this line, we also expanded our focus to deformation measurements which is of high interest to our industry partner in this project (GEVU).

Similarly, in oil & gas we focus on the practical use of machine learning algorithms for automatic interpretation of well integrity logs (WP4-4). Moving forwards, we will start a new activity in WP4-3, WP4-2 is partially covered in WP5, and WP4-5 is not currently prioritised.

Activities in 2020

The year 2020 has been productive for WP4, with several publications both in medical and industrial domains, and with national and international collaboration partners. Our efforts have been noticed abroad and we are being invited to talk at several highly relevant conferences. We were also invited to join a consensus review paper on artificial intelligence (AI) in echo. One DOFI was submitted and one licence agreement was signed with GE Vingmed Ultrasound.

Going Forward in 2021

In 2021 we will continue our work on integrating AI in the echo lab, and to develop methods for simplifying echo outside the hospital. A new Gemini centre on medical image analysis called MIRA, which will gather research communities in Trondheim, will start up in 2021. We will begin several new industrial projects, including a PhD project on seabed classification, and a PhD project on AI analysis when imaging fish. We will also continue our efforts on using machine learning in oil & gas well logging in collaboration with Equinor.

5

Asta Håberg, Professor, NTNU
WP leader

Multimodality and Interventional Imaging

This work package covers the development and application of multimodal and interventional imaging. 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

In this project we are developing and investigating novel methods for multimodal imaging in cardiology and image-guided surgery.

In 2020, the final step in the validation of a new 3D Doppler ultrasound method for the quantification of valvular regurgitation was completed in a patient population after three years of method development and testing. A new 3D Doppler method for more precise evaluation of aortic stenosis is also under assessment.

For cardiac interventions, a new registration tool to fuse preoperative CT data of the heart with ultrasound images recoded during surgery in real-time, is under development. Furthermore, registration of longitudinal ultrasound volumes taken during surgery is investigated. This allows for detection and compensation of ultrasound probe movement during surgery and thereby provides more consistent fusion with the pre-operative imaging data.

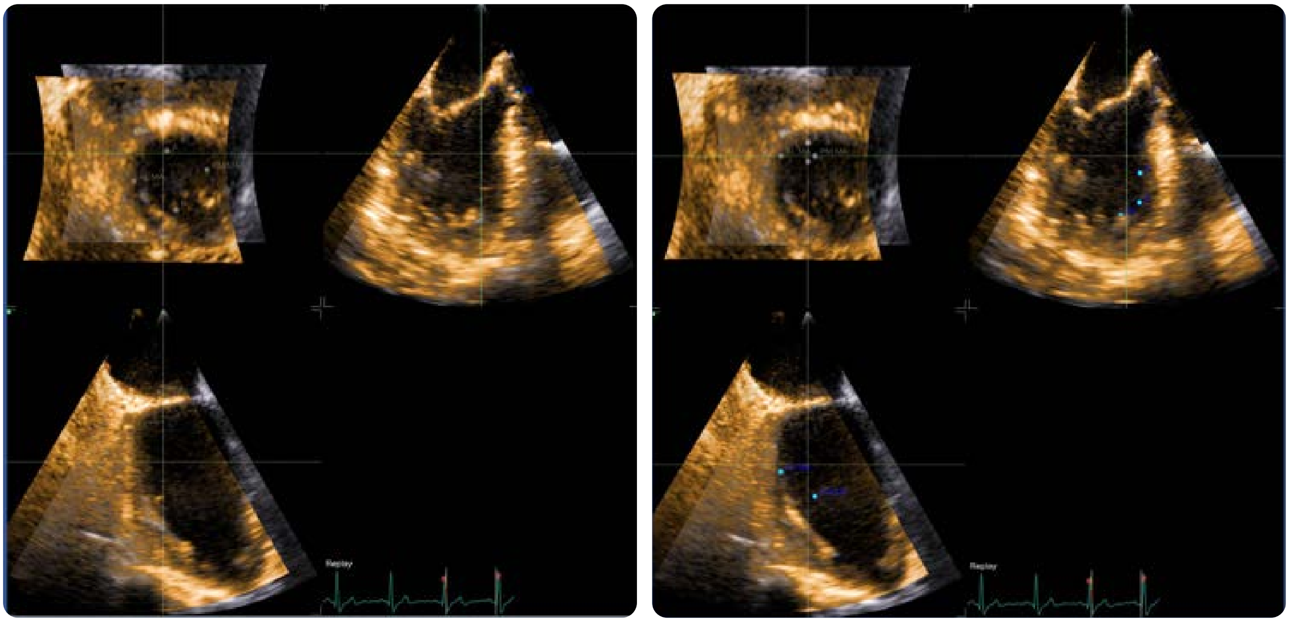
7T MRI data has been added to neuroimaging data used in an ultrasound guided neuronavigational system during brain tumour surgery in 2020. The added value of the multimodal and multiparametric data (PET-MRI, 3T and 7T MRI) for brain tumour resection and outcome is under evaluation.

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

The aim of this project is to evaluate the feasibility and added value of multimodal imaging in the diagnostics, treatment and follow-up of patients with brain tumours, cognitive impairment, or prostate-, head- or neck cancers. The main modality here is PET-MRI in combination with other imaging modalities and the implementation of these results in planning and performing surgery and radiation therapy, or evaluation of drug effects or other types of interventions. A new AI-based method for attenuation correction of PET-MRI data was published in 2020, which is relevant across patient groups. The CIUS partner, St. Olavs hospital, has invested in infrastructure to synthetise new PET tracers locally, which opens new possibilities with regard to types of pathology to be assessed and the evaluation of feasibility and value of such new tracers in the clinical work-up in different patient groups.

WP5-4: Ultrasound -mediated Drug Delivery

This project aims to use US in combination with microbubbles for targeted drug delivery (TDD) in cancer treatment and to delivery drugs across the blood-brain



Intraoperative screenshot of a new automatic fusion technology where preoperative CT images are fused continuously in real-time with intraoperative transesophageal ultrasound images using landmark alignment, developed by An Pham, Gabriel Kiss and the GE team. The method allows for realtime, flexible, multiple projection view of the heart valves during the procedure.

barrier. A prerequisite for successful cancer therapy is that the therapeutic agents reach all tumour cells and kill them. Focused US (FUS) combined with microbubbles improves the delivery of nanoparticles loaded with drug as well as free drugs in tumour tissue, thereby increasing the therapeutic efficacy.

ExACT Therapeutics (formerly EXACT Therapeutics AS) is aiming for treatment of pancreatic tumours in patients. To support such important clinical studies, research in mice with pancreatic tumours are performed at NTNU. Tissue uptake, bio- and microdistribution of a novel nanoparticle and other drugs, combined with acoustic cluster therapy (ACT) are examined. The immune response to such treatment is also assessed. The ability of ACT to delivery nanoparticles across the blood-brain barrier has been studied. Other preclinical work aims to understand the biological and physiological mechanisms which enhance or hinder ultrasound-mediated drug delivery to the target tissue.

Intravital microscopy is a new method established in 2020 to study tumour growth and response to ultrasound mediated therapies. A dual frequency ring transducer to be placed around the microscope objective has been developed and tested to image the effect of ACT on the blood- brain barrier and brain tissue.

At St. Olavs hospital, a clinical study with focused ultrasound for treatment of liver metastases in colorectal cancer patients is underway. The patients receive standard chemotherapy and one liver metastasis is treated with focused ultrasound while another metastasis is used as internal control. To ensure that the correct metastasis is treated with ultrasound, the CustusX platform combining tracking and registration of notable landmarks (e.g., metastasis, aortic bifurcation) is used. Data collection will be finalised in 2021. In another clinical study, patients with non-resectable pancreatic tumours are treated with standard chemotherapy (FOLFIRINOX) plus the clinical approved microbubble Sonovue and focused ultrasound. A new dual-frequency ultrasound transducer (high frequency for imaging and lower frequency for treatment) has been designed and produced. 11 patients have been enrolled.

Going Forward in 2021

2021 will be a busy year writing up and publishing the results from several clinical and preclinical studies completed in all the different research areas covered in WP5 in 2020.

If successful, ultrasound guided intervention methods and workflow improvements will be integrated into partner products and services.

For PET-MRI, new tracers will be implemented in new patient groups. For ultrasound mediated therapy, new mechanisms enhancing the ACT effect will be uncovered.

6

Ole Christian Mjølstad, Head of Cardilogy,
St. Olavs Trondheim University Hospital 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 diagnostics 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 be a paradigm shift for practices in the healthcare sector, where the goal is to offer patients more rapid diagnosis outside of 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.

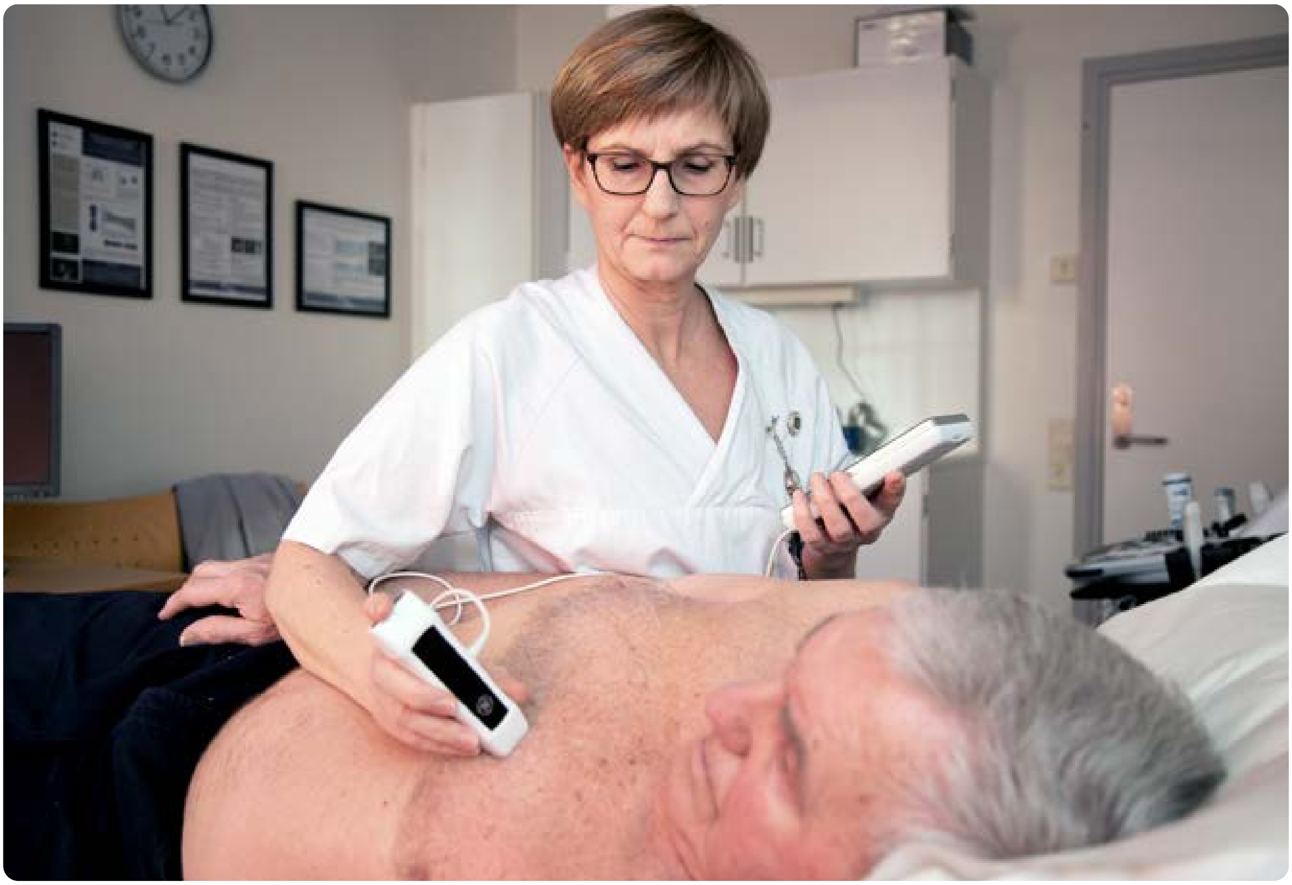
At NTNU/Levanger Hospital, general practitioners that provide services in nursing homes have been trained in simplified use of ultrasound to detect heart failure and fluid overload. They have assessed and scanned patients with pocket-sized ultrasound in a cardiac outpatient clinic and transferred the recordings to a cardiologist using a telemedicine system. Training and education, as well as data collection, is completed, the database is closed, and data analyses and publishing are ongoing.

Our industrial partner GEVU has provided five Vscan Extend devices for the clinical general practitioner (GP) study at NTNU. The study includes evaluation of:

1. GPs for assessment of left ventricle (LV) function
2. Automatic software for LV analyses integrated in pocket-sized ultrasound device
3. Diagnostic support of the GPs by telemedicine

Project Updates

- Evaluation of infrastructure for telemedicine support of inexperienced ultrasound users in outpatient heart failure clinic (PhD Hjorth-Hansen). Publication: Completed, Q2 2020.
- Feasibility and Reliability of Automatic Quantitative Analyses of Mitral Annular Plane Systolic Excursion by Handheld Ultrasound Devices (PhD Magelssen). Publication: Completed, Q3 2020.
- Large normal reference data for automatic measurements (PhD Grue). This analysis was a necessary step before an app with reference values can be implemented on a Vscan.
- Real-time evaluation of AI algorithms for improved image quality during scanning. This study is the first clinical step towards real-time guidance of the operator during scanning.
- Pocket-sized ultrasound for rapid diagnoses in stroke/TIA patients (PhD Saxhaug). Submitted. This is a study conducted in Levanger Hospital with Vscan with Dual probe.



Can handheld devices change healthcare systems? Hilde Haugberg Haug (nurse) is using handheld ultrasound to examine a patient. Read the full story in the CIUS Annual Report of 2019. Photo: Karl Jørgen Marthinsen/NTNU.

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

This part was merged into WP6-1 as the physicians at the nursing homes at our partner municipalities of Levanger and Verdal were the same, who were selected to join the clinical GP study.

WP6-3 Automatic Detection of Signs of Rheumatic Heart Disease

Approximately 8-15 million children worldwide are affected by rheumatic fever and rheumatic heart disease. These are conditions that lead to significant valvular regurgitation and stenosis. This project will evaluate pocket-sized ultrasound for the screening of children in Nepal, Australia or other countries with high incidence of infectious valvular disease.

For the MAPSE study, the team presented a poster for the 67th Annual Scientific Meeting of the Cardiac Society of Australia and New Zealand hosted by CSANZ in Adelaide, in August 2019. Enrolment and data analyses is delayed. We have not received adequate feedback from our partners in Australia, and the present activity is not known.

Going Forward in 2021

PhD candidate David Pasdeloup will continue with machine learning and AI in cooperation with Professor Lasse Løvstakken (NTNU) and Sigmund Frigstad (GEHC) in order to develop technology for quality assurance of echo images and computer-assisted guidance for cardiac applications. PhD candidates Magelssen and Hjorth-Hansen will perform data analyses and submission of manuscripts (NB! The latter is on parental leave for most of 2021). The submission of papers will then be the main focus for the next two-year period.

PhD candidates Magelssen and Hjorth-Hansen are ahead of their planned 6-year schedule. PhD candidate Saxhaug is in the process of publishing his work. PhD candidate HN Pettersen and medical research student Sæbø will collect data and publish their first manuscripts. We will plan evaluation of real-time guiding on the hand-held platform when we have developed the technology needed.

7

Asbjørn Støylen, Professor, NTNU
WP leader

Clinical Feasibility

This work package focuses on clinical assessment of new technical ultrasound modalities for 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 challenges are 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 be a paradigm 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 in later stages of testing in vivo, as well as evaluating findings in terms of function.

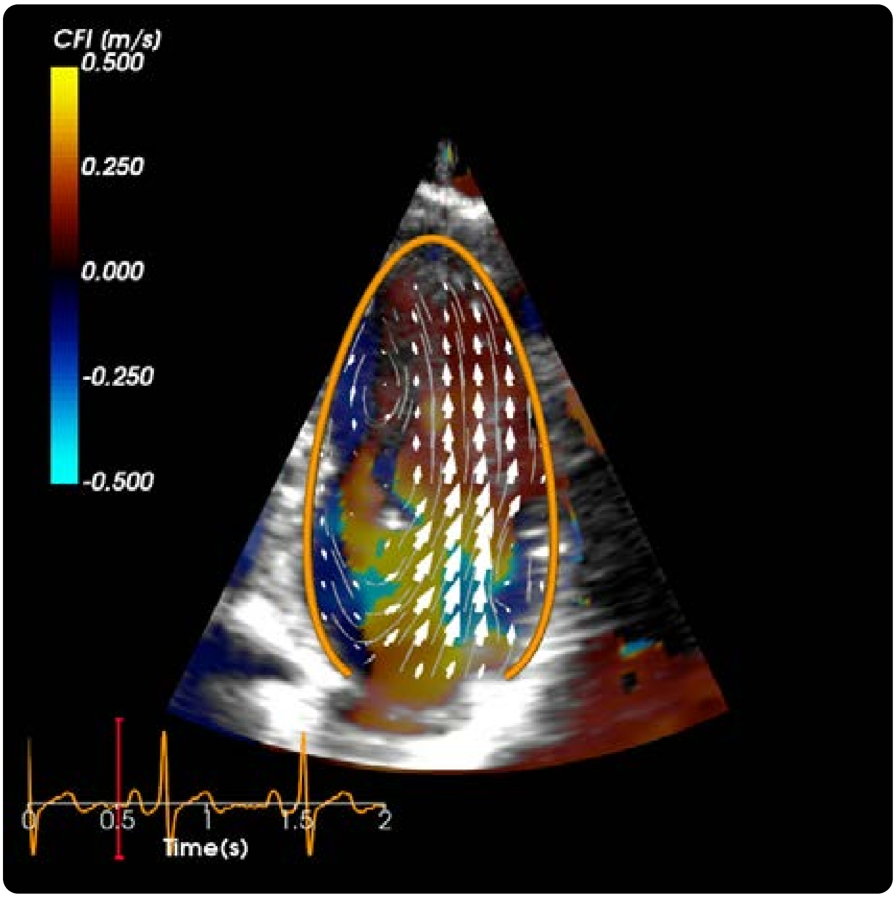
WP7-1 Ultrasound Coronary Angiography and Cardiac Flow – Feasibility and Validation

The main aim of this project is to assess the feasibility of new 3D methods for visualising coronary arteries and quantification of coronary stenosis with Doppler. The methods will be compared to coronary angiography with fractional flow reserve (FFR).

The WP resources have been diverted to flow vector imaging (clinical) in 2020. 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 a new high-end scanner 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 previous scanner generations, and therefore lacks clinical data. The analysis is under way.

WP7-2 and 7-3 Ultrasound Imaging and Quantification of Tissue at Risk and Myocardial Viability – Feasibility and Validation

Acute ischemia and viability were originally in two different work packages, but 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 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,



Intraventricular vortices and flow visualized with Blood Speckle Tracking (BST): Still image from one timepoint in the cardiac cycle, specifically the rapid filling phase (the E-wave), showing the complexity of the blood flow with the development of several vortices. Photo: Annichen Søyland Daae and Morten Smedsrud Wigen.

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 further aim is to take this into real time 3D deformation imaging. This project has one full time PhD student.

The analysis tool is finished for reconstruction a 3D plane model from 2D tissue Doppler echocardiography. Analysis is finished in the chronic infarct population and the acute study, and 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.

Additional Projects in WP7

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. Inclusion of patients at SickKids Hospital in Toronto is ongoing. In addition, the technique is being tested for feasibility in adults, in a cooperative project, with the Department of Circulation and Medical Imaging (ISB, NTNU) (3D flow quantification acquired). The project on 3D intracardiac flow in adults has included the healthy volunteers in the pilot study, and analysis is ongoing on:

- The physiology of intraventricular flow in normal subjects,
- Retrospective tissue Doppler and Doppler in normal subjects, and
- Changes in intraventricular flow pattern in heart failure, both with concentric and dilated ventricles.

Going Forward in 2021

- Publication of feasibility and normal intraventricular flow in adults. Publication of validation of reconstructed from thick slice:
    - Pulsed wave Doppler and tissue Doppler
    - Colour M-mode and Tissue Doppler
- Publication of intraventricular flow in heart failure in adults.
- Publication of feasibility and added value of flow vector imaging in paediatric congenital heart disease.
- Publication of feasibility of area measurement by high frame-rate 3D tissue Doppler in coronary disease in adults.
- Thesis completion intraventricular flow in adults.

8 | 9

Svein-Erik Måsøy, Industry Liaison and Researcher, 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 2020 and Covid-19

The Covid-19 pandemic has hit the oil & gas and maritime industries hard. There are of course variations from partner to partner, but in general our partners report furlough of larger or smaller parts of their staff for periods of time and reduction in income and subsequently R&D efforts. It is a very challenging time for the industry just after it started re-bounding from the wake of the oil & gas downturn starting in 2015.

This has affected several of the projects planned during the autumn of 2019 and several projects planned to start in 2020 will be postponed, and some will potentially be abandoned.

Oil & Gas

Detailed planning of a Minimum Viable Product (MVP) pilot in collaboration with Equinor on machine learning for evaluation of downhole logging operations was ongoing in 2020.

The work is based on CIUS Postdoc Erlend Viggen's research into this topic, which has resulted in several academic papers and now an interest from Equinor to test this internally within their logging team. The project aims to start up in February 2021 with a six-month horizon.

Halfwave is continuing the development of their crack detection tool and has carried out the first field run successfully collecting data in a gas transport pipeline. The data collected have since been processed and analysed in line with algorithms developed and matured through ongoing internal development, along with advances from the accompanying CIUS PhD project of Simen Midtbø.

Archer BTC has assisted CIUS PhD Per Kristian Bolstad in high pressure and temperature testing of a prototype transducer manufacture with the SLID bonding technique. This is the first step along a possible new way of manufacturing transducers with the aim of improving durability and tolerance to rough conditions. The company

Halfwave / NDT-Global assembly and testing of the newly developed crack detection tool for 20–24' gas pipelines. Photo: Halfwave/NDT-Global.

has also analysed results from CIUS PhD candidate Andreas Talberg and evaluated the potential for use in their products.

Maritime

Kongsberg Maritime has been planning field tests of improved multibeam imaging and mapping quality for multibeam echosounders, based on the PhD work of Tor Inge Lønmo. The company has also developed new prototype transducers from the work of PhD candidate Ellen Sagaas Røed.

The results are very promising and may constitute new products in the future for the company. The new prototype transducers use single crystal as the piezoelectric active material. This material has enabled a compact transducer design and the prototype can be used in a wide frequency range. These are important advantages for the increasing amount of small transducer platforms.

The prototype fabrication has demonstrated that the fragile crystals can be successfully processed using the Kongsberg Maritime facilities.

Going Forward in 2021

Next year we hope to determine whether to start projects which have been postponed this year. Three new projects are also planned to start in 2021, but due to Covid-19 this is still uncertain.

Lab-visit from Aalto University, Finland, at the beginning of 2020. Photos: Karl Jørgen Marthinsen/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.

This year, we have collected a series of stories illustrating the range CIUS covers in ultrasound research – from physical transducer design to computer science, medical applications and how to process signals using an open source toolbox.

From Glue to Metal Bonding
Transducers used in the oil & gas industry meet with very different conditions compared to a medical ultrasound probe. PhD candidate Per Kristian Bolstad (USN and recent start-up and CIUS partner ReLab) works on using metal bonding rather than glue to make transducers more robust.

Making Robots 'Listen' to the Ocean
Follow us on a re-visit to Ellen Sagaas Røed at Kongsberg Maritime, who is working on making transducers as small as possible with an as wide as possible frequency band to collect more data about the oceans, tying in nicely with the UN sustainability goal #14 Life Below Water.

A Perfect Match
This story highlights one of CIUS' strengths in bringing industry and academia together. CIUS partner Medistim faced a challenge in interpreting blood flow data which became a nice master's student project involving artificial intelligence (AI) for Benjamin Nedregård, supervised by Lasse Løvstakken (NTNU).

Ultrasound makes Chemotherapy more Efficient
Our project on delivering chemotherapy more efficiently and precisely using bubbles and ultrasound, is progressing nicely. Margrete Haram (NTNU/St. Olavs hospital) and David Bouget (SINTEF) continues our success story of bringing doctor and technologist together, this time to help liver cancer patients.

The UltraSound ToolBox
Finally, Ole Marius Hoel Rindal (UiO) gives us an update on the Ultrasound Toolbox (USTB) – an open source tool for processing ultrasonic signals enabling researchers from around the world to share and compare methods. USTB is a collaboration within CIUS, and can so far boast of being part of 41 publications.

FROM GLUE TO METAL BONDING

It is a well-known problem that transducers struggle in harsh conditions, such as those found in oil wells. However, it is possible to make transducers with metal bonding that last and are cheaper.

The development of ultrasound transducers for operation in high pressure, high temperature environments is the topic for Per Kristian Bolstad's ongoing PhD at the University of South-Eastern Norway (USN) and CIUS.

"My project aims to develop a new technique for assembling transducers. It is experimental research with lots of trying and failing," explains Bolstad.

He has been at USN for the past five years. First as a master's student in the Micro-Nano System Technology programme, then as a research assistant for one year before starting his PhD.

"All my work, both during my studies and after, has been focused on transducer design and production," he says.

Per Kristian Bolstad. Photo: Victoria Higueras.

From Glue to Metal Bonding

Normally, the different layers in a transducer are glued together to form a sandwich of multiple layers. But there are different challenges with glue when used in oil wells for monitoring and inspection.

Deep down in the wells, the transducers meet corrosive liquids, and both the pressure and temperature can be extremely high. Most glues are not suited to these conditions. The alternative is to use a type of metal bonding called Solid-Liquid InterDiffusion (SLID).

"Luckily, USN has a lot of research experience with SLID bonding for interconnected applications. This is valuable for my PhD work," Bolstad says.

"We have seen that the advantage of using metal bonding over glue for bonding ultrasound transducers, is the increased acoustic impedance and the temperature stability of metals. I am therefore looking into ways of using metal for bonding the different layers in the transducers.

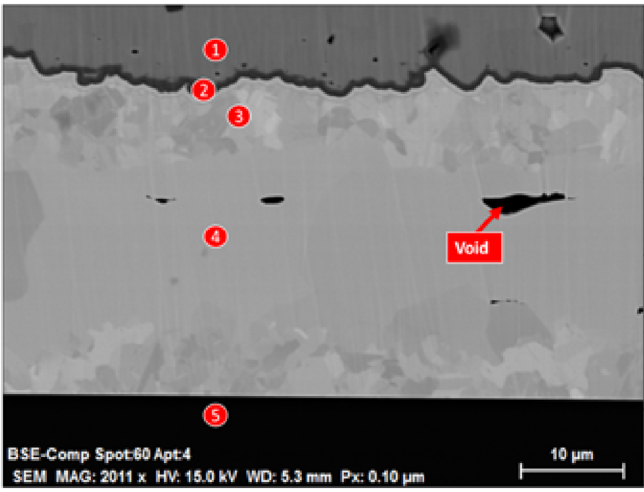
"This should make the transducers more robust and therefore better suited to harsh environments. Hopefully, the results from my work will be of interest to both the oil and gas-, and the medical industry."

Experimental Research

Bolstad is now halfway through his PhD and is enjoying the work: "This is experimental research, so I work at lot in the laboratory with production and testing. I constantly face new challenges, but that just makes the work more interesting."

He likes to work with ultrasound because it is so multidisciplinary. And he gets to work across different subject fields such as electronics, mechanics, physics, and programming.

"I guess I geek-out the most when I discuss transducers with my colleagues at CIUS or USN that are into the field.



Location	Composition	Comment
1	28.1% Pb 11.8% Zr 15.9% Ti 44.2% O	This is PZT, the piezoelectric material
2	Ni	A nickel layer improves adhesion
3	Au	Electroplated gold layer where the grains are visible
4	17.0% Sn 83.0% Au	This SLID bond is a made up of gold and tin
5	Si	A silicon substrate

The figure shows a micrograph from the scanning electron microscope at USN. With such a microscope we can analyse elementary composition of our samples. This sample is made up of a SLID bond between a piezoelectric material (PZT) and a silicon substrate. Illustration: Per Kristian Bolstad/USN.

Even better, is coming up with a new idea for a design or process and going straight into the lab to try it out. Working in the lab allows me to do that and I really like it."

Future Plans

Bolstad is not only working on his PhD. He is also working in a 50% position at a start-up company, ReLab AS. The company was founded by former CIUS PhD candidate, Kenneth Andersen, and has received start-up funding from the Research Council of Norway.

"This will be Norway's first company to produce ultrasound transducers for the open market," Bolstad is proud to point out, and he hopes that this will be his workplace after finishing his PhD.

"If everything goes according to plan, ReLab will be developing and producing transducers for Norwegian ultrasound companies that do not have their own solutions or production lines. We aim to be a cheaper and more efficient alternative to the current big players in the market."

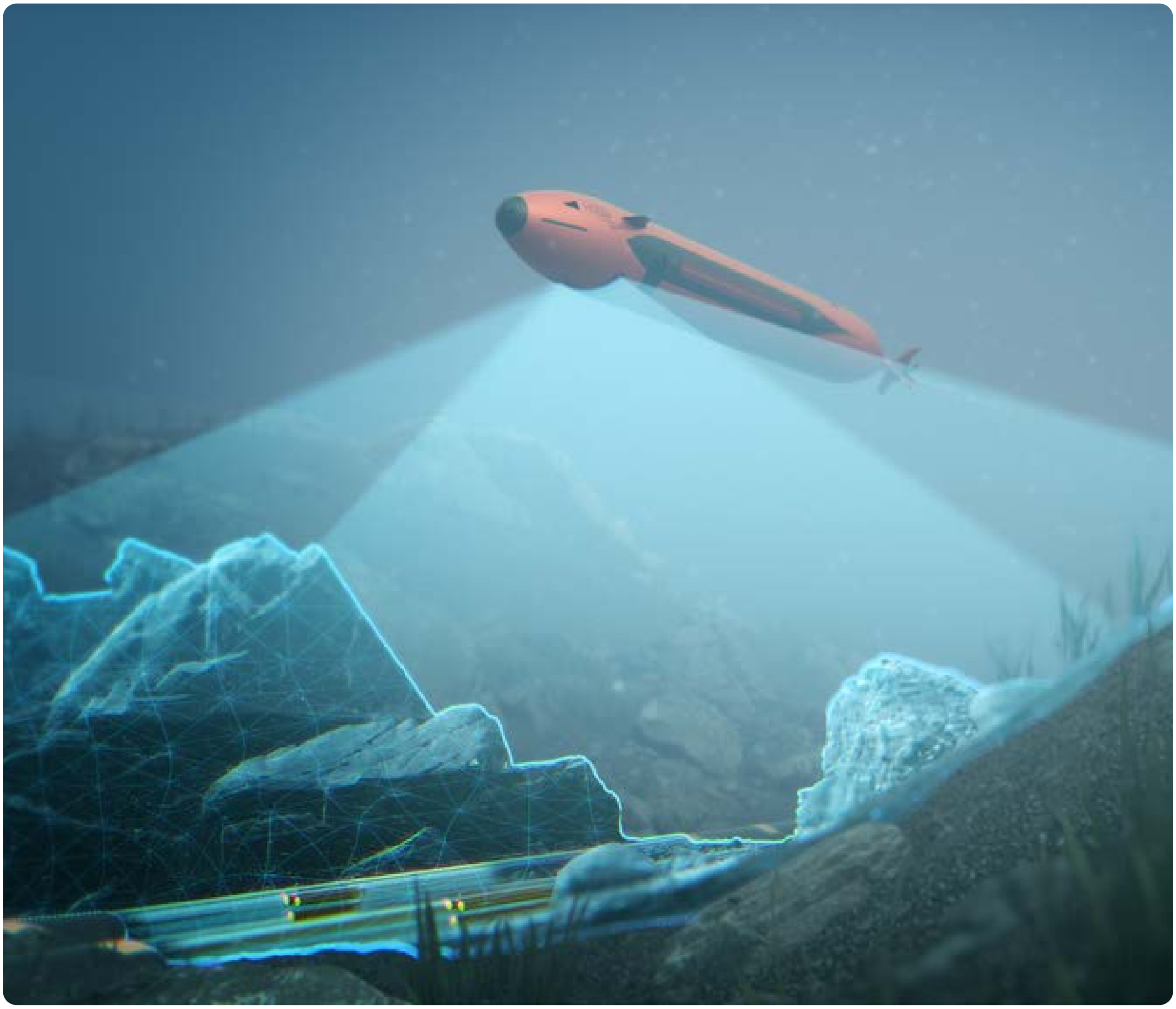
Becoming a CIUS partner towards the end of 2020, ReLab is now one step closer to reaching that goal.

"If everything goes according to plan, ReLab will be developing and producing transducers for Norwegian ultrasound companies that do not have their own solutions or production lines. We aim to be a cheaper and more efficient alternative to the current big players in the market."

By: Anne-Lise Aakervik

MAKING ROBOTS 'LISTEN' TO THE OCEAN

This is a story about how high-end medical transducers inspire Kongsberg Maritime in helping marine researchers gather more climate data from the ocean.



The HUGIN Endurance from Kongsberg Maritime. Photo: Kongsberg Maritime.

PhD candidate Ellen Sagaas Røed works as a transducer designer at Kongsberg Maritime. Many of the transducers Kongsberg makes are mounted on large fishing boats or research vessels, but there is also an increasing market for lightweight transducers for small underwater vehicles and other small platforms.

“With such platforms equipped with the right transducers, we can collect data from underwater locations and over time-spans not previously possible – be it all night, over several days, or via a platform left on the seabed to monitor passing fish. It is important to understand what change means for life in the sea and all life that depends on the ocean,” Røed says.

Knowledge-Based Management

UN Sustainability Goal #14 is called "Life below water" and it aims to "conserve and sustainably use the oceans, seas and marine resources for sustainable development”. In Norway, the 2019-2028 plan for research and education has "ocean" as one of five priorities. Successful resource management is based on knowledge, and underwater information is being collected from an increasing number of small platforms.

As an example, Røed tells the story about *Saildrone*: “This autumn, three unmanned surface vehicles of the type Saildrone were equipped with Kongsberg transducers to zigzag the Bering Sea for more than two months, completing the survey of the codfish Alaska pollock. This fish has moved its habitat north, due to warming seas.”

To gather as much information as possible from each of the small platforms, the industry needs compact, multipurpose transducers. Each transducer should have a wide frequency band, as the signal strengths from the different frequencies provide information on the type of biology, gas, or oceanographic layers, for example.

"My job is to make an as small as possible piezoelectric device, which at the same time sends and receives sound in the largest possible frequency band. Therefore, in collaboration with the Norwegian Research Council and CIUS, we have taken interest in piezoelectric single crystals and textured ceramics," Røed says.

The Challenge

Compared to the conventional piezoelectric ceramics used in most underwater transducers, piezoelectric single crystals have a higher coupling between electrical and mechanical energy.

The single crystals deliver higher sound pressure for a given voltage and resonate at a lower frequency for a given transducer thickness. High sound levels and low frequencies are necessary to make the sound travel long distances underwater.

“On small platforms, we want lightweight transducers. This is something single crystals may help us with. The batteries will last longer, and we get greener products," Røed says.

“CIUS partner GE has launched impressive medical transducers with single crystals, and this inspired us to start a research project on high coupling materials. Doing this inside the CIUS community has really added value to my work.”

Successful Collaboration

“You must make a special design that lets the new material flourish. This is what makes this project so exciting, and therefore I need to take a step away from my usual workflow and the traditional transducer design guidelines and make an in-depth design study," Røed explains.

"It has been so helpful to do this together with the transducer group at the University of South-Eastern Norway in Horten, taking advantage of their academic skills, a different perspective, and large laboratory.”

Kongsberg Maritime has already benefited greatly from work done by others in CIUS in the past, such as transducer modelling programmes, material characterisation, and studies of complex piezoelectric parameters.

“We are now building prototypes in the Kongsberg production department, getting to know the advantages and disadvantages of the crystals, and we are looking forward to seeing how much extra information we can gather from the sea,” Røed concludes.

By: Anne-Lise Aakervik

A PERFECT MATCH

Artificial intelligence (AI) creates new possibilities, and do students! When industry partner Medistim ASA wanted to explore AI to support the interpretation of blood flow data, CIUS had the knowledge and a student to deal with it.

The Medistim MiraQ system is used during both cardiac and peripheral vascular surgical procedures to measure blood flow in vessels and acquiring high-resolution ultrasound images of the blood vessels. Photo: Medistim ASA.

"Student projects are popular with our industry partners. If we are to succeed, we need to find the right topics and the right students to work with them. Everything must match: the topic, students- researchers, and the industry partner. I must say that we succeeded in this project," says Professor Lasse Løvstakken at NTNU and Head of CIUS work package 4 "Image processing, analysis and visualisation".

In this case, Medistim ASA had a relevant research problem and CIUS recruited a master's student to dive into the task for his master's thesis. The lucky one was Benjamin Nedregård, more about him later.

Flow Data

Medistim ASA develops, manufactures, markets, and distributes medical equipment. Ultrasound-based systems for imaging and measuring blood flow during surgery are the main product. The equipment is often used in bypass operations to assess the blood flow in the new blood vessel supplying much-needed blood to the heart muscle.

"We have long seen the need to develop software that can support the surgeon's interpretation of time curves from blood flow measurements based on empirical data, and the use of machine learning is very relevant," says Jonas Crosby, Senior development engineer in Medistim, and Co-supervisor in the project.

"We had limited internal expertise, and the collaboration with CIUS was a perfect opportunity for us to explore the possibilities of this technology."

Domain knowledge meets academic knowledge

"This is part of what makes CIUS a success. The industry partners contribute with domain knowledge and relevant data, and together we form a useful research project. CIUS has experience in using machine learning, and for this project, we could use our prior technology and expertise as a starting point," Løvstakken summarises.

Before the project, Medistim coordinated a large multicentre study that explored the clinical use of ultrasound imaging and blood flow measurements. The study collected systematic measurements from over 1000 patients, which constitutes a significant database.

"It was therefore very interesting to investigate whether we could use this information to support the surgeon's interpretation of blood flow in the operating room using machine learning," says Erik Swensen, VP Research & Development in Medistim.

Machine Learning

The data material was not specifically collected for machine learning, but contained electrocardiogram (ECG) data that could be utilised.

"Usually, we need to connect an ECG machine to get information about the heart phases. We wanted to see if we could use the data material to train a computer to recognize the heart phase from the blood flow curve without an external ECG. This will enable us to increase the user-friendliness of our equipment considerably, Swensen, says."

Opened Doors

Master's student Nedregård was put on the task. The project resulted in the master's thesis "Heart phase recognition and insufficiency detection using machine learning on intra-operative transit time blood flow measurements."

It verified that it was possible to recreate the same division of the heart- and blood flow phase without an ECG, based on machine learning.

The next step will be to evaluate how the algorithms work in real-time on Medistim's devices in the operating theatre. If successful, it could pave the way for further use of AI at Medistim:

"This project has clearly opened several doors for us. We see other possibilities for using this further, for example by being able to help surgeons find defects in blood vessels by using machine learning and flow data," Crosby says.

Industry Experience

"Such tasks make it possible to include the student in highly relevant projects, which is positive for everyone involved," Løvstakken says.

For Swensen at Medisitim ASA, the project showed that the SFI's ability to address specific challenges faced by the industry, can be further refined into finished products with the aid of a researcher's approach to finding solutions.

"This clearly shows how relevant academic knowledge and research can lift our products. And that is why we see that it is important to be part of an SFI," says Swensen.

"In this project, we found a combination with a partner, a problem and student, that succeeded in every possible way – a perfect match," Løvstakken concludes.

By: Anne-Lise Aakervik

ULTRASOUND MAKES CHEMOTHERAPY MORE EFFICIENT

Will ultrasound-delivered bubbles combined with cytotoxic drugs work better on cancerous tumours than cytotoxic drugs given alone?

There is a lot of exciting interdisciplinary research combining medicine and technology. For Chief physician and PhD candidate Margrete Haram at St. Olavs hospital/NTNU, the collaboration with engineer/researcher David Bouget from CIUS and SINTEF is important. His research helps her to complete her PhD, which involves testing targeted delivery of cytotoxic drugs.

"We are investigating whether there may be increased treatment response in tumours that receive focused ultrasound and gas bubbles in addition to regular chemotherapy," Haram says.

Inefficient Chemotherapy

Solid tumours absorb as little as 0.01% of the chemotherapeutic drugs when administered intravenously. To increase the likelihood that the patient will achieve the desired effect, the doses are high, with high side effects.

For many years, the research community has worked to enable the cytotoxic drug to be absorbed in a better and more efficient way, and preferably mostly by the tumour and not the rest of the body.

"We must get the map to match the terrain every time so that we know which tumour we are going to give extra medicine to."

One of the concepts that have been explored is the use of cytotoxic drugs in combination with bubbles that, with the application of ultrasound, burst when they reach the tumour. This method is one of many being tested to improve personalised treatment.

Testing on Patients with Metastases

Haram and Bouget are now testing this concept with a proof-of-principle study on patients with liver metastases.

"We have selected patients who have several metastases in the liver and who receive life-prolonging, also called palliative, treatment. In addition to regular chemotherapy, they also receive experimental treatment, which aims to increase the uptake of cytotoxic drugs into the tumour. Each participant receives four experimental treatments within eight weeks," Haram says.

Selected Tumours

A CT examination of each patient's liver has previously been carried out, allowing Haram to select two tumours. One is randomly chosen to receive treatment with focused ultrasound, whilst both will receive systemic treatment with microbubbles and cytotoxic drugs. In this way, the patient acts as their own control.

The research team hope they can increase the chemotherapy uptake in the tumour that receives additional treatment with ultrasound.

"But then we must be sure that we treat the same tumour during all four treatments and that it is the only one that is

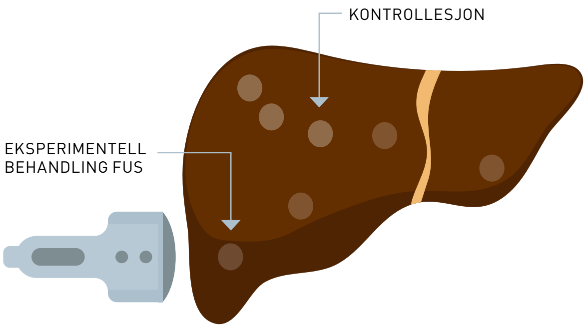
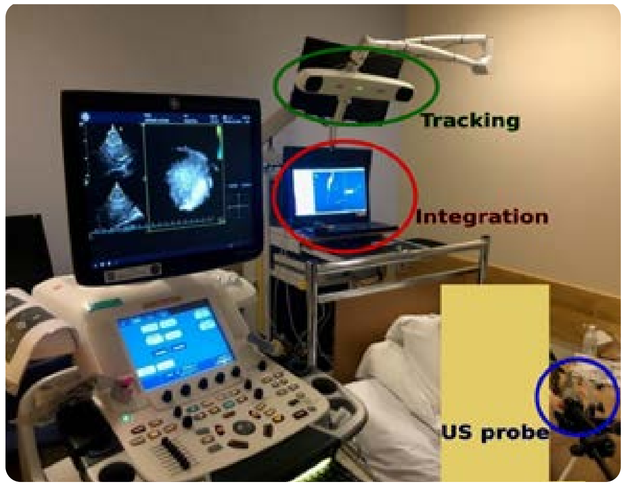


Illustration of the setup used during patient treatment. The different elements displayed are: GE E9 scanner, 4V Ultrasound probe, NDI tracking system, and external laptop. Illustration: Margrete Haram and David Bouget/NTNU



Representation of the treatment strategy where the ultrasound probe is placed over the target lesion. In general, the control lesion is selected far away to ensure no concurrent and unwanted beaming. Illustration: Margrete Haram/NTNU

exposed to focused ultrasound. David's expertise is important here," Haram points out.

What he does is, in short, is to 'merge' the ultrasound image we have on screen, which is a real-time image, with the CT image that was taken in advance when the tumour was selected.

"Here we must get the map to match the terrain every time so that we know which tumour we are going to give extra medicine to," Bouget says.

Cracking Bubbles with Ultrasound

The experimental treatment is given just after the patients have received chemotherapy in the usual way at a cancer outpatient clinic. They are then moved into a separate room where Haram, Bouget, and a research nurse are present.

The bubbles that are supposed to help increase the uptake of the chemotherapy are inserted by the research nurse into a venous cannula in the arm. The ultrasound probe is always held over the tumour. It is then important that the patient stays completely still.

When the bubbles reach the tumour, the ultrasound will cause them to start vibrating, and eventually, they crack.

"We hope to be able to utilise the forces created in this process to improve the uptake of cytotoxic drugs inside the tumour," Haram says.

"We must outsmart the forces that work against us," Bouget says.

"A tumour has poor circulation and increased pressure, which counteracts the uptake of medicine. With the help of ultrasound and microbubbles, we hope that the medicine penetrates more easily into the tumours and thus increases the treatment effect," Haram adds.

CIUS as a Junction Box

"It is so exciting to work with technologists," Haram says.

"My project would not have been possible without David and his colleagues at CIUS. This is an interdisciplinary project in the true sense of the word. In this case, SFI CIUS has acted as a junction box between technologist and doctor. It is perceived as important to exchange both experiences and ideas across disciplines. In this there are probably great opportunities waiting also for other research groups," Haram concludes.

By: Anne-Lise Aakervik

THE ULTRASOUND TOOLBOX

Open source processing of
ultrasound images with the UltraSound ToolBox.

The UltraSound ToolBox (USTB, www.USTB.no), is a collaboration between several international institutions lead by former and current CIUS researchers Alfonso Rodriguez-Molares, (University of Vigo, Spain), Ole Marius Hoel Rindal (UiO and SINTEF) and Stefano Fiorentini (NTNU).

It is an open source toolbox for processing of ultrasonic signals, where researchers can share and compare processing methods for ultrasound imaging.

The idea is to make it easier to compare increasingly complex methods introduced in the medical ultrasound research literature.

With researchers collaborating and sharing the implementation of their methods, one can scrutinise and build on each other's methods and research findings - thus bringing the research field forward.

The USTB has so far been used in 41 scientific publications by researchers from institutions such as the Johns Hopkins University (USA), University of Granada (Spain), Iran University of Science and Technology, Federal University of Technology – Parana (Brazil) and the Indian Institute of Technology.

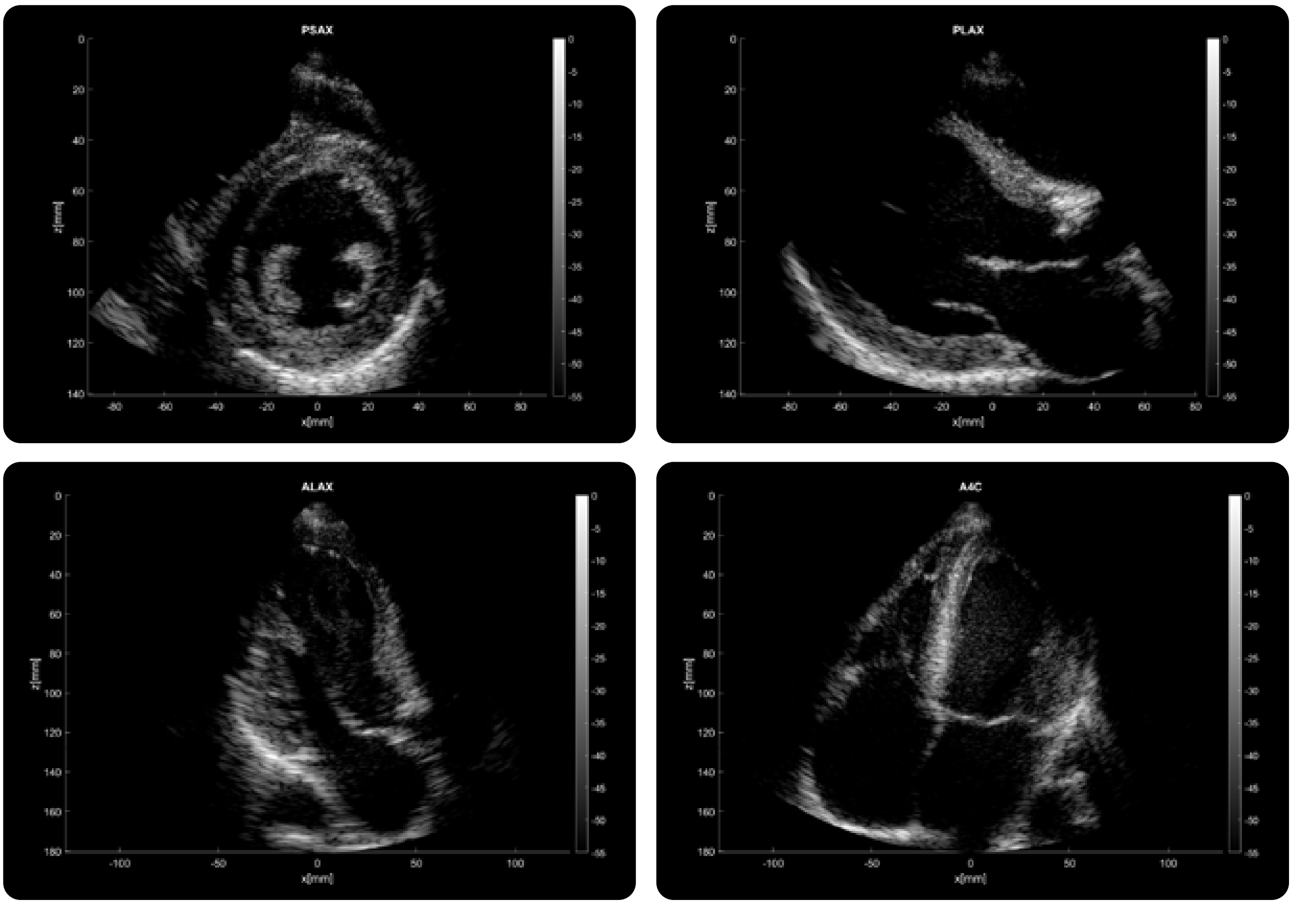
The methods currently included in the USTB are: Beamforming including several adaptive beamforming methods, elastography imaging, and some Doppler and image post processing techniques.

The development of the USTB is an ongoing project with improvements and bug fixes added continuously. Recent developments include the addition of and integration with other research software developed in CIUS.

This includes the FlowLine Ultrasound Simulation Tool (FLUST) developed by CIUS researchers Jørgen Avdal, Ingvild Kinn Ekroll and Hans Torp at NTNU. And the development of a data pipeline between the USTB and Framework for heterogenous medical image computing and visualisation (FAST - www.eriksmistad.no/fast/) developed by CIUS researchers Erik Smistad and Andreas Østvik at NTNU.

"It is an open source toolbox for processing of ultrasonic signals, where researchers can share and compare processing methods for ultrasound imaging."

UltraSound ToolBox
MATLAB toolbox for processing ultrasonic signals



The figures display images of four cardiac views from a patient heart recorded by CIUS cardiology researchers Erik Andreas Berg and Torvald Espeland. The parasternal short axis (PSAX), the parasternal long axis (PLAX), the apical long axis (ALAX) and the apical four chamber (A4C) view. The raw ultrasound channel data was recorded on a GE Vingmed E95 scanner by CIUS cardiologist researchers, however the images displayed here are processed using the USTB.

By: Ole Marius Hoel Rindal

Translation from Academic Research into Practical Applications

– fuelled by the CIUS Licencing Strategy

The success of the academic research in CIUS is due to research topics, challenges and work packages being defined by the CIUS Corporate partners in collaboration with the academics. The outcome of the CIUS research will not only comprise first-class scientific journal papers, which is important in academia; but it will also encompass results, findings and inventions that are applicable to CIUS' Corporate partners within medical technology, the maritime and oil & gas industries, and to CIUS Healthcare partners in order to resolve their defined challenges.

Results and findings will be applicable to CIUS partners to resolve their defined challenges. (Illustration: Bankrx/Shutterstock.com)

The translation from research to practical applications will be manifested in CIUS by licences. A licence allows a CIUS Corporate partner to use the resulting technologies and inventions in commercial products or services. The CIUS licence agreement is also an instrument for designated, formal technology transfer between a Research partner and a Corporate partner.

Enabling Resulting IPR
Resulting IPR that represents a breaktrough invention or innovation that is essential, or a significant contribution, to the practical implementation of new products, methods or technology with a substantial commercial potential.

Incremental Resulting IPR
Resulting IPR that represents minor invention/innovation that is directly building on or improving existing products, methods or technology.

Background IPR
IPR brought into CIUS owned or controlled by one of the CIUS Participants prior to the start of CIUS, or developed or retained outside the scope of CIUS and later brought into CIUS.

Each Corporate partner is immediately notified about every resulting innovation or invention in CIUS. The partner has an option, within a limited timeframe, to license the resulting intellectual property right (IPR) for commercial utilisation, either with exclusive licence rights within the partner's "Field of Use", or non-exclusive licence rights outside. The licence may comprise several elements, like pending patent rights, technology transfer and know-how transfer.

In the case of none of the Corporate partners being interested in licencing, the invention can be utilised in certain other ways outside the CIUS consortium, after a formal CIUS Board resolution. As an example, recently a CIUS invention which no CIUS partners wanted to license, was decided to be licensed as open source, according to the wishes of the inventors, for the benefit of the wider research and development community around the world.

CIUS results (so far)	'17	'18	'19	'20
DOFIs	4	7	7	6
Patent pending	0	1	1	0
Licencing considered or discussed	3	5	3	3
Licence agreements	0	0	0	0
Open Source licences	0	0	0	1

CIUS results (so far). (Row 2) Number of Disclosure of Innovation/inventions (DOFI); (Row 3) Number of patent pending or patent applications; (Row 4) Number of licence considerations or discussions; (Row 5) Number of closed licence agreements; (Row 6) Number of Open Source Licences.

The number of licences established in the timeframe of an SFI consortium like CIUS, however, is still not the single measure of successful collaboration between university partners and industry partners, since there are inherent obstacles for closing such license agreements:

The timeline for introducing new technologies into the market may be long, even longer than the SFI period itself, which is normally eight years. Research-based technologies and radical innovations have by nature low technology readiness level (TRL level) and need thorough validation in a more relevant environment.

Furthermore, there are several challenges and risks involved by introducing new technologies, regarding e.g. intellectual property protection and infringement, manufacturability, product road mapping, changing markets and internal or external competing technologies.

A Corporate partner will probably not want to spend time on negotiating licence agreements for technologies that are not yet put into the partner's product planning roadmap. On the other hand, introducing new technologies involves large investments, so at the time when a product planning roadmap decision is about to be made by the partner, the licences must also be in place.

Therefore, in the timeframe of an SFI, one is more likely to finalise licence agreements for incremental innovations than for brand new and enabling technologies, even if the latter eventually may have a substantial value for the market and society. Incremental innovations pose a lower risk and can more easily and rapidly be adapted by the partner into their existing product planning.

The CIUS consortium agreement differentiates between incremental and enabling IPR results. It advises a simple licencing scheme with low payment for incremental innovations. For the enabling technologies a high level of resources, cost and time have to be spent, and therefore the licence agreement structure is more complex, and payment will be based on commercial terms.

A successful SFI, like CIUS aims to be, should finally exhibit several licence agreements between university partners and industry partners. Thus the industry partners have formally got exclusive and non-exclusive rights to use the new technologies; the university partners have manifested that their SFI research is relevant to industry and society, and the governmental bodies can monitor that their research and innovation programmes actually foster advanced research and innovation with relevance, technology transfer and exchange of know-how.

By: Svein-Erik Måsøy, Industry liaison,
Eivind Andersen, Head of projects, NTNU TTO,
Tormod Njølstad, Innovation manager

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
Hohai University, China
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
The Indigenous Cardiac Outreach Program, Queensland, Australia
University of Queensland, Australia

PhD Candidates

Kenneth K. Andersen (WP1)
Unconventional ultrasound transducer design
New ultrasound imaging and therapeutic modalities may require or benefit from ultrasound transducers that can operate at significantly different frequencies. To handle the complexity of these dual-frequency transducers, we have developed a numerical optimisation method based on linearising the phase spectrum. Using this method, a dual-frequency transducer has been designed and optimised for EXACT Therapeutics. The transducer has been prototyped and tested, and is used in pre-clinical trials.

Erik Andreas Berg (WP5)
Multimodality and interventional imaging
We refine and validate a computerised algorithm for 3D transthoracic and tran-sesophageal echocardiographic measures for reconstruction of aortic root morphology. We also work on a semi-automatic com-puterised 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.

Antoine Blachet (WP2)
SONAR seabed mapping
Together with Kongsberg Maritime, I am exploring new SONAR designs that could lead to improved performance in particular applications. One possibility is to transmit advanced coded waveforms, inspired by modern techniques used in radar and wireless communication. We are trying to mitigate interferences between signals transmitted at the same time. This will make it possible to map multiple parts of the seabed at the same time. It may also increase the sounding density, and make the survey more efficient.

Per Kristian Bolstad (WP1)
Transducer design
Central topics of the PhD-project will be 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.

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.

Cristiana Golfetto (WP3)
Doppler and deformation imaging
Doppler measurements in coronary arteries are difficult due to the rapid motion of the myocardium and the small vessel dimensions. High frame rate 3D Doppler imaging with retrospective spectral Doppler processing could potentially solve this. However, the combination of low blood flow velocities and excessive tissue motion in parts of the cardiac cycle makes clutter suppression challenging. I am working on finding an adaptive clutter filter able to reduce power Doppler artefacts such as flashing and dropouts. The project focuses on flow velocity measurements in nonstationary and noisy surroundings.

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 will 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 will use tissue Doppler, strain rate and 3D high frame rate imaging.

Aslak Lykre Holen (WP1)
Transmitters and receivers for ultrasound systems
This project is to develope transmitter and receive 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 utilise 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 non-ideal effects in this system, defined as any effect that can not 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.

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, in order to improve the delivery of NPs to tumor tissue. Of special interest is clarifying the cause and mechanism of the enhanced tissue extravasation and flow through the Extracellular Matrix (ECM), esspecially 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.

Malgorzata Magelssen (WP6)
Diagnostic accuracy of handheld ultrasound
Significant efforts are being made to improve the diagnostic accuracy of handheld ultrasound device (HUD). This can enhance the art of clinical examination by revealing disease at an earlier stage, and help to better identify patients in need for 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 and specialised nurses after a period of focused training. We want to evaluate the usefulness of using HUD 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 quantifi-cation 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. Halfwave AS 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 in order 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 the 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 (Analog to Digital Converter) will be studied/compared, the aim of the project being to find new ideas of improving current state-of-the-art of the circuits.

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.

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.

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. In particular, we will explore the use of 3D Doppler ultrasound and Machine Learning to measure regurgitant orifice areas and flow volumes.

Andreas Østvik (WP4)
Image processing, analysis and visualisation
The goal of my PhD project is to utilise and further develop machine learning methods to improve state-of-the-art solutions in the field of ultrasound image analysis and visualisation. More specifically, research will be conducted on tasks such as classification of standard plane views in echocardiography, cardiac landmark detection and heart chamber segmentation in ultrasound images.



A selection of digital public PhD-defences: Cristiania Golfetto, Kenneth K. Andersen and Jahn Frederik Grue. Photos: Karl Jørgen Marthinsen/NTNU and private.

Postdocs

David Bouget (WP5)
Multimodality and interventional imaging
In order to measure blood pressure and flow through a specific coronary artery, catheter insertion in the body is the current diagnostic approach. To perform the same measurement in a non-invasive manner, a solution is to use a US probe to image the flow inside the coronaries. One critical drawback is then the difficulty for the surgeon to properly target a specific coronary using only the US data. We are developing a system able to perform automatic registration between a pre-recorded CT with segmented coronaries and intra-diagnosis US data. In addition, the system is planned to be able to track the US probe motion in time in order to provide an accurate guidance map to the surgeon to reach regions of interest more easily.

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 analyses 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.

Yucel Karabiyik (WP2)
Ultrasound elastography
I am working with cardiac ultrasound elastography and -primarily with methods that utilise external actuators to generate shear waves. Tissue displacements generated by the actuators are estimated in the axial direction or in 2D. These estimates are then used mainly in magnetic resonance elastography methods, such as direct inversion and phase gradient methods. The ultimate goal is to create 3-D stiffness maps of the myocardium and correlate these maps with myocardial dysfunction and relaxation abnormalities of the heart.

Hoai An Pham (WP5)
Interventional ultrasound
The aim of the Postdoc project is to solve some of the challenges in the development of the interventional cardiology ultrasound such as detecting probe movement from 3D TEE data, dynamic movement compensation, and dynamic tracking of anatomic landmarks by using ultrasound to-ultrasound global rigid motion registration. The developed tools will be implemented in a software plugin provided by GE and then in real-time on a GE scanner for the local clinical team to evaluate the developed tools.

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.

Morten Wigen (WP3)
2D and 3D echocardiography
My Postdoc project topics are related to measurements of both tissue and flow properties in the heart, using 2D and 3D echocardiography. The enabling technology for both projects is high frame rate imaging, which is sensitive to rapid changes needed to capture mechanical waves traveling in the heart walls and the blood speckle movement in the ventricles. The methods used for the projects have undergone technical validation, and are currently in a phase of clinical validation. For this I'm working together with clinicians who are using software where the methods are implemented. I am also working on technological novelties related to the processing of ultrasound signals to further improve our measurements, and to the new parameters that can be extracted from them.

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 aproduct. Primarily, the product will be a GE Vingmed ultrasound scanner intended for cardio vascular 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.

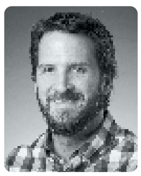
Jan D'hooge
Professor
Professor Jan D'hooge of the University of Leuven in Belgium visited NTNU as a guest researcher of CIUS in 2017. Although D'hooge has long-standing relations with some of the CUIS investigators, the main purpose of his stay was to optimise the collaboration between his lab in Leuven and CIUS' in Trondheim, in order to maximally exploit potential synergies and avoid redundancy where possible.

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 echocardio-graphy, valvular disease, coronary artery disease and echocardiography in valve interventions.

Bjørn Olav Haugen
Professor
Haugen is a professor at NTNU and consultant cardiologist at Trondheim Hjertesenter. He has been involved in ultrasound technology research since 1998, and is the leader of WP 6 and 7 in CIUS.

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.



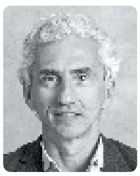
Alan Hunter
Associate professor
Dr. Alan Hunter is a researcher and engineering lecturer at the University of Bath, UK. His research interests are in underwater remote-sensing using acoustics and autonomous systems, and he is a specialist in high-resolution synthetic aperture SONAR imaging. Dr. Hunter has been an Adjunct a ssociate professor at the Department of Informatics at the University of Oslo (UiO) since 2017.

Tonni Franke Johansen
Researcher

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

Gabriel Hanssen Kiss
Researcher

Hanssen Kiss works on fast registration and fusion tools for cardiac applications in order to identify and characterise the dynamics and function of cardiac structures based on multi-modal image data. In addition, he is also involved with augmented reality visualisation techniques to be used in the echocardiographic lab under image acquisition.



Luc Mertens
Professor

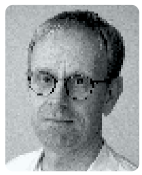
Luc Mertens is Section head, Echocardiography at the Labatt Family Heart Centre, Hospital for Sick Children in Toronto, Canada. Dr. Mertens' research interests focus on using new echocardiographic techniques to study the heart function in children. He was recently appointed as a Guest scientist at CIUS, collaborating on applications of high frame-rate ultrasound in children with heart disease.

Alfonso Rodriguez Molares
Associate professor

Molares' fields of research are acoustics and ultrasonics. He is currently developing new beamforming techniques to improve the ultrasound imaging of acoustically hard surfaces, aiming to improve the visualisation of bone tissue in ultrasound images to support intraoperative monitoring of spinal surgery.

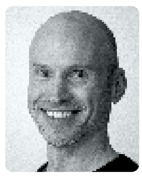
Ole Christian Mjølstad
Researcher and Head of Cardiology

Mjølstad has worked with the development of pocketsized 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 pocketsized ultrasound in daily clinical care. An important part is the development and clinical evaluation of applications that increase the usability among non-experts.



Anders Thorstensen
Researcher

Thorstensen and his colleagues aim to evaluate the diagnostic accuracy of post systolic foreshortening for direct echocardiographic quantification of myocardial infarct size, using LE-MRI as the reference method. The areas of post systolic of foreshortening are likely to benefit from early revascularisation in patients with acute myocardial infarction.



Svein Arne Aase
Lead engineer

Svein Arne Aase and a small group of GE Vingmed employees are co-located with NTNU's ultrasound researchers. Aase is Vingmed's CIUS contact for research projects within Doppler and Deep Learning. Within Vingmed, he is leading a team integrating Deep Learning models into the ultrasound scanners. Their goal is to improve accuracy, reproducibility and efficiency by supporting human intelligence with automatic tools.

Researchers with External Financing in CIUS-projects

Postdoctoral Researchers

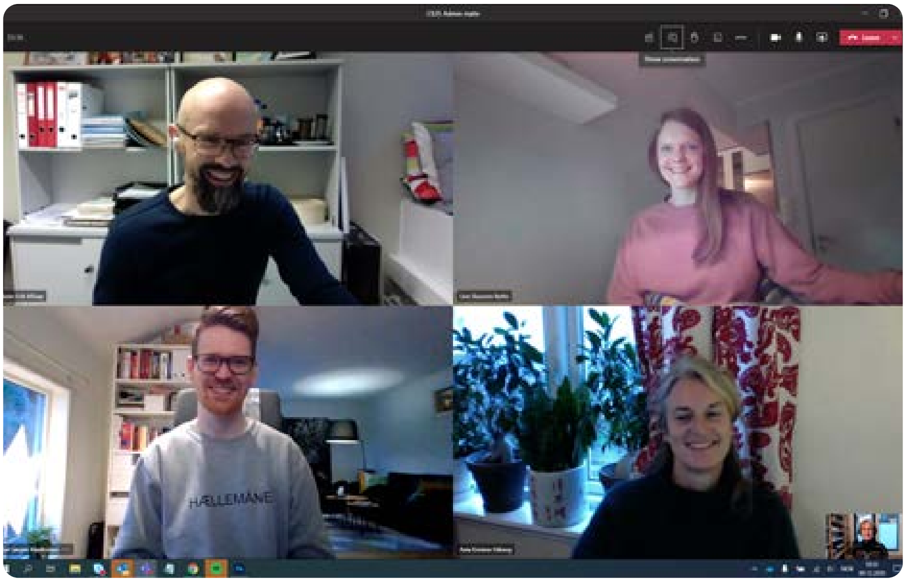
Jørgen Avdal, NTNU
Anna Karlberg, NTNU
Lucas Omar Muller, NTNU
Hong Pan, UiO
Sofie Snipstad, NTNU

PhD Candidates

Anders Tjellaug Braathen, NTNU
Annichen Søyland Daae, NTNU
Caroline Einen, NTNU
Torvald Espeland, NTNU, St. Olavs hospital
Henrik Fon, NTNU
Harald Garvik, NTNU
Thomas Grønli, NTNU
Anna Hjort Hanssen, NTNU
Margrete Haram, NTNU, St. Olavs hospital
Jieyu Hu, NTNU
Trine Husby, NTNU
Stine Hverven, UiO
Melina Mühlenpfordt, NTNU
Sindre Hellum Olaisen, NTNU
Marieke Olsman, NTNU
Håkon Pettersen, NTNU
Sebastian Price, NTNU
Elisabeth Grønn Ramsdal, UiO
Ole Marius Rindal, UiO
Ellen Sagaas Røed, USN
Ivar Salte, SSHF
Lars Saxhaug, NTNU
Sigbjørn Sæbø, NTNU
Silje Kjærnes Øen, NTNU

CIUS Faculty

Svend Aakhus, Professor, NTNU
Knut E. Aasmundtveit, Professor, USN
Andreas Austeng, Professor, UiO
Jørgen Avdal, Research Scientist, SINTEF
Sigrid Berg, Research Scientist, SINTEF
David Bouget, Research Scientist, SINTEF
Lars Eirik Bø, Research Scientist, SINTEF
Sigrid Kaarstad Dahl, Research Scientist, SINTEF
Håvard Dalen, Associate Professor, NTNU
Live Eikenes, Associate Professor, NTNU
Ingvild Kinn Ekroll, Researcher, NTNU
Solveig Fadnes, Researcher, NTNU
Roy Edgar Hansen, Professor II, FFI/UiO
Rune Hansen, Senior Research Scientist, SINTEF
Espen Holte, Assistant Professor, St.Olav/NTNU
Thomas Langø, Chief Scientist, SINTEF
Tung Mahn, Associate Professor, USN
Sébastien Muller, Research Scientist, SINTEF
Siri Ann Nyrnes, Reasearcher, NTNU
Erik Smistad, Research Scientist, SINTEF
Ole Vegard Solberg,Senior Research Scientist, SINTEF
Cecilie Våpenstad, Research Scientist, SINTEF
Annemieke van Wamel, Researcher, NTNU
Rune Wiseth, Professor, St. Olav/NTNU
Andreas Østvik, Research Scientist, SINTEF
Andreas Åslund, Researcher, SINTEF



Glimpses of how Covid-19 affected day-to-day business in 2020. Photos: NTNU

Dissemination, Media Coverage and Outreach

CIUS acknowledges the importance of communication our research to the public, and in 2020, CIUS projects have been featured in local and national press.

Though a very different year has come and gone, we have successfully managed to disseminate CIUS research both within and beyond the realms of academia.

We have continued to blog on the Norwegian version of ScienceNorway (Forskning.no) and all posts in 2020 were read 200-300 times. The most popular was "(Ikke) science fiction på legekontoret" on the automation of diagnosis via the handheld ultrasound device VScan. This was also our most popular social media post, reaching 6365 readers on Facebook.

New in 2020, was the decision to begin sharing scientific journal articles on Twitter and LinkedIn. These posts have not yet reached the top in terms of statistics, but nevertheless are a welcome addition to our communication activities.

The financial impact of the pandemic around the world may have had an effect on our Twitter and LinkedIn statistics. The top post on LinkedIn, and the second most read tweet, was that concerning the 8 paid PhD-positions we advertised before the summer.

This recruitment round incidentally resulted in this newspaper article highlighting the lack of Norwegian applicants: "Andreas er norsk og i mindretall på dette prestisjestudiet i Trondheim".

Our hope for 2021 is to once again be able to disseminate and communicate with our audiences in person – be it physical CIUS seminars, the Norwegian Science Week, or other opportunities that may arise!

CIUS PEOPLE TO FOLLOW

BLOGS

erlend-viggen.no
www.eriksmistad.no

TWITTER

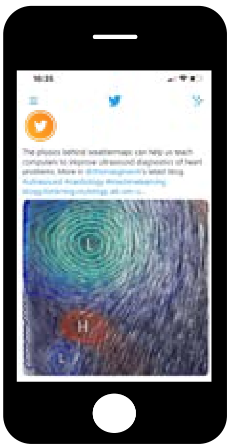
@olemjolstad (Ole Christian Mjølstad)
@ErlendViggen (Erlend Viggen)
@alfonso_molares (Alfonso Molares)
@larshoff1 (Lars Hoff)
@annichendaae (Annichen Søyland Daae)
@strain_rate (Asbjørn Støylen)
@ErikSmistad (Erik Smistad)
@DrAlanHunter (Alan Hunter)
@andtal1 (Andreas S. Talberg)
@bgrenne (Bjørnar Grenne)
@load_dependent (Lars Mølgaard Saxhaug)
@bjornolavhaugen (Bjørn Olav Haugen)
@Sverre_Holm (Sverre Holm)

CIUS IN SOCIAL MEDIA 2020

@ CIUS_NTNU
182 followers
32 tweets

@ CIUS
212 followers
31 updates

TOP CIUS POSTS 2020



777 IMPRESSIONS

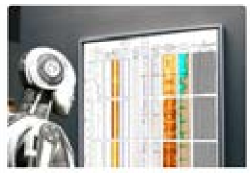
12 LIKES
24 CLICKS
564 IMPRESSIONS

50 LIKES
6365 REACH
1300 ENGAGEMENTS
@teknat.ntnu
11 749 FOLLOWERS

48 LIKES
3010 REACH
277 ENGAGEMENTS
@NTNUhelse
7876 FOLLOWERS


Andreas er norsk og i mindretall på prestisjestudie


Skal forbedre et produkt som dekker halve verdensmarkedet:
– Dette er helt unikt

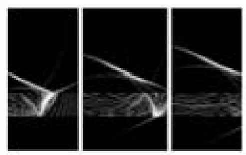

La datamaskina sjekke oljebrønnen!
Blogg: Alt om Ultralyd - en blogg om forskning hos SFI CIUS | 15 Oct 2020 - 15:05:00
Det kan være krevende å tolke ultralydmålingene som brukes til å sjekke om oljebrønner er tette. Vi har funnet ut hvordan datamaskiner kan hjelpe til med tolkningsjobben.


Ny norsk behandlingsmetode mot kreft prøves på mennesker for første gang


(Ikke) science fiction på legekontoret
Blogg: Alt om Ultralyd - en blogg om forskning hos SFI CIUS | 06 Aug 2020 - 13:46:07
De som vokste opp med Star Trek så legen der bruke noe som lignet en mobiltelefon, som etter et sveip kunne fortelle hva som var galt med pasienten. Dette er ikke ren science fiction lenger - i hvert fall ikke for hjertediagnoser!


Trøndersk teknologi henter 60 millioner – og kan forebygge hjerneskade hos tidligfødte barn
Cimon Medical har utviklet ny ultralydteknologi som kan redde premature og kritisk syke barn. Nå henter gründerbedriften fra Trondheim 60 millioner for å kommersialisere produktet.


De tjener penger på rust
Alle har erfaring med at rust betyr trøbbel. En teknologibedrift i Trondheim har greid å tjene penger på dette irriterende fenomenet.


Ultralyd – i jakten på oljebrønner som lekker
Blogg: Alt om Ultralyd - en blogg om forskning hos SFI CIUS | 24 Jun 2020 - 09:00:00
Hva har strømningen i blodårer og en lekkende oljebrønn til felles? I begge tilfeller kan vi oppdage og måle væskestrømmen med ultralyd!


Den livreddende hortensbedriften til Dagfinn foreviges på frimerke


Snart kan ultralyd bli like vanlig som stetoskopet hos fastlegen

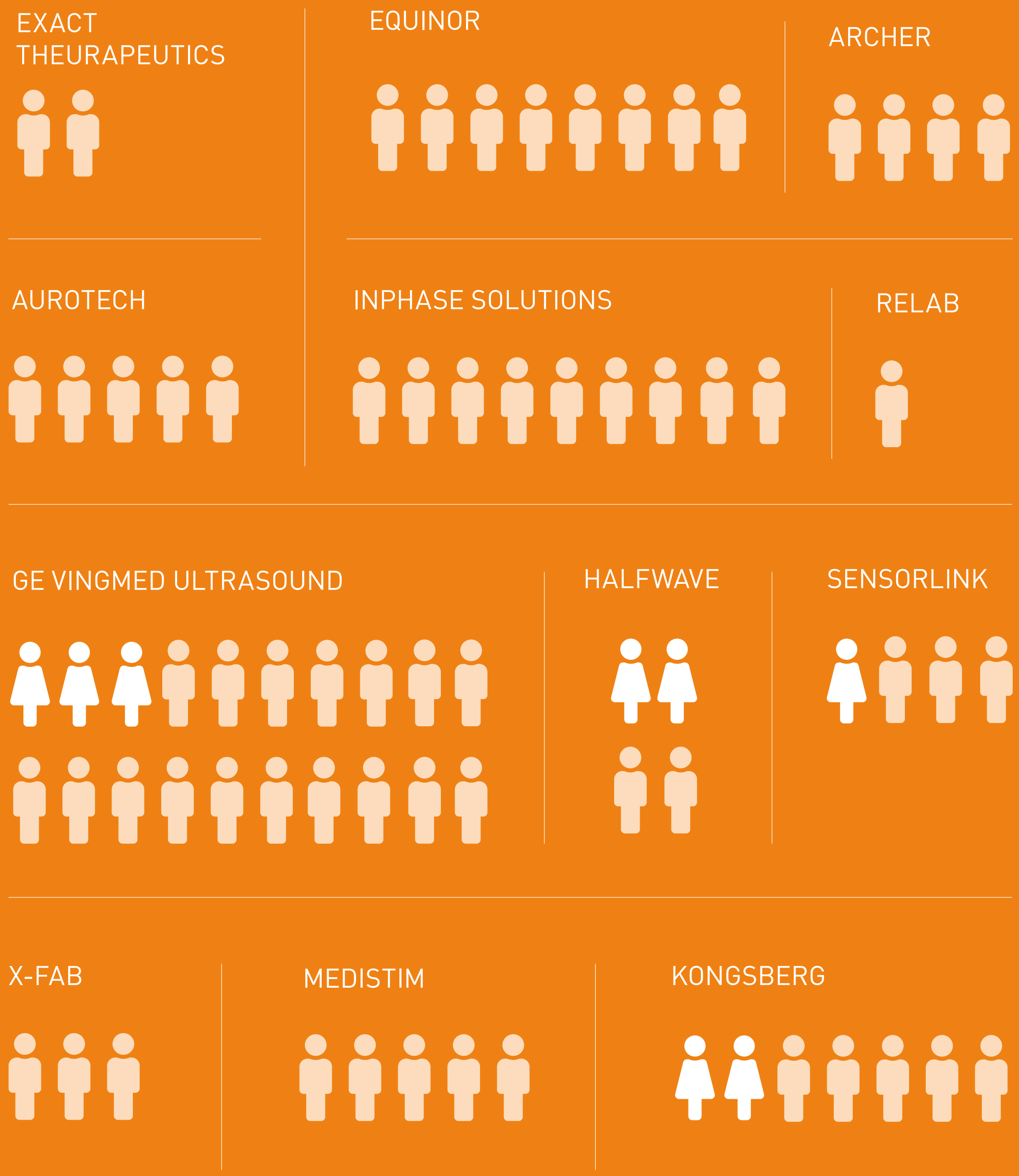
TITLE	MEDIUM
Snart kan ultralyd bli like vanlig som stetoskopet hos fastlegen	NRK
Ultralyd-forbedringer gir også utfordringer	Titan.uio.no
Ny norsk behandlingsmetode mot kreft prøves på mennesker for første gang	NRK
Bruk av ultralydapparat i lommeformat ved karkirurgi	Tidsskriftet
Tema Lokal Hjerteundersøkelse	NRK Radio
Treff nerven med ultralyd og kunstig intelligens	Forskning.no
Andreas er norsk og i mindretall på dette prestisjestudiet i Trondheim	Adressa+
Trøndersk teknologi henter 60 millioner - og kan forebygge hjerneskade hos tidligfødte barn	Adressa
Fra meteorologi til hjertediagnostikk	Forskning.no
Ultralyd og mikrobobler for mer effektiv kreftbehandling	blogg.forskning.no
Robotene lytter til hva havet forteller om klimaendringene. Vi gir dem bedre hørsel	Forskning.no
Ultralyd – i jakten på oljebrønner som lekker	Forskning.no
Ultralyd og mikrobobler for mer effektiv kreftbehandling	Gemini Blogg
(Ikke) science fiction på legekontoret	Forskning.no
Den livreddende hortensbedriften til Dagfinn foreviges på frimerke	Gjengangeren Pluss
Ny teknologi fra Horten kan redde barn over hele verden	Gjengangeren Pluss
Kaffe med en forsker - Forskningsdagene	Forskningsdagene 2020
Dette skal Dagfinn og den verdensledende hortensbedriften bruke 7 millioner kroner på	Gjengangeren Pluss
La datamaskina sjekke oljebrønnen!	Forskning.no
Dette er helt unikt	Tønsbergs Blad
Skal forbedre et produkt som dekker halve verdensmarkedet: – Dette har ingen i verden gjort før oss, det er helt unikt	Vestviken24
De tjener penger på rust	Adressa
Trøndersk teknologi henter 60 millioner - og kan forebygge hjerneskade hos tidligfødte barn	Adressa+
60 millioner til ultralydteknologi	NRK
Trøndersk teknologi henter 60 millioner - og kan forebygge hjerneskade hos tidligfødte barn	Adressa

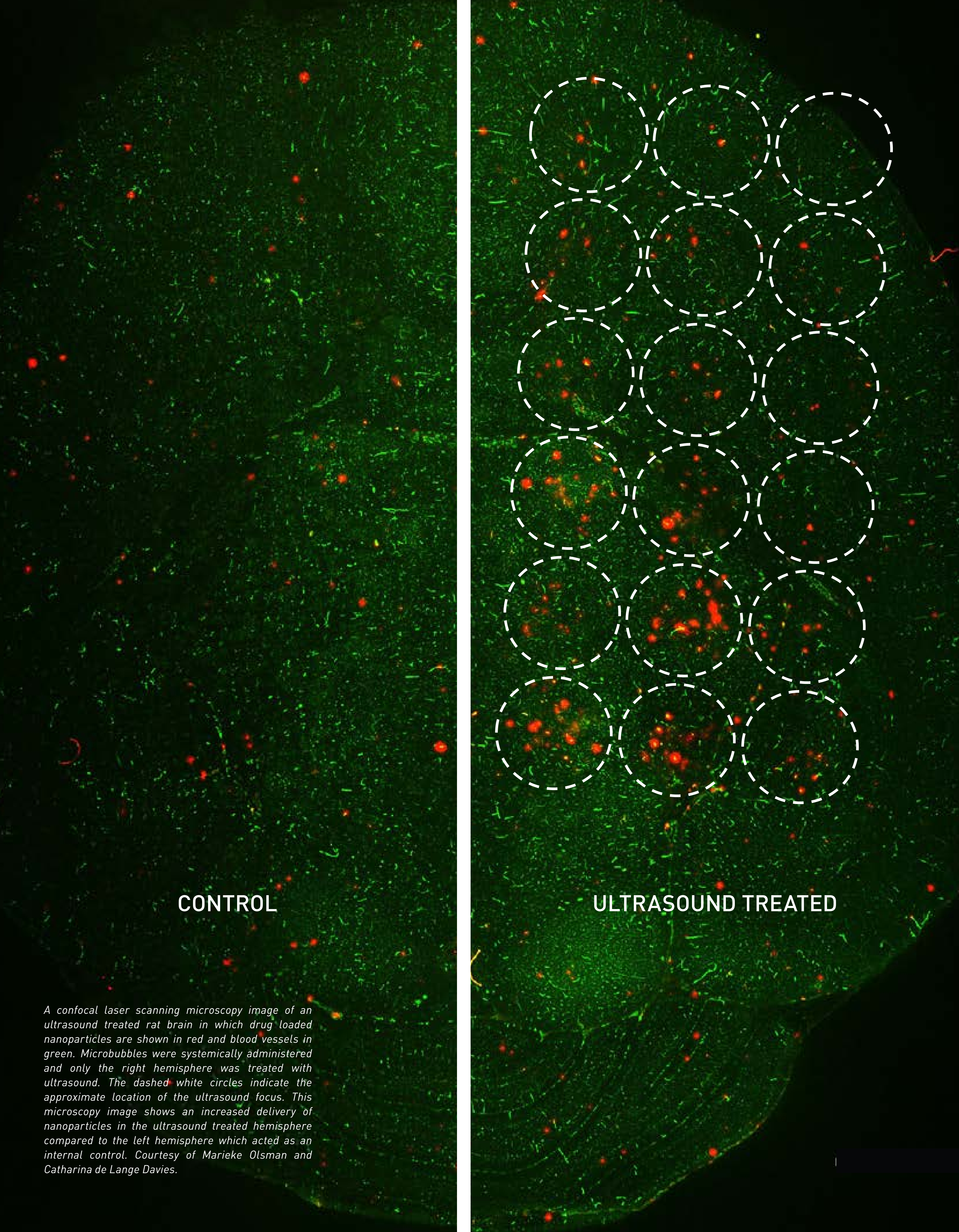
Innovation Prize

Postdoc Jørgen Avdal and Professor Hans Torp working in WP3 at NTNU were awarded the CIUS Declaration of Innovation (DOFI) Prize for 2020 of NOK 25 000. The prize was for the DOFI "Automated quantification of valvular jet flow using 3D high frame rate ultrasound".

Hans Torp and Jørgen Avdal. Photo: Karl Jørgen Marthinsen.

Industry Partner R&D Staff

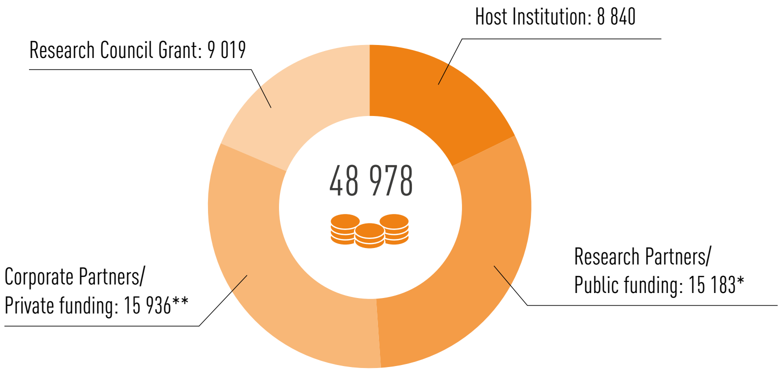




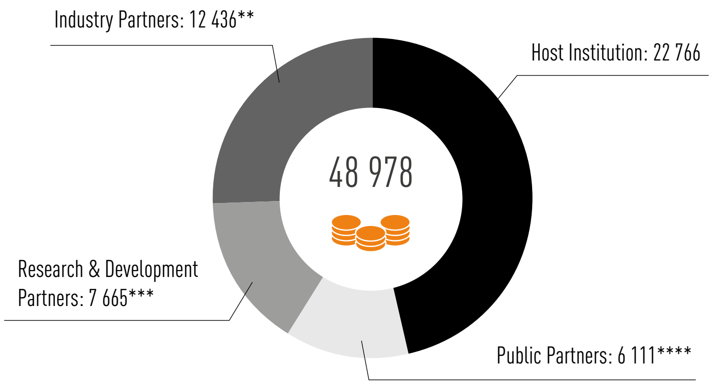
A confocal laser scanning microscopy image of an ultrasound treated rat brain in which drug loaded nanoparticles are shown in red and blood vessels in green. Microbubbles were systemically administered and only the right hemisphere was treated with ultrasound. The dashed white circles indicate the approximate location of the ultrasound focus. This microscopy image shows an increased delivery of nanoparticles in the ultrasound treated hemisphere compared to the left hemisphere which acted as an internal control. Courtesy of Marieke Olsman and Catharina de Lange Davies.

Annual Accounts for 2020

FUNDING (in 1000 NOK)



COSTS (in 1000 NOK)



*SINTEF, University of Oslo, University College of Southeast Norway, Helse Midt-Norge RHF, St. Olavs University Hospital HF, Nord-Trøndelag Hospital Trust, Levanger municipality, Verdal municipality, Sørlandet Hospital health authority

**Equinor, GE Vingmed Ultrasound AS, Archer-Bergen Technology Center AS, Sensorlink AS, EXACT Therapeutics AS, InPhase Solutions AS, Kongsberg Maritime AS, Halfwave AS, Aurotech Ultrasound AS, X-Fab Semiconductor Foundries AS, Medistim ASA

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

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

Journal Articles and Conference Proceedings - CIUS

AUTHOR/AUTHORS	TITLE	JOURNAL
Rodriguez-Molares A, Rindal OMH, D'hooge J, Måsoy S-E, Austeng A, Bell MAL, Torp H	The Generalised Contrast-to-Noise Ratio: A formal Definition for Lesion Detectability	IEEE Transactions on Ultrasonics, Ferroelectrics, and Frequency Control
Shad EHT, Molinas M, Ytterdal T	A fully differential capacitively-coupled high CMRR low-power chopper amplifier for EEG dry electrodes	Analog Integrated Circuits and Signal Processing
Låte E, Ytterdal T, Aunet S	An Energy Efficient Level Shifter Capable of Logic Conversion From Sub-15 mV to 1.2 V	IEEE Transactions on Circuits and Systems II: Express Briefs
Letnes JM, Nes B, Vaardal-Lunde K, Slette MB, Mølmen-Hansen HE, Aspenes ST, Støylen A, Wisløff U, Dalen H	Left Atrial Volume, Cardiorespiratory Fitness, and Diastolic Function in Healthy Individuals: The HUNT Study, Norway	Journal of the American Heart Association
Grue JF, Storve S, Dalen H, Mjølstad OC, Samstad SO, Eriksen-Volnes T, Torp H, Haugen BO	Automatic Quantification of Left Ventricular Function by Medical Students Using Ultrasound	BMC Medical Imaging
Smistad E, Østvik A, Salte IM, Melichova D, Nguyen TM, Haugaa K, Brunvand H, Edvardsen T, Leclerc S, Bernard O, Grenne B, Løvstakken L.	Real-time Automatic Ejection Fraction and Foreshortening Detection Using Deep Learning	IEEE Transactions on Ultrasounics, Ferroelectrics, and Frequency Control
Støylen A, Mølmen HE, Dalen H	Over All Variability of Mitral Annular Plane Peak Systolic Velocity and Peak Global Longitudinal Strain Rate in Relation to Age, Body Size, and Sex: The HUNT Study	Echocardiography
Liu X, Ytterdal T, Shur M	Plasmonic FET Terahertz Spectrometer	IEEE Access
Nyrnes SA, Fadnes S, Wigen MS, Mertens L, Løvstakken L	Blood Speckle-Tracking Based on High-Frame Rate Ultrasound Imaging in Pediatric Cardiology	Journal of the American Society of Echocardiography
Hjorth-Hansen AK, Andersen GN, Graven T, Gundersen GH, Kleinau JO, Mjølstad OC, Skjetne K, Stølen S, Torp H, Dalen H	Feasibility and Accuracy of Tele-Echocardiography, With Examinations by Nurses and Interpretation by an Expert via Telemedicine, in an Outpatient Heart Failure Clinic	Journal of Ultrasound in Medicine
Ramalli A, Rodriguez-Molares A, Avdal J, D'hooge J, Løvstakken L.	High-Frame-Rate Color Doppler Echocardiography: A Quantitative Comparison of Different Approaches	IEEE Transactions on Ultrasonics, Ferroelectrics, and Frequency Control
Andersen KK, Frijlink ME, Johansen TF, Hoff H	A Dual-frequency Coupled Resonator Transducer	IEEE Transactions on Ultrasonics, Ferroelectrics, and Frequency Control
Cochran Z, Ytterdal T, Madan A, Rizkalla M	High Speed Terahertz Devices via Emerging Hybrid GNRFET/Josephson Junction Technologies	IEEE Transactions on Applied Superconductivity
Lund JS, Aksetøy ILA, Dalen H, Amundsen BH, Støylen A	Left Ventricular Diastolic Function: Effects of High-Intensity Exercise After Acute Myocardial Infarction	Echocardiography
Kvåle KF, Salles S, Lervik LCN, Støylen A, Løvstakken L, Samset E, Torp H	Detection of Tissue Fibrosis using Natural Mechanical Wave Velocity Estimation: Feasibility Study	Ultrasound in Medicine & Biology
Viggen EM, Merciu IA, Løvstakken L, Måsøy SE	Automatic interpretation of cement evaluation logs from cased boreholes using supervised deep neural networks	Journal of Petroleum Science and Engineering
Leclerc S, Smistad E, Østvik A, Cervenansky F, Espinosa F, Espeland T, Berg EAR, Belhamissi M, Israilov S, Grenier T, Lartizien C, Jodoin PM, Løvstakken L, Bernard O	LU-Net: a mulit-stage attention network to imporve the robustness of segmentation of left ventricular structures in 2D echocardiography	IEEE Transactions on Ultrasonics, Ferroelectrics, and Frequency Control
Magelssen MI, Palmer CL, Hjort-Hansen A, Nilsen HO, Kiss G, Torp H, Mjolstad OC, Dalen H	Feasibility and Reliability of Automatic Quantitative Analyses of Mitral Annular Plane Systolic Excursion by Handheld Ultrasound Devices	Journal of Ultrasound in Medicine
Shad EHT, Molinas M, Ytterdal T	Impedance and Noise of Passive and Active Dry EEG Electrodes: A Review	IEEE Sensors Journal
Park J, Liu X, Ytterdal T, Shur M	Carbon Nanotube Detectors and Spectrometers for the Terahertz Range	Crystals
Dalen H, Holte E, Guldal AU, Hegvik JA, Stensaeth KH, Braaten AT, Mjølstad OC, Rossvoll O, Wiseth R	Acute perimyocarditis with cardiac tamponade in Covid-19 infection without respiratory disease	BMJ Case Reports
Perrot V, Ekroll IK, Avdal J, Saxhaug LM, Dalen H, Vray D, Løvstakken L, Liebgott H	Translation of Simultaneous Vessel Wall Motion and Vectorial Blood Flow Imaging in Healthy and Diseased Carotids of the Clinic: a Pilot study	IEEE Transactions on Ultrasonic, Ferroelectrics, and Frequency Control

AUTHOR/AUTHORS	TITLE	JOURNAL
Låte E, Ytterdal T, Aunet S	Benefiting From State Dependencies in Asymmetric SRAM Cells Through Conditional Word-Flipping	IEEE Transactions on Very Large Scale Integration (VSI) Systems
Salles S, Espeland T, Molares A, Aase SA, Hammer TA, Støylen A, Aakhus S, Løvstakken L, Torp H	3D Myocardial Mechanical Wave Measurements. Toward In Vivo 3D Myocardial Elasticity Mapping	JACC: Cardiovascular Imaging
Støylen A, Dalen H, Molmen HE	Left ventricular longitudinal shortening: relation to stroke volume and ejection fraction in ageing, blood pressure, body size and gender in the HUNT3 study	BMJ Open Heart
Huynh T, Haugen GU, Eggen T, Hoff L	Nonlinearity in a medical ultrasound probe under high excitation voltage	IEEE Transactions on Ultrasonic, Ferroelectrics, and Frequency Control
Sengupta P, Shrestha S, Berthon B, Messas E, Donal E, Tison GH, Min JK, D'hooge J, Voigt JU, Dudley J, Verjans JW, Shameer K, Johnson K, Løvstakken L, Tabassian M, Piccirilli M, Pernot M, Yanamala N, Duchateau N, Kagiyama N, Bernard O, Slomka P, Deo R, Arnaout R	Proposed Requirements for Cardiovascular Imaging-Related Machine Learning Evaluation (PRIME): A checklist	JACC: Cardiovascular Imaging
Ekroll IK, Perrot V, Liebgott H, Avdal J	Tapered vector Doppler for improved quantification of low velocity blood flow	IEEE Transactions on Ultrasonic, Ferroelectrics, and Frequency Control
Bolstad PK, Kuziora SL, Nguyen HV, Manh T, Aasmundtveit KE, Hoff L	Impact of High Pressures on Au-Sn Solid Liquid Interdiffusion (SLID) Bonds	2020 IEEE 8th Electronics System-Integration Technology Conference
Shad E, Molinas M, Ytterdal T	A low-power and Low-noise Multi-purpose Chopper Amplifier with High CMRR and PSRR	2020 42nd Annual International Conference of the IEEE Engineering in Medicine & Biology Society (EMBC)
Cochran Z, Ytterdal T, Madan A, Rizkalla M	Emerging Josephson Junction/Graphene Device Technologies towars THz Signal Generation	2020 IEEE International Symposium on Circuits and Systems (ISCAS)
Golfetto C, Ekroll IK, Torp H, Løvstakken L, Avdal J	Retrospective transmit beamforming and coherent plane wave compounding for microvascular Doppler imaging: a comparison study	IEEE Transactions on Ultrasonic, Ferroelectrics, and Frequency Control
Bolstad PK, Manh T, Midtseter N, Frijlink M, Hoff L	Ultrasound Transducers for High Pressure Environments Up to 1000 Bar	2020 IEEE International Ultrasonics Symposium (IUS)
Røed ES, Andersen KK, Bring M, Tichy F, Åsjord EM, Hoff L	Increased Usable Frequency Band for Underwater Transducers with Single Crystal	2020 IEEE International Ultrasonics Symposium (IUS)
Huynh T, Hoff L, Eggen T	Nonlinear electrical impedance of the acoustic stack in cardiac ultrasound probe	2020 IEEE International Ultrasonics Symposium (IUS)
Rindal OMH, Rodriguez-Molares A, Austeng A	Resolution Measured as Separability Compared to Full Width Half Maximum for Adaptive Beamformers	2020 IEEE International Ultrasonics Symposium (IUS)
Fatemi A, Måsøy SE, Rodriguez-Molares A	Row-column based coherence imaging using a 2D-array transducer: a row based implementation	IEEE Transactions on Ultrasonics, Ferroelectrics, and Frequency Control
Mawad W, Mertens L, Pagano JJ, Riesenkampff E, Reichert M, Mital S, Kantor PF, Greenberg M, Liu P, Nathan P, Grosse-Wortmann L	Effect of anthracycline therapy on myocardial function and markers of fibrotic remodelling in childhood cancer survivors	European Heart Journal – Cardiovascular Imaging
Karur G, Mawad W, Grosse-Wortmann L	Progressive right ventricular outflow tract fibrosis after repair of tetralogy of Fallot	Cardiology in the Young
Fadnes S, Sørensen K, Nyrnes SA, Wigen MS, Løvstakken L	Intraventricular Pressure Gradients - Vector Flow Imaging versus Color M-Mode	2020 IEEE International Ultrasonics Symposium (IUS)
Liu X, Ytterdal T, Shur MS	TeraFET Optimisation for 0.1 THz to 10 THz Operation	Radio Science Bulletin
Park J, Liu X, Ytterdal T, Kim JH, Xu J, Shur MS	Carbon Nanotube Metal Polymer Composites for Flexible Active Interconnects	ECS Transactions
Wild MS, Bring M, Hoff L, Hjelmervik K	Characterisation of Piezoelectric Material Parameters Through a Global Optimisation Algorithm	IEEE Journal of Oceanic Engineering
Shur MS, Park J, Zhang Y. Liu X, Ytterdal T	Percolation Carbon Nanotube Thin Film Transistors	ECS Transactions
Viggen EM, Hårstad E, Kvalsvik J	Getting started with acoustic well log data using the dlisio Python library on the Volve Data Village dataset	Proceedings of the 43rd Scandinavian Symposium on Physical Acoustics
Whittaker K, Rizkalla M, Ytterdal T	A Low Power FinFET Charge Pump for Energy Harvesting Applications	IEEE 63rd International Midwest Symposium on Circuits and Systems
Liu X, Ytterdal T, Shur M	TeraFET amplifier detector	Proceedings of the 2020 International Topical Meeting on Microwave Photonics

Journal articles and Conference Proceedings - CIUS related

AUTHOR/AUTHORS	TITLE	JOURNAL
Stenberg J, Håberg AK, Follestad T, Olsen A, Iverson GL, Terry DP, Karlsen RH, Saksvik SB, Karaliute M, Ek JAN, Skandsen T, Vik A.	Cognitive Reserve Moderates Cognitive Outcome After Mild Traumatic Brain Injury	Archives of Physical Medicine and Rehabilitation
Fagerland SMT, Hill DK, van Wamel A, de Lange Davies C, Kim J.	Ultrasound and Magnetic Resonance Imaging for Group Stratification and Treatment Monitoring in the Transgenic Adenocarcinoma of the Mouse Prostate Model	The Prostate
Wu G, Dong H, Ke G, Song J	An adapted eigenvalue-based filter for ocean ambient noise processing	Geophysics
Bush N, Healey A, Shah A, Box G, Kirkin V, Eccles S, Sontum PC, Kotopoulis S, Kvåle S, van Wamel A, de Lange Davies C, Bamber J	Theranostic Attributes of Acoustic Cluster Therapy and Its Use for Enhancing the Effectiveness of Liposomal Doxorubicin Treatment of Human Triple Negative Breast Cancer in Mice	Frontiers in Pharmacology
Aanes S, Bjuland KJ, Lærum AMW, Weider S, Evensen KAI, Indredavik MS, Brubakk AM, Håberg A, Løhaugen GC, Skranes J	Relationship between hippocampal subfield volumes and memory function in adults born preterm with very low birth weight (VLBW)	Clinical Obestrics, Gynecology and Reproductive Medicine
Zhang G, Forland TN, Johnsen E, Pedersen G, Dong H.	Measurements of Underwater Noise Radiated by Commercial Ships at a Cabled Ocean Observatory	Marine Pollution Bulletin
Stankovic I, Stefanovic M, Prinz C, Ciarka A, Daraban AM, Kotrc M, Aarones M, Szulik M, Winter S, Kukulski T, Aakhus S, Willems R, Fehske W, Penicka M, Faber L, Neskovic AN, Voigt JU	The Association of Mechanical Dyssynchrony and Resynchronisation Therapy With Survival in Heart Failure With a Wide QRS Complex: A Two-World Study	The International Journal of Cardiovascular Imaging
Chaban V, Clarke GJB, Skandsen T, Islam R, Einarsen CE, Vik A, Damås JK, Mollnes TE, Håberg AK, Pischke SE	Systemic Inflammation Persists the First Year After Mild Traumatic Brain Injury: Results From the Prospective Trondheim Mild TBI Study	Journal of Neurotrauma
Stenberg J, Karr JE, Terry DP, Håberg AK, Vik A, Skandsen T, Iverson GL.	Change in Self-Reported Cognitive Symptoms After Mild Traumatic Brain Injury Is Associated With Changes in Emotional and Somatic Symptoms and Not Changes in Cognitive Performance	Neuropsychology
Tannvik TD, Kiss G, Torp H, Rimehaug AE, Kirkeby-Garstad I	No Evidence of Cardiac Stunning or Decoupling Immediately After Cardiopulmonary Bypass for Elective Coronary Surgery	Acta Anesthesiologica Scandinavia
Saksvik SB, Karaliute M, Kallestad H, Follestad T, Asarnow R, Vik A, Håberg AK, Skandsen T, Olsen A	The Prevalence and Stability of Sleep-Wake Disturbance and Fatigue Throughout the First Year After Mild Traumatic Brain Injury	Journal of Neurotrauma
Sunde SL, Berto F, Haugen B	Efficient implementation of critical plane for 3D stress histories using triangular elements	International Journal of Fatigue
Pettersen EM, Avdal J, Hisdal J, Torp H, Seternes A	Validation of a novel ultrasound Doppler monitoring device (earlybird) for detection of microvascular circulatory changes	Clinical Hemorhelogy and Microcirculation
Olsman M, Sereti V, Andreassen K, Snipstad S, van Wamel A, Eliasen R, Berg S, Urquhart AJ, Andersen TL, de Lange Davies C	Ultrasound-mediated delivery enhances therapeutic efficacy of MMP sensitive liposomes	Journal of Controlled Release
Ladefoged CN, Hansen AE, Henriksen OM, Bruun FJ, Eikenes L, Øen SK, Karlberg A, Højgaard L, Law I, Andersen FL	AI-driven attenuation correction for brain PET/MRI: Clinical evaluation of a dementia cohort and importance of the training group size	NeuroImage
Olsen A, Babikian T, Bigler ED, Caeyenberghs K, Conde V, Dams-O'Connor K, Dobryakova E, Genova H, Grafman J, Håberg AK, Heggland I, Hellstrøm T, Hodges CB, Irimia A, Jha RM, Johnson PK, Koliatsos VE, Levin H, Li LM, Lindsey HM, Livny A, Løvstad M, Medaglia J, Menon DK, Mondello S, Monti MM, Newcombe VFJ, Petroni A, Ponsford J, Sharp D, Spitz G, Westlye LT, Thompson PM, Dennis EL, Tate DF, Wilde EA, Hillary FG	Toward a global and repoducible science for brain imaging in neurotrauma: the ENIGMA adult moderate/severe traumatic brain injury working group	Brain Imaging and Behavior

AUTHOR/AUTHORS	TITLE	JOURNAL
Wu G, Dong H, Ke G, Song J	Shear-Wave Tomography Using Ocean Ambient Noise with Interference	Remote Sensing
Karlsen RH, Saksvik SB, Stenberg J, Lundervold AJ, Olsen A, Rautio I, Folvik L, Håberg AK, Vik A, Karr JE, Iverson GL, Skandsen T	Examining the Subacute Effects of Mild Traumatic Brain Injury Using a Traditional and Computerized Neuropsychological Test Battery	Journal of Neurotrauma
Moe HK, Follestad T, Andelic N, Håberg AK, Flusund AMH, Kvistad KA, Saksvoll EH, Olsen Ø, Abel-Grüner S, Sandrød O, Skandsen T, Vik A, Moen KG	Traumatic axonal injury on clinical MRI: association with the Glasgow Coma Scale at scene of injury or at admission and prolonged posttraumatic amnesia	Journal of Neurosurgery
Skandsen TS, Stenberg J, Follestad T, Karaliute M, Saksvik SB, Einarsen CE, Lillehaug H, Håberg AK, Vik A, Olsen A, Iverson GL	Personal Factors Associated with Postconcussion Symptoms Three Months after Mild Traumatic Brain Injury	Archives of Physical Medicine and Rehabilitation
Hindenes LB, Håberg AK, Johnsen LH, Mathiesen EB, Robben D, Vangberg TR	Variations in the Circle of Willis in a large population sample using 3D TOF angiography: The Tromsø Study	Plos One
Sørensen K, Fadnes S, Wigen MS, Salvesen Ø, Mertens L, Løvstakken L, Nyrnes SA	Assessment of Diastolic Intraventricular Pressure Gradients in Children by Blood Speckle Tracking. A Feasibility Study	Journal of the American Society of Echocardiography
Zadeh SH, Ytterdal T, Aunet S	Multi-threshold voltage and dynamic body biasing techniques for energy efficient ultra low voltage subthreshold adders	IEEE Nordic Circuits and Systems Conference (NORCaS)
Zadeh SH, Ytterdal T, Aunet S	Comparative Study of Single, Regular and Flip well Subthreshold SRAMs in 22 nm FDSOI Technology	IEEE Nordic Circuits and Systems Conference (NORCaS)
Shad EHT, Moeinfard T, Molinas M, Ytterdal T	A Power Efficient, High Gain and High Input Impedance Capacitively-coupled Neural Amplifier	IEEE Nordic Circuits and Systems Conference (NORCaS)
Naderi K, Shad EHT, Molinas M, Heidari A, Ytterdal T	A Very Low SEF Neural Amplifier by Utilizing a High Swing Current-Reuse Amplifier	2020 XXXV Conference on Design of Circuits and Integrated Systems (DCIS)
Zadeh SH, Ytterdal T, Aunet S	An ultra low voltage subthreshold standard cell based memories for IoT applications	2020 28th Iranian Conference on Electrical Engineering

Presentations - CIUS

AUTHOR/AUTHORS	TITLE	LOCATION
Nyrnes SA	Blood Speckle Tracking in Congenital Heart Disease	ASE 2020 Virtual Experience
Daae AS, Wigen MS, Løvstakken L, Støylen A	Vortex formation during the isovolumetric contraction in the left ventricle	Euro Echo
Espeland T, Salles S, Støylen A, Berg EAR, Hammer T, Amundsen BH, Aakhus S, Løvstakken L, Torp H	Measuring myocardial mechanical wave velocities using 3D - initial clinical results	Meeting on myocardial function imaging
Grønli T, Leinan PR, Wigen MS, Skjetne P, Nyrnes SA, Dahl SK, Løvstakken L	Flow regularisation and reconstruction in echocardiography	Meeting on Myocardial Function Imaging
Jarmund AH, Ødegård SS, Torp H, Nyrnes SA	Characterisation of Instant Hemodynamic Responses to Tilt in Healthy Term Neonates using NeoDoppler	Young Investigator Award
Liu X, Ytterdal T, Shur MS	Plasmonic FET terahertz spectrometer using Si MOS, InGaAs and GaN HEMTs and pdiamond FETs	SPIE Optical Engineering + Applications
Løvstakken L	Simplifying echocardiography - opportunities and challenges	MICCAI ASMUS workshop
Rindal, OMH	Software Beamforming in Medical Ultrasound Imaging - A Blessing and a Curse	Basic Science and Instrumentation - Lecture Series
Salles S, Fadnes S, Nyrnes SA, Løvstakken L	High-frame-rate imaging of cardiac tissue-flow interaction: Towards the origin of the atrial kick wave	IEEE International Ultrasonics Symposium 2020
Shur MS, Park J, Zhang Y, Liu X, Ytterdal T	Percolation Carbon Nanotube Thin Film Transistors	Pacific Rim Meeting on Electrochemical and Solid-State Science (PRiME)
Talberg AS, Dong H, Johansen TF, Måsøy SE	Ultrasonic Wave Propagation in Layered Media - Beamforming for target detection and flow measurements	Scandinavian Symposium on Physical Acoustics
Viggen EM, Hårstad E, Kvalsvik J	Getting started with acoustic well log data using the dlisio Python library on the Volve Data Village dataset	43rd Scandinavian Symposium on Physical Acoustics
Whittaker K, Rizkalla M, Ytterdal T	A Low Power FinFET Charge Pump for Energy Harvesting Applications	63rd IEEE International Midwest Symposium on Circuits and Systems
Wigen MS, Fiorentini S, Støylen A, Løvstakken L	Aortic volume flow estimation using 4D vector flow imaging	2020 IEEE International Ultrasonics Symposium
Bolstad PK, Kuziora S, Nguyen HV, Manh T, Aasmundtveit K, Hoff L	Impact of High Pressures on Au-Sn Solid Liquid Interdiffusion (SLID) Bonds	Electronics System-Integration Technology Conference
Cochran Z, Ytterdal T, Madan A, Rizkalla M	Emerging Josephson Junction/Graphene Device Technologies towards THz Signal Generation	2020 IEEE International Symposium on Circuits and Systems (ISCAS)
Smistad, Erik	Eksempler og utfordringer i maskinlæringsbasert bildeanalyse innen ultralyd, CT, MR og digital patologi	Medisinsk bildebehandling og maskinlæring
Dalen H	Improved cardiac diagnostic imaging at the patients' point of care	Nord-Trøndelag Hospital Trust, Research seminar
Nyrnes SA	Blood speckle tracking based on high frame rate ultrasound in pediatric cardiology	Leuven Meeting on Myocardial Function Imaging
Liu X, Ytterdal T, Shur M	Current-driven TeraFET Detector	45th International Conference on Infrared, Millimeter, and Terahertz Waves
Park J, Liu X, Ytterdal T, Shur M	Carbon nanotube-thin film transistor model for terahertz detectors	45th International Conference on Infrared, Millimeter, and Terahertz Waves
Liu X, Ytterdal T, Shur M	TeraFET amplifier detector	2020 International Topical Meeting on Microwave Photonics

Presentations - CIUS realated

AUTHOR/AUTHORS	TITLE	LOCATION
Snipstad S, Segers T, Lajoinie G, Yemane PT, Åslund A, Nawijn C, Sulheim E, Mørch YA, Hansen R, Versluis M, de Lange Davies C, Berg S	Mechanisms and effects of nanoparticle-stabilized microbubbles designed for enhanced drug delivery	The 25th European symposium on Ultrasound Contrast Imaging
Berg, S	Nanopartikler, mikrobobler og ultralyd for mer målrettet kreftbehandling	FOR-fagseminar 2020
Naderi K, Shad EHT, Cabrera MMM, Heidari A, Ytterdal T	A Very Low SEF Neural Amplifier by Utilizing a High Swing Current-Reuse Amplifier	2020 XXXV Conference on Design of Circuits and Integrated Systems

Posters - CIUS

AUTHOR/AUTHORS	TITLE	LOCATION
Mawad W, Fadnes S, Grønli T, Løvstakken L, Mertens L, Nyrnes SA	Children with Pulmonary Hypertension Have Abnormal Flow patterns in the Main Pulmonary Artery as Shown By High Frame Rate Ultrasound Imaging	ASE 2020
Pasdeloup DFP, Østvik A, Smistad E, Løvstakken L, Dalen H, Olaisen SH, Grønli T	Automatic Apical Standard Views extraction from 3D ultrasound volumes using Deep Learning	Virtual IEEE IUS Symposium
Fadnes S, Sørensen K, Nyrnes SA, Wigen MS, Løvstakken L	Intranventricular Pressure Gradients - Vector Flow Imaging versus Color M-Mode	IEEE International Ultrasonics Symposium 2020
Bolstad PK, Manh T, Midtseter Nils, Frijlink ME, Hoff L	Ultrasound Transducers for High Pressure Environments Up to 1000 Bar	2020 IEEE International Ultrasonics Symposium
Huynh T, Hoff L, Eggen TH	Nonlinear electrical impedance of the acoustic stack in cardiac ultrasound probe	2020 IEEE International Ultrasonics Symposium
Røed EKS, Andersen KK, Bring M, Tichy F, Åsjord EM, Hoff L	Increased Usable Frequency Band for Underwater Transducers with Single Crystal	2020 IEEE International Ultrasonics Symposium
Mawad W, Fadnes S, Grønli T, Løvstakken L, Mertens L, Nyrnes SA	Children with Pulmonary Hypertension Have Abnormal Flow patterns in the Main Pulmonary Artery as Shown By High Frame Rate Ultrasound Imaging	Journal of the American Society of Echocardiography

Posters - CIUS related

AUTHOR/AUTHORS	TITLE	LOCATION
Nawijn C, Segers T, Lajoinie G, Berg S, Snipstad D, Versluis M	High-speed optical characterisation of the acoustic response of protein-and-nanoparticle-stabilized microbubbles	The 25th European symposium on Ultrasound Contrast Imaging
Sørsensen K, Fadnes S, Wigen MS, Salvesen Ø, Løvstakken L, Nyrnes SA	Assessment of Diastolic Intraventricular Pressure Gradients in Children by Blood Speckle Tracking. A Feasibility Study	ASE 2020 Virtual Experience

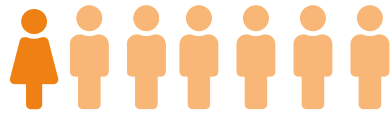
Øivind Rognmo and Jahn Frederik Grue share a Covid-19-friendly footshake after Grue's PhD defence.

Photo: Karl Jørgen Marthinsen/NTNU

Degrees 2020

MASTER THESES

PHD THESES



MASTER STUDENTS OBTAINING THEIR DEGREE IN 2020 ON A CIUS TOPIC AND SUPERVISER

Cole Nielsen	Ultra Low Power Frequency Synthesizer	T Ytterdal
Dewan Abu Md Arefin	An Integrated Sub-nW CMOS Temperature Sensor for Realtime Thermal Monitoring of an Ultrasonic Probe	T Ytterdal
Pål Gunnar Hogganvik	An all-digital sub-sampling integer-N PLL with wide tuning range in a 22nm UTBB FDSOI process	T Ytterdal
Sanjida Orin Tawhid	Asynchronous 16-bit ALU Design For Ultrasound Application	T Ytterdal
Karoline Kjeldsaas	Detection of Air Emboli in the Brain of Neonates by Ultrasound Doppler	H Torp
Yohann Sandvik	Machine Learning for Classification of Myocardial Infarction and Heart Failure Using Longitudinal Myocardial Strain	L Løvstakken
Benjamin Nedregård	Heart phase recognition and insufficiency detection using machine learning on intra-operative transit time blood flow measurements	L Løvstakken
Hector Mercado Valls	GAN for ultrasound image generation and speckle reduction	L Løvstakken
Sigurd Wifstad	Reconstruction of Ultrasound Blood Velocity Fields using Deep Learning	L Løvstaken
Krister Vikedal	Examining immune responses and nanoparticle uptake in tumors caused by Acoustic Cluster Therapy	C Davies
Matilde Maardalen	Examining immune responses and nanoparticle uptake in tumors caused by Acoustic Cluster Therapy	C Davies
Anna Kurbatskaya	Effects of Ultrasound-Stimulated Microbubble Treatment on Blood Perfusion and Vascular Permeability in Tumors. Master biophysics	C Davies
Ida Sandsbraaten	Tissue Deformation Estimation with Deep Learning on Ultrasound Data	G Kiss
Kristoffer Røise	Deep Learning Based Ultrasound Volume Registration for Interventional Applications	G Kiss

PHD CANDIDATES 2020- CIUS FINANCED

Kenneth K Andersen, USN	Therapeutic dual-frequency ultrasound transducers	L Hoff, M Frijlink, TF Johansen

PHD CANDIDATES 2020- CIUS RELATED

Stefano Fiorentini, NTNU	3-D Doppler imaging in cardiac applications using high frame-rate sequences	J Avdal, H Torp, R Wiseth, LR Hellevik
Petros Yemane, NTNU	Ultrasound for the delivery of a nanocarrier across biological barriers in tumors: impact of cavitation and acoustic radiation force	C Davies, BAJ Angelsen, R Hansen
Stein Martin Fagerland, NTNU	Nanoparticles, ultrasound and microbubble mediated drug delivery in cancer models	C Davies, E Hofsli, S Berg
Jahn Frederik Grue, NTNU	Automatic measurements of mitral annular motion indices	BO Haugen, H Dalen, H Torp
Thu Thuy Nguyen	Layer-specific strain and strain rate: Estimation using miniature transducers attached to the epicardium	L Hoff, J D'hooge, EW Remme
Fredrik Fossan	Physics-based and data-driven reduced order models: applications to coronary artery disease diagnostics	LR Hellevik, LO Müller, H Torp

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