ANNUAL REPORT

CIUS – Centre for Innovative Ultrasound Solutions

2016

sfi Centre for Research-based Innovation

The Research Council of Norway

cius

NTNU Norwegian University of Science and Technology

Corporate partners

Archer The well company

AUROTECH ultrasound

GE Vingmed Ultrasound

HALFWAVE

InPhase Solutions

KONGSBERG

MEDISTIM

PHOENIX SOLUTIONS

Sensorlink

Statoil

XFAB MIXED-SIGNAL FOUNDRY EXPERTS

User partners

ST. OLAVS HOSPITAL TRONDHEIM UNIVERSITY HOSPITAL

HELSE MIDT-NORGE

HELSE NORD-TRØNDELAG

Levanger kommune

Verdal Kommune

Academic partners

HSN Høgskolen i Sørøst-Norge

NTNU

Universitas Osloensis MDCCCXI

SINTEF

Host

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

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Homepage: **https://www.ntnu.edu/cius**

Thanks to Skipnes Kommunikasjon; Alfhild M. Borgen and Isak E. Stene

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INTRODUCTION

2016 was the first year with SFI CIUS research activity. This annual report gives you an overview of what we have achieved in 2016, but also points toward where we will be going in 2017 and beyond.

CIUS is a unique meeting place for ultrasound based technologies for use in medical, oil&gas and maritime sectors. CIUS overarching goal is to secure long-term competitive advantage within areas where Norway is internationally recognized for excellent research, innovation and product deliveries. I want to acknowledge and thank the Research Council of Norway, CIUS' corporate, user and academic partners, and our host institution for providing funding and support for SFI CIUS.

We have used 2016 to further the relationships between CIUS' academic, corporate and user partners and improve upon our initial research plans as we have started the work in work packages 1-7 (See WPs descriptions). Concurrently, we have hired PhD, postdocs, and guest professors (see CIUS employees, p. 41), and now have scientific-corporate-user-partner teams working towards our innovation goals (see Innovation goals, p. 4). Likewise, administrative support personnel are in place. New international collaborations have been established and old strengthened to ensure that CIUS' ambitious goals will be reached. Although CIUS' start was delayed, we gained momentum in 2016 and will be on track by 2017.

The CIUS board has focused on procedures ensuring best hiring practices, follow up of projects and identification of innovation potentials. The CIUS academic faculty group follows up the progress within each WP on a monthly basis, and works towards improved integration of activities across WPs and involvement of appropriate partners. The CIUS administration works on bringing together all CIUS partners as well as communicating what we do to the world around us.

CIUS research is led by experts in their respective fields, CIUS corporate partners are in the forefront with their products, and CIUS user partners create health care for the future based on innovation and establishment of improved or novel best practices. This constellation makes working in CIUS both intellectually challenging and satisfactory. It also provides an excellent environment for educating the next generation ultrasound experts.

I want to thank all CIUS academic and administrative personnel for their contributions in 2016, and look forward to 2017!

Asta Håberg
Center director
Faculty of Medicine and Health Sciences
NTNU

At **NTNU**,
we **CREATE KNOWLEDGE**
for a **BETTER WORLD**
and **SOLUTIONS**
that can **CHANGE EVERYDAY LIFE**

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GREETINGS FROM THE DEAN

The Faculty of Medicine and Health Sciences at the Norwegian University of Science and Technology (NTNU) is proud to host the Centre for Research-based Innovation (SFI) – Centre for Innovative Ultrasound Solutions for health care, maritime, and oil & gas (CIUS).

The Centre builds on NTNU's longstanding tradition in ultrasound research for medical applications and encompasses new research areas within oil, gas and maritime sectors. It aims to enhance and strengthen the innovation capability by promoting interdisciplinary collaboration and combining knowledge and skills from universities and innovative industry and innovative public enterprises.

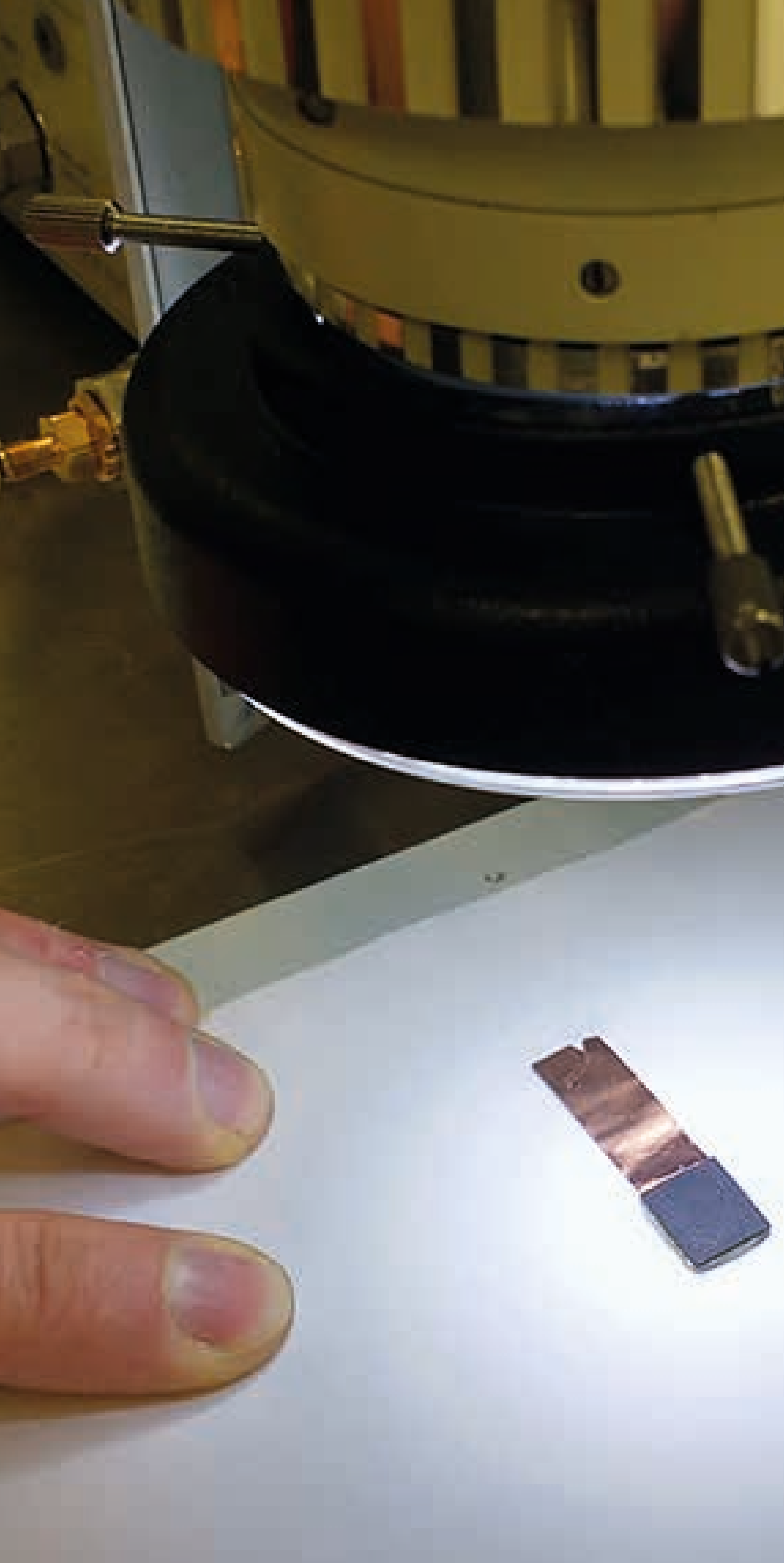
Interdisciplinary collaboration and knowledge exchange are often a key to innovation and successful environments. The Faculty of Medicine and Health Sciences welcomes more collaboration with industry and public enterprises.

NTNU and the University Colleges in Sør-Trøndelag, Gjøvik and Ålesund recently merged to become one university, forming larger research communities and a more comprehensive range of study programs and increased number of students. Collaboration with the working life is also important for the ability to offer research- and experience-based education and to educate students with relevant knowledge for the industry and public enterprises.

At NTNU, we create knowledge for a better world and solutions that can change everyday life. For more information about the Faculty of Medicine and Health Sciences, please see: http://www.ntnu.edu/mh

Increased knowledge, innovation and technology development are crucial to strengthen the adaptability and competitive power of the Norwegian economy. On behalf of the faculty and the university, I wish CIUS good luck with their research and development of technology and competence for the future.

Björn Gustafsson
Dean, Professor
Faculty of Medicine and Health Sciences
NTNU



CIUS 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 application 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 health care sector

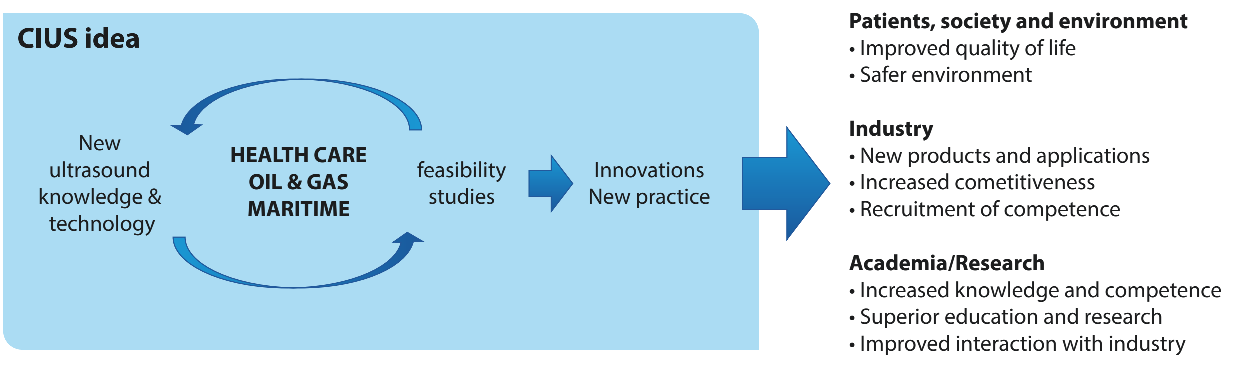
CIUS ORGANIZATION AND LOCATION

SFI CIUS is hosted by the Faculty of Medicine and Health Sciences (MH) at The Norwegian University of Science (NTNU), and localized to Department of Circulation and Medical Imaging (ISB).

Physically the academic research activity is divided across four institutions: NTNU, University College of Southeastern Norway (USN), University of Oslo (UiO), and SINTEF. SFI CIUS has 11 corporate partners; GEVU, Medistim, Aurotech and Phoenix Solutions within the medical sector, and Statoil, Halfwave, Sensorlink, Inphase Solutions and Archer BTC within the oil& gas sector, Kongsberg Maritime within the martime sector and X-Fab for advanced analog and mixed-signal process technologies. In addition there are four user partners within the medical health provision sector; St. Olav's Hospital, Midt-Norge Regional Health Authorities, Nord-Trøndelag Hospital Trust plus Levanger and Verdalen Community Health Services.

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 are also localized 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 critical for SFI CIUS' success.

The daily activity of the center is overseen by center director Professor Asta Håberg. Further, the CIUS administration includes the administrative coordinator Christina Kildal, communication specialist Kari Williamson and intranet responsible Sigrid Berg. Each WP has a primary investigator (PIs) 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 Nilsen, Director of R&D GE Vingmed



CIUS Organization

CIUS Board

Board director Eva Nilsen (GE)

Dean of host faculty Professor Bjørn Gustafsson (NTNU)

Appointed board representatives:

Statoil (Fredrik Varpe)

Kongsberg Maritim (Frank Tichy)

St. Olav (Petter Aadahl)

NTNU (Olav Haraldseth)

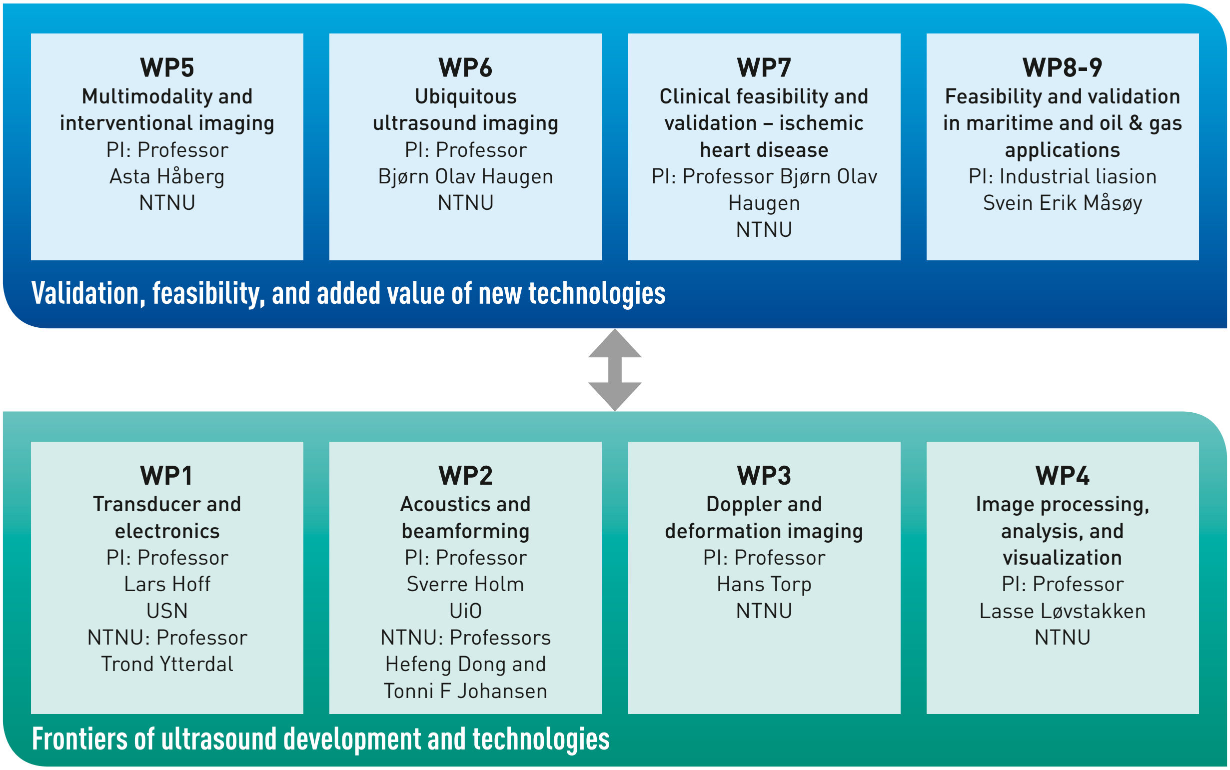
NTNU (Berit L Stand)

Elected Board representatives among the CIUS Corporate Partners

Erik Swensen (Medistim)

Dag Håkon Frantzen (Archer BTC)

Overview of CIUS' Work Packages (WP)



Ultrasound. The board meets twice-trice a year. During CIUS first year of existence, the CIUS' board work has focused on hiring procedures, methodology for identification of innovation potential, activity in and plans for WPs 1-7. At each meeting two WP leaders present a synopsis of the WPs' milestones and resources. Particular emphasis is given to new technical developments and unexpected discoveries. The Board has the mandate to change the scope and area of research in the WPs. The Board handles all IP questions.

Organized meeting places for CIUS personell and partners include monthly academic meetings for all WP leaders, twice yearly CIUS scientific meetings, and twice yearly CIUS PhD and postdoc lunches. In addition there are team- and topic based meetings for partners and academic personnel within and between WPs.

CIUS ADMINSTRATION

Bjørn Gustafsson
Dean,
Professor of gastroenterology,
Faculty for Medicine and
Health Sciences

Øysten Risa
Head of Department,
PhD, Circulation and Medical
Imaging

Asta Håberg
Professor of Neuroscience,
NTNU and St. Olavs Hospital
and Centre Director, CIUS

Christina Kildal
Project coordinator/
Administrator at CIUS/
Department of Circulation and
Medical Imaging

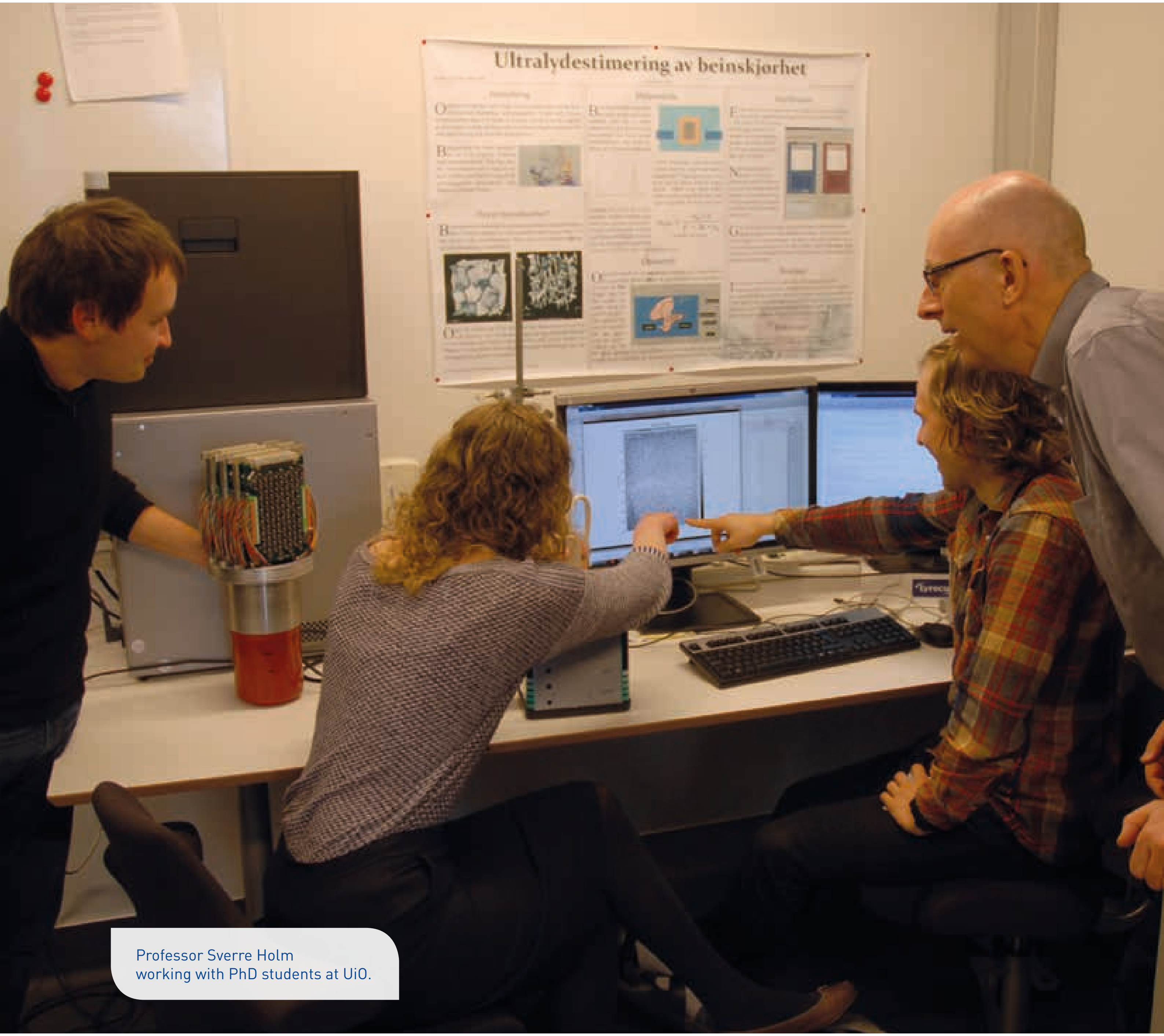
Eirik Dønjar
Financial Adviser and
Project Economist CIUS/
Department of Circulation and
Medical Imaging

Kari Williamson
Web & Communication,
CIUS

Sigrid Berg
Postdoc,
Intranet coordinator,
CIUS

CIUS WORK PACKAGE LEADERS

From left: Professor Hans Torp (WP3, NTNU), Professor Lars Hoff (WP1, USN), Professor Asta Håberg (WP5 and CIUS director, NTNU), Professor Lasse Løvstakken (WP4, NTNU), Professor Sverre Hom (WP2, UiO), Professor Toril N Hernes (former WP5, now Dean of Innovation, NTNU), Industrial liasion Svein Erik Måsøy (from 2017). Professor Bjørn Olav Haugen (WP5-6, NTNU) was not present.



Professor Sverre Holm
working with PhD students at UiO.

PRESENTATION OF A SELECTION OF CIUS' CORPORATE PARTNERS

Archer
The well company

Archer is a global oil services company with a heritage that stretches back over 40 years. With a strong focus on safety and delivering the highest quality products and services, Archer operates in 40 locations over 19 countries providing drilling services, well integrity & intervention, plug & abandonment and decommissioning to its upstream oil and gas clients. We focus on our customers' most vital assets: their wells – We help create new wells, or equip those already in service to produce oil and gas profitably and safely by extending the life of the well, with no harm to people or the environment. We have 30-year heritage in delivering a complete range of cased hole wireline services—helping our customers to enhance the integrity and performance of their wells. We continually innovate on all levels to deliver exceptional customer benefits via technology, techniques and processes.

The Archer subsidiary Bergen Technology Center develops, manufacture and sustain state of the art logging services that provides Archer Wireline with a leading position within Well Integrity Diagnostics. The R&D team has more than a decade experience in developing and running ultrasonic well logging tools worldwide and following the reorganization into a technology center in 2012, people with background from medical ultrasound, telecommunication, software development and embedded electronics were added to the team. We bring significant experience from transferring medical ultrasound to the Oil & Gas industry, we have lab and test facilities and a flexible technology platform which allows for rapid verification of new sensors, algorithms and applications. We are looking forward at taking these efforts to a new level as an industrial partner in the CIUS SFI.

AUROTECH
ultrasound

AUROTECH ultrasound AS develops ultrasound systems and offers high-end digital ultrasound scanners to OEM and license partners. The MANUS platform is unique, and combines flexibility, image quality and size with low manufacturing cost. The high degree of modularity and flexibility in the architecture makes the technology easy to adapt to new applications and products. The market can be both medical products and applications and for products for industrial use.

The good relation to the unique ultrasound research team at NTNU, has made it possible for AUROTECH to acquire both basic and advanced knowledge about the ultrasound technology of today and tomorrow. This has been very important to be able to design an ultrasound platform with a high degree of flexibility and modularity with many years lifetime in the market.

The long term ambition is to become the number 1 technology partner for high quality ultrasound engines. This ambition entails that we have to be in front of the technological development of ultrasound scanner front-end technology.

The high frequency capabilities and the very good signal quality performance our product have today, is an advantage in the market. It is a long term goal to maintain this position.

AUROTECH is today a very small company with limited resources and capacity. Participating in a centre like CIUS will give the company access to R&D resources which not is possible to access in any other ways. This possibility will give us an advantage in the market, and also for our customers and cooperating companies.

HALFWAVE

Halfwave delivers advanced inspection services to the oil & gas industry that allows its customers to make informed decisions to maintain the integrity of their critical assets. Key to Halfwave´s offering is its patented ultra-wideband acoustic resonance technology (ART), giving penetration and measurement capabilities which exceed those of exisiting inspection technologies.

The company has established ART as a superior technology for pipeline & subsea inspection, and

our highly- qualified team continues to develop the advantages of the ART platform to commercialize the inherent potential. In this respect CIUS is instrumental and provides avantgarde competence that, when paired with Halfwave's industry knowledge and engineering solutions, increase the probability of success significantly. Halfwave contributes to CIUS with project funding in development projects and relevant laboratory facilities both for subsea and gas applications.

With renowned industry owners such as Chevron we are positioned for exciting opportunities and commercial growth in the years to come.

MEDISTIM

Medistim's mission over the past three decades has been to serve patients, surgeons and health care providers with innovative and cost effective medical devices that measure blood flow and visualize atherosclerosis, and thereby help improve the quality and outcome of cardiac and vascular surgery.

Being an innovator and market leader within intra-operative transit time flow measurement (TTFM) and ultrasound imaging, Medistim is serving the global market with the devices **VeriQ™**, **VeriQ C™** and the latest generation, **MiraQ™**. These systems enable medical professionals to reduce risk and enhance quality of cardiac, vascular and transplant surgery. They provide clinically relevant information that empowers surgeons to make better-informed decisions in the operating room.

Medistim has subsidiaries with marketing and sales organizations in the USA, Germany, the United Kingdom, Spain, Denmark and Norway, in addition to a global distributor network representing the company in more than 50 countries in Asia, Europe, America and Africa. Today, Medistim's proprietary products are regarded to be standard-of-care in most European countries and Japan, while market adoption is growing in the USA, Asia and the Middle East.

The main objective for Medistim in the CUIS SFI is to secure future innovation in the areas of ultrasound transducers for surgical applications and to explore new ways to utilize ultrasound imaging for the cardiovascular surgeon.

GE Vingmed Ultrasound

GE Healthcare provides transformational medical technologies and services to meet the demand for increased access, enhanced quality and more affordable healthcare around the world. GE works on things that matter - great people and technologies taking on tough challenges. From medical imaging, software & IT, patient monitoring and diagnostics to drug discovery, biopharmaceutical manufacturing technologies and performance improvement solutions, GE Healthcare helps medical professionals deliver great healthcare to their patients.

GE Vingmed Ultrasound (GEVU) is part of GE Healthcare business in Norway and is a world leader in the development and production of cardiovascular U/S systems for medical applications and is a Center of Excellence in GE Healthcare. The company was founded in 1985 and now has a total of around 200 employees, with headquarters in Horten, Norway and offices in Oslo and Trondheim. Continued innovation is a key part of our business model: our goal is to establish new solutions to clinical challenges and to improve customer productivity and diagnostic capabilities through innovation. This is the enabler for gaining market share and for opening up new markets.

GEVU started as a spin-off company producing successful Doppler instruments for use in cardiology, initially developed at NTNU in the mid-seventies. GEVU continues to collaborate closely with medical and technological research institutes in Norway and abroad, and more than 60 PhD theses have been published based on work related to development or use of equipment produced by GEVU. Many of these PhD's are now employees in our company, working in close collaboration with the PdD candidates and Post Docs employed by the SFI program. This interaction is of great value both to the SFI and to GEVU, resulting in true value to our customers and patients around the world.

GEVU won both national and international prizes when introducing pocket size ultrasound, Vscan, setting a new standard of performance for an imaging device of that size. (Norwegian Engineering Achievement Award and TIME Magazine's 14th Best Inventions of 2009).

PhD student Thong Huynh at USN working in the ultrasound transducer lab.

WP1 TRANSDUCERS AND ELECTRONICS

WP leader Professor Lars Hoff, USN

This work package covers joint research for design, fabrication, characterization 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.

Research goals:

- WP1-1: Acoustic source characterization and optimization (PhD students Marcus S. Wild and Thong Huynh)
- WP1-2: Integrated high-performance transducer array electronics (PhD student Harald Garvik)
- WP1-3: Embedded ultrasonic sensors
- WP1-4: Dedicated high-frequency and multi-bandwidth transducers (PhD student Kenneth K. Andersen)

Main activities 2016

The main activities in 2016 have been finalizing our ultrasound transducer laboratory and starting PhD student projects, in close contact with industry partners.

A variety of concepts are used to create ultrasonic waves. The by far most common method is using a piezoelectric material to excite the vibrations to generate the sound pulses, and using the same, or

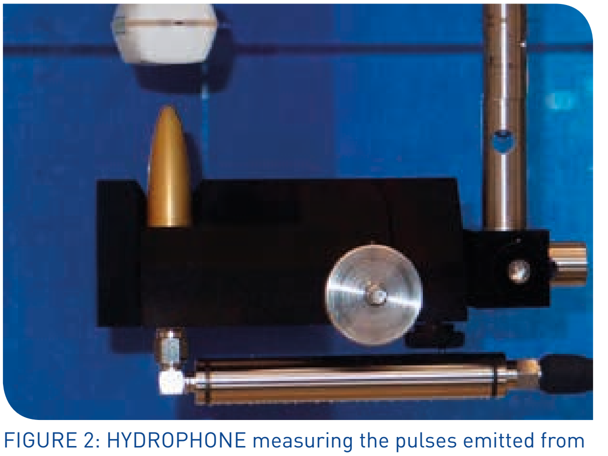


FIGURE 2: HYDROPHONE measuring the pulses emitted from a medical ultrasound probe

another, piezoelectric plate to receive the incoming sound waves. The piezoelectric plate is embedded into an acoustic stack consisting of carefully designed layers of materials with well-defined thickness and elastic properties, to optimize the energy transfer between the piezoelectric plate and the load medium. This stack is diced to form a 1D or 2D array of smaller elements, which are controlled individually to steer and focus the ultrasound beam.

The main goal of this first year has been to establish a laboratory at HSN to design, fabricate and characterize such arrays. This laboratory is now operative, and we can provide facilities to design, build and test prototype transducer arrays for novel applications, both for industry and for academic projects.

The services we can provide include

- Analytical and software tools to theoretically model the behavior of transducer designs
- Tools and equipment to build transducers operating in the MHz frequency range. This includes equipment for grinding, polishing and bonding together layers of well-defined thickness, and dicing saws to create arrays with kerf down to 40 µm,
- Equipment for electrical and acoustical measurements, e.g. electrical impedance, acoustic pulse-echo measurements, measurements of acoustic material properties (compressional and shear wave velocities, dispersion, attenuation), and pulse measurements using calibrated hydrophones scanned in 3D.
- Microscope inspection of devices, using optical microscopes, SEM (scanning electron microscope) and SAM (scanning acoustic microscope)

In addition to the HSN staff, four master students were involved in developing the lab during 2015-2016, and it is now used by the PhD students in the CIUS-project.

Four PhD-projects were started in 2016, seeking to answer the research goals defined in the work package

- **Kenneth K Andersen** Multi-bandwidth transducers, as defined in WP1-4. The aim of this project is to explore and develop methods to optimize transducers for operation effectively in two or more frequency bands. The main application is towards novel imaging methods based on nonlinear acoustics, and systems combining medical imaging and therapy. He is presently working on a transducer concept with the industrial partner Phoenix Solutions
- **Marcus S. Wild** Thermal effects in maritime transducers, as defined in WP1-1. Novel methods, both in underwater sound and medical imaging, require transmitting sound at higher duty cycles than has been common earlier, and heating of the transducer is becoming a limitation. The aim of this project is to obtain better models for the sources of loss in various transducer designs, i.e. the electrical, piezoelectric and mechanical loss mechanisms, and to find ways to reduce this. The work is done in collaboration with the industry partner Kongsberg Maritime, but the results will also be of interest for other applications.

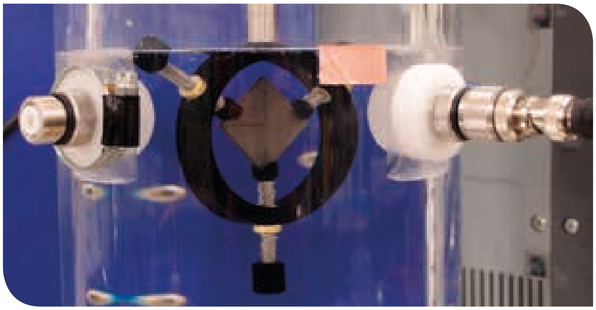


FIGURE 3: MEASURING the compressional and shear wave velocities in a sample material used as acoustic matching layers in a in a transducer

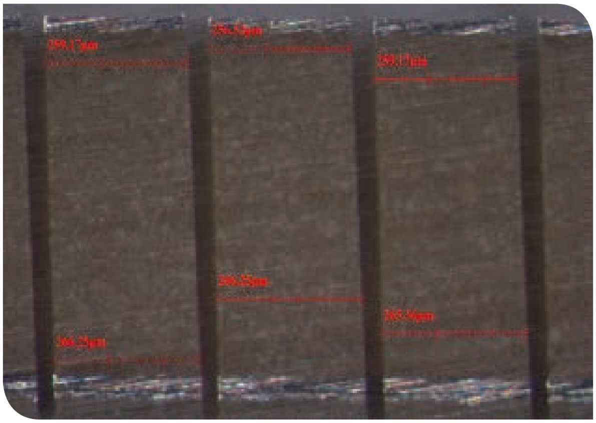


FIGURE 4: MICROSCOPE IMAGE of the elements in a piezoelectric transducer array. The elements are approximately 265 µm wide, separated by 40 µm kerfs.

- **Thong Huynh** Non-ideal effects in transducers, defined in WP1-1. Novel medical ultrasound imaging utilize the nonlinear properties of the tissue. This requires a good control of the nonlinear behavior of the transmit system, i.e. electronics and transducer. 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 cannot be described by an impulse response. The ultimate goal 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.

- **Harald Garvik** Integrated high-performance electronics, described in WP1-2. Modern ultrasound systems contain transducer arrays with up to thousands of densely packed elements. The aim of this project is to explore and optimize dedicated front-end electronics to interface to such arrays, with emphasis on very low noise and energy efficiency.

Highlights 2016

- The ultrasound transducer laboratory at USN is operative. We now have a complete line for design, fabrication and characterization of ultrasound transducer arrays in the MHz-range.

- Four PhD-projects started, all with strong involvement from the industry partners.

- Four presentations from the group at the *IEEE Ultrasonics Symposium*

- Established collaboration with *Resource Center for Medical Ultrasonic Transducer Technology at University of Southern California*, supported from the SIU/NFR INTPART-program. Two master-students from USN are currently doing their project there.

- Arranged our ultrasound transducer conference, for the 2^{nd} time: *The 2^{nd} Ultrasound Transducer Workshop at HSN*, with international and industrial participation.

From left: Professor Bjørn Olav Haugen in white coat (WP6-7), Professor Hans Torp (WP3) looking at the screen, Professor Lasse Løvstakken's (WP4, on the bench) and Professor Asta Håberg (WP5) in the back.

WP2 ACOUSTICS AND BEAMFORMING

WP leader Professor Sverre Holm, UiO

This work package covers the fundamentals of acoustic wave propagation and image formation (beamforming) common to all applications. Knowledge and simulation tools will be 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).

The topic of acoustic wave propagation is investigated and validated using measurements (water tank) laboratories at NTNU (medical and oil & gas) and UiO (sonar and medical). 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.

Highlights:

- New beamforming technique about to be implemented in Kongsberg Maritime bathymetry multibeam sonars
- Promising test of nonlinear acoustics in Kongsberg Maritime bathymetry multibeam sonars
- New ultrasound/MR elastography reconstruction methods from international partners King's College London and Charité, Berlin

Research goals:

- WP2-1: Establish simulation tools for acoustic and elastic wave propagation in heterogeneous and layered media
- WP2-2: Investigate guided waves in steel plates and pipes for the oil and gas industry (PhD student Andreas Talberg)
- WP2-3: Investigate non-linear sonar imaging in bathymetry applications with the goal of finding out if it improves image quality (Postdoc Fabrice Prieur)
- WP2-4 Establish elastography imaging in cardiac imaging with the goal of making a method that complements strain imaging
- WP2-5 Investigate advanced sonar array design in underwater mapping and imaging with the goal of creating ideas for next generation products (PhD student Antoine Blachet from 2017)
- WP2-6: Suppression of reverberation artifacts in ultrasound imaging in order to improve cardiac image quality in the 20-30 % of cases where images are hazy (PhD student Ali Fatemi)

WP3 DOPPLER AND DEFORMATION IMAGING

WP leader Professor Hans Torp, NTNU

Research and development of technology to improve on methods for detecting and measuring flow and displacements in ultrasound images.

Research goals:

To perform basic research on Doppler measurements and -imaging in 2D and 3D, with applications in medicine, oil and gas industry, as well as subsea.

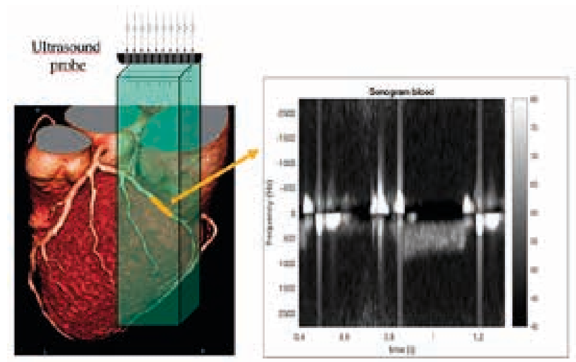
The current work package includes the following tasks:

- WP3-1: Three-dimensional vector-flow imaging
- WP3-2: Flow measurement in non-stationary and noisy surroundings (PhD student Cristiana Golfetto)
- WP3-3: High frame rate tissue deformation imaging (Post.Doc Sebastien Salles)
- WP3-4: Doppler imaging of flow in cement behind steel casing

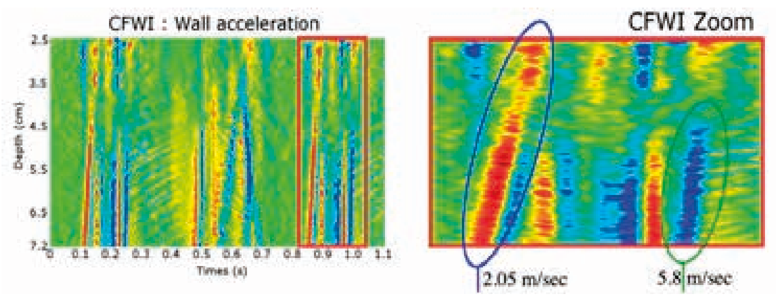
Highlights from 2016:

3D coronary flow imaging with high frame rate ultrasound

One of the innovation goals I Cius is "3D ultrasound coronary anatomical and functional imaging". After several months of hard work we managed to perform the first in vivo data acquisition of 3D coronary artery Doppler imaging data. The framerate (5000 frames/sec) was sufficient for quantitative analysis of blood flow velocities simultaneously in a 3D volume, large enough to cover a substantial part of the left coronary artery (LAD).



December 2016: First in vivo dataset of 3D coronary flow imaging with high frame rate ultrasound (5000 frames/sec). Left panel shows the recorded 3D volume intersecting part of the left coronary artery (LAD). Right panel shows quantitative analysis of blood flow in the coronary artery.



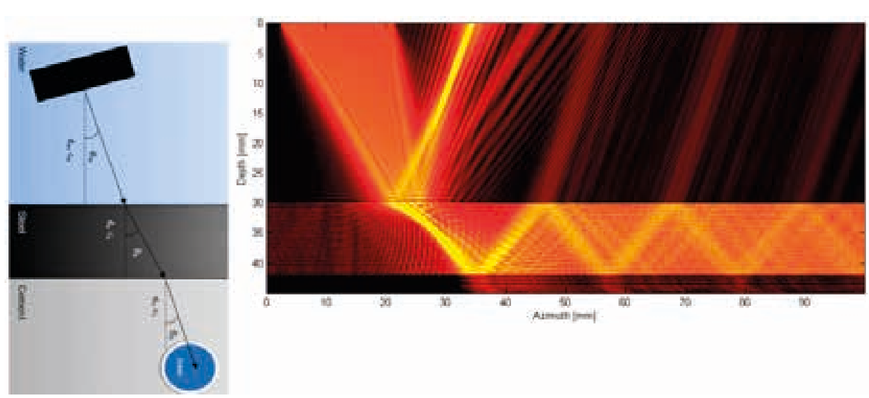
Mechanical wave propagation imaging in the left ventricle muscle, septal part. Left panel shows the wave propagation through one entire heart cycle; right panel shows a zoomed view in late diastole/early systole.

Mechanical wave imaging in the heart muscle

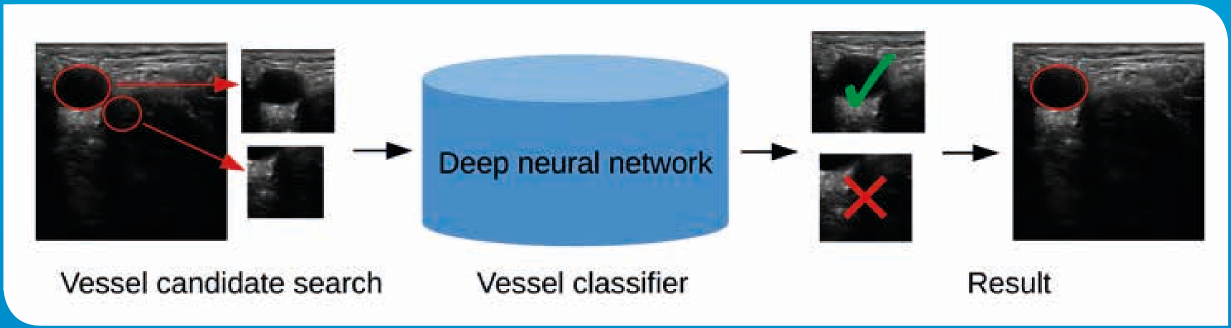
A new data acquisition setup for high frame rate 2D cardiac data has been implemented, as well as processing for vector Doppler and shear wave imaging. Postdoctor Sebastien Salles has developed a new method for quantitative shear wave imaging, called clutter Filter Wave Imaging (CFWI). The method is under evaluation by NTNU technology transfer organization for possible patent application submission. The method images mechanical wave propagation in the heart muscle, and propagation speed of several mechanical events though the cardiac cycle can be estimated with high presicion. This is related to heart conditions like myocardial infarction and fibrosis, and we hope that this method can give an early warning of these conditions (ill. above).

Doppler flow detection in cement behind steel casing

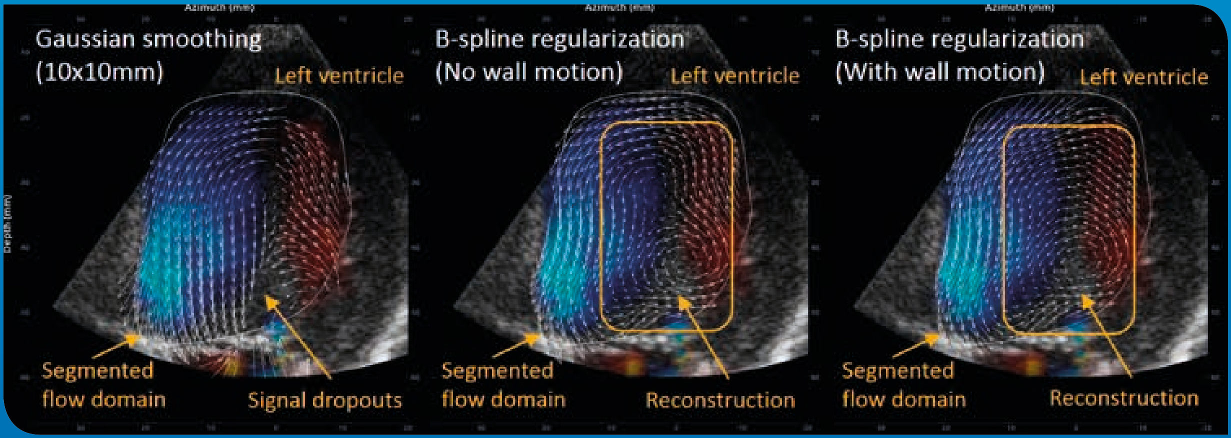
A joint project between two PhD students, A. Tallerås (WP2) and C. Golfetto (WP3. Startup meeting for the project was arranged in december 2016. Participants from BTC-Archer, Bergen, Sintef acoustics, and dep. Electrical engineering, NTNU (ill. below).



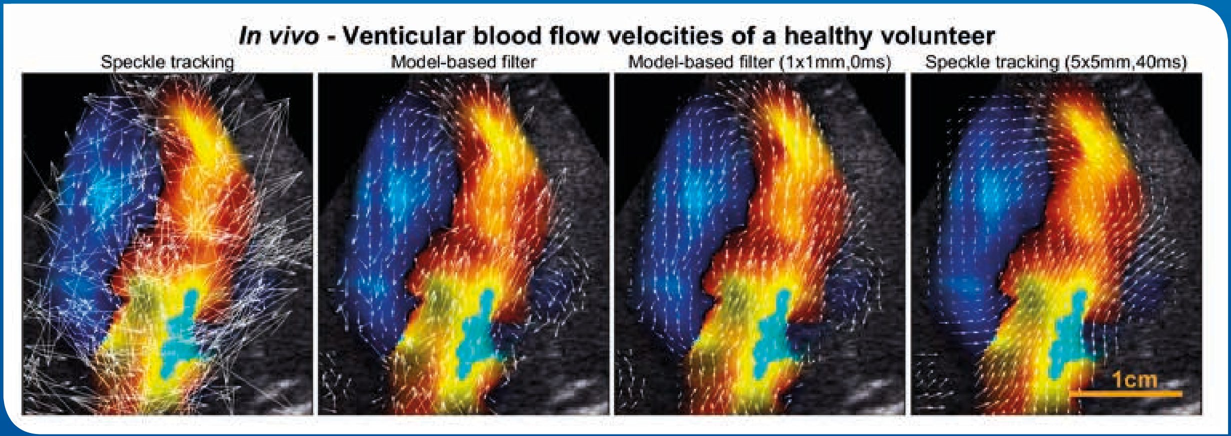
Doppler flow detection in cement behind steel casing.Illustations by Torbjørn Hergum, BTC-Archer, Bergen. Left panel: sketch of wave propagation direction when passing through the steel plate. Right panel: Computer simulation of wave propagation.



A DEEP LEARNING FRAMEWORK for detection of blood vessels in medical ultrasound imaging.



A FRAMEWORK for B-spline-based regularization and reconstruction of blood velocity fields. From left: Conventional image smoothing and measurement dropouts, B-spline regularization and reconstruction of image dropouts (using only blood velocities), same as previous but with added use of cardiac wall boundary conditions.



A MODEL-BASED ESTIMATION FRAMEWORK (Unscented Kalman filter) for improved estimation of blood velocity fields. From left: Noisy input measurements, model-based output without any image smoothing, model-based filter with some image smoothing, conventional image smoothing masking relevant information.

WP4 IMAGE PROCESSING, ANALYSIS, AND VISUALIZATION

WP leader Professor Lasse Løvstakken, NTNU

This work package covers the development of image processing and analysis methods used to improve the extraction of relevant and contextual information from US images, and to provide an improved workflow to reduce the time to decision or diagnosis. These tasks are also coupled to enhanced data visualization to provide a basis for further data exploration and interaction. Challenges in medical, maritime and industrial applications will be addressed using modern approaches in signal and image processing, as well as using recent machine learning algorithms for classification and extraction of data and image features. The work package outcome will provide a basis for improved extraction of relevant high-level image information, and also a basis for improved data acquisition and processing at lower levels by providing an initial and relevant context and interpretation of the problem at hand.

Highlights from 2016

- The development of a web-based data annotation framework for machine learning projects
- The development of a real-time deep neural network interface for classification of medical ultrasound data
- The development of a B-spline and Kalman-filter based framework for regularization and reconstruction of noisy (vector) measurements
- Conference paper presented on deep learning framework used to detect vessel structures in medical ultrasound images, published in the proceedings of 2nd Workshop on Deep Learning in Medical Image Analysis (DLMIA), Athens, Greece. Initial results proved significantly better than previous model-based attempts to the same problem.
- Two conference proceeding papers on regularization and reconstruction of noisy ultrasound blood velocity measurements presented and published at the IEEE International Ultrasonics symposium. Initial results significantly reduced measurement noise, without smoothing relevant blood flow information.
- An invited talk at the IEEE Society of Biomedical imaging (ISBI), Prague, 2016, entitled: 3D cardiac flow imaging – towards ultrafast.

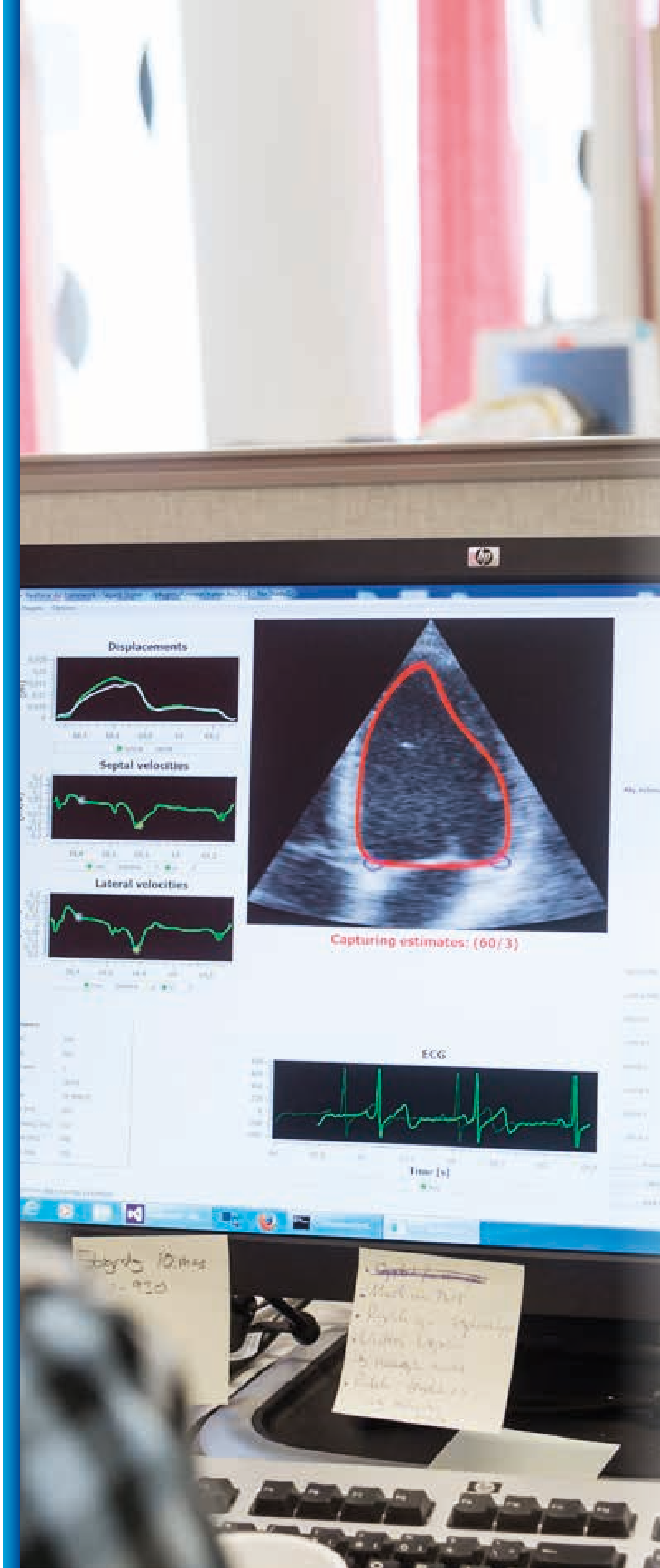
Research goals:

Our overall research goal will provide independent innovation value, and also support the overall innovation goals defined in CIUS, such as ultrasound-based anatomical and functional coronary imaging, improved seabed classification, and improved well integrity monitoring. The current work package tasks are as follows:

- WP4-1: Real-time 3D image segmentation of all heart chambers (PhD student Andreas Østvik)*
- 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*

* Post.Doc Erik Smistad works on fundamental imaging analysis methods applicable to the activity in all WP4's research goals

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



WP5 MULTIMODALITY AND INTERVENTIONAL IMAGING

WP leader Professor Toril N. Hernes and Asta Håberg, NTNU

The overarching aim of this work package is to develop and establish clinical feasibility as well as added value of multimodal and interventional imaging for diagnosis, follow-up and treatment of cardiovascular-, brain disease and cancer.

Multimodal imaging combines the strengths of different modalities such as ultrasound (US), magnetic resonance (MR), computer tomography (CT), and positron emission tomography (PET) for more precise diagnosis and follow-up, as well as guidance during surgery and targeted drug-delivery.

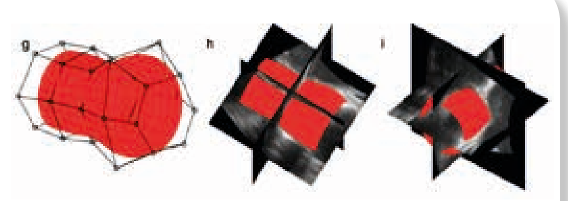
Research goals:

1. Multimodal imaging in cardiology
2. Multimodal imaging for image guided surgery
3. Multimodal US and PET-MR for improved diagnosis in brain and cardiovascular disease
4. Improved and targeted drug delivery with ultrasound technology

Highlights from 2016

Multimodal imaging in cardiology

Ultrasound imaging of heart structures and function is noninvasive and non-harming and is fundamental in both diagnostics and follow up in heart disease. The main objectives of this project is to develop ultrasound based methods in order to improve and simplify both visualization of and measurements on heart valves, valve leaks and the supplying blood vessels to the heart. Furthermore, we try to develop tools to improve the monitoring of heart function during major surgery.

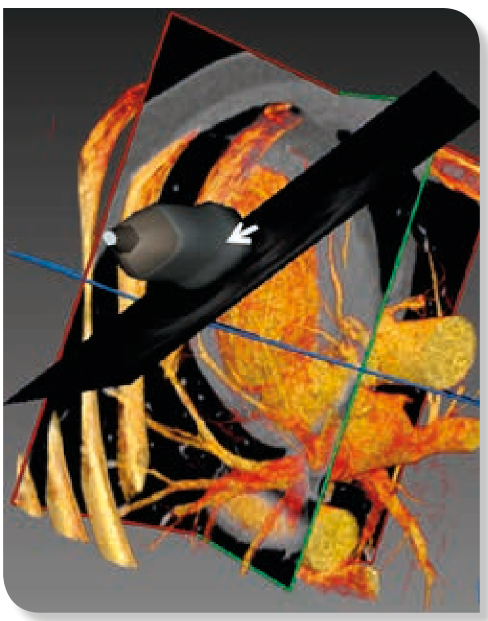


The figure shows the current three-dimensional ultrasound model of the structure of the aortic root, i.e. where the aorta leaves the heart. (Images curtesy of PhD student and cardiologist Erik Andreas Berg)

If successful, the new methods will become tools to enhance clinical decision-making.

Multimodal imaging for image guided surgery

Ultrasound could be used to visually guide the cardiologist when performing angiography and estimating blood flow in the blood vessels supplying the heart. Visual real time guidance of the positions of interventional catheters will make it easier for the cardiologist to estimate blood flow in the blood vessels of the heart, and improve the doctor's ability to focus on the areas of interest.



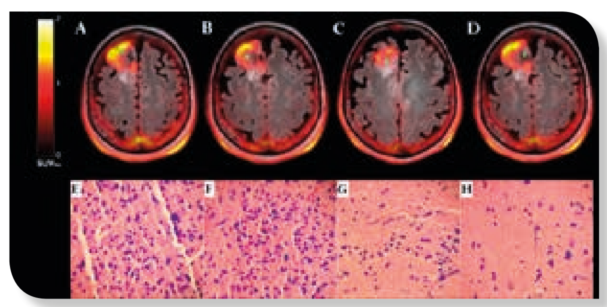
The figure depicts the principle of CT based real-time guidance for ultrasound based blood flow measurement in vessels supplying the heart. The ultrasound data, obtained with the transducer marked with a white arrow is aligned with the CT based map of the vessels supplying the heart (in orange reconstructed from the CT image in grey scale in the back). The CT data is used to guide the ultrasound transducer t towards blood vessels of interest for instance those suspected to be stenotic, i.e. have narrowing of the vessel lumen. The next step is to develop estimation of flow in these heart vessels which is done in WP3. (Image curtsey of postdoc David Bouget and Researcher Gabriel Kiss).

Ultrasound is an ideal technology to use for such real-time visual guidance thanks to its real-time acquisition capability, noninvasive nature and no use of X-rays.

In WP5, the work on establishing ultrasound guidance for diagnosis of stenotic/clogged heart vessels with 3D CT angiography was started in 2016, including implementation in CustusX. Real-time US probe tracking, automatic segmentation of anatomical regions of interest, acquisition of bloodflow parameters within the arteries supplying the heart, and multi-modality registration (US, CT) are currently investigated. Upon completion, the developed methodology can be tested in WP7 to assess its added-value for improving surgical practice and patient outcome.

PET-MR combined with ultrasound guided navigation for improved neurosurgery of brain tumors

St. Olav's hospital, NTNU and SINTEF have a long-standing tradition in the development and evaluation of ultrasound based navigated neurosurgery combined

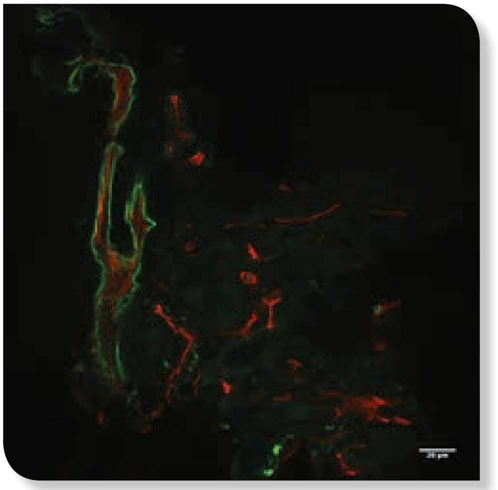


The images in the upper panel show the tumor on fused PET and MR images obtained simultaneously on the PET MR system. The tumor has a red-yellow color resulting from accumulation of the PET tracer. One clear advantage of using FACBC is that is does not enter all brain cells, but appears to be specific for tumor cells. FACBC was originally a tracer for detection of prostate cancer. This case clearly shows the potential of the tracer in glioma diagnostic and treatment planning. The green dots represent the sites from which tissue samples were obtained for microscopic examination by pathologist. (Image curtesy of PhD student and physicist Anna Karlberg, St. Olavs hospital, and Associate professor Live Eikenes, NTNU).

with various MRI scans. This was in 2016, this was extended to include the use of PET-MR data. The PET tracer ^{18}F-fluciclovine (FACBC), which enters cancer cells via amino acid transporters, was used. The PET-MRI results from one glioma patient with histology samples from the tumor are shown in figure X. This work will continue as patients are prospectively included in this study of added value of PET-MR combined with ultrasound guided navigation for brain tumor treatment.

Acoustic cluster therapy for improved and targeted drug delivery with ultrasound technology

Professor Catharina de Lange Davis' group works on mechanisms and refinement of targeted drug delivery with ultrasound to cancer and brain tissue. The principles behind acoustic cluster therapy are explained here https://tv.nrk.no/serie/kunnskapskanalen/MDDP17004116/17-12-2016 by PhD student Sofie Snipstad at Researcher Grand Prix 2016. Sofie Snipstads presentation is 37:30 min into the program. The group exploits the potential of drug-loaded polymeric nanoparticles forming a shell around gas filled microbubbles in combination with focused ultrasound. This has been demonstrated to enhance the uptake of the drug in breast cancer tumors growing in mice. The therapeutic response was very promising as all tumors showed complete remission. To further enhance ultrasound based drug delivery, new probes with dual ultrasound frequencies are developed in WP1 and work on methods of encapsulating drugs and understanding basic mechanisms are ongoing. This work is in collaboration with Phoenix Solutions and SINTEF. For cancer this work will be taken into the clinic in 2017. For brain, more work is required, but results as promising as shown in the image above.



The image is a fluorescent microscopy image of a slice of rat brain. The red structures are blood vessels and the green is the drug which has passed into the brain tissue and started to diffuse (blurry green). Delivering drugs into the brain is challenging due to the brain's blood vessels being impermeable to many drugs. This example illustrates how this hurdle can be bypassed by combining nanomedicine and ultrasound technology. The image is curtesy of Andreas Åslund and Catharina de Lange Davis.

PhD student Sofie Snipstad working in the lab

Postdoc Siri Ann Nyrnes and Associate Professor Lasse Løvstakken (WP4) have been collaborating for a number of years and are currently taking their methodology on improved cardiac ultrasound in children internationally for larger scale clinical testing.

WP6 UBIQUITOUS ULTRASOUND IMAGING

WP leader Professor Bjørn Olav Haugen, NTNU

Pocket-sized ultrasound devices are extremely portable, and can increase the use of ultrasound imaging as part of the diagnostics of patients in rural district hospitals to nursing homes in the Western world. Development of easy-to-use ultrasound technology has significant innovation potential and can be paradigm altering for practices in the health care sector, where the goal is to offer patients quicker diagnoses outside hospitals as well as avoid unnecessary hospital admissions. This work package covers research to test ultrasound technology for imaging of multiple organs to increase the usefulness in different clinical scenarios, and automatic measurements of relevant physiological parameters to aid non-expert users.

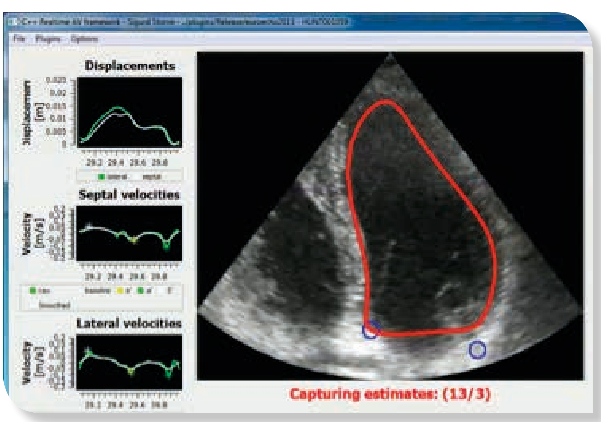
Research goals:

1. Multipurpose ultrasound imaging for non-experts (PhD Cameron Palmer)
2. Clinical benefit of use of pocket-sized ultrasound imaging in nursing homes (Associate professor Håvard Dalen)
3. Automatic detection of signs of Rheumatic heart disease

Highlights from 2016

Multipurpose ultrasound imaging for non-experts

Assessment of function of organs, especially the heart, is challenging for non-experts. Fully automatic



The image in the upper panel show the left ventricle in the heart. An automatic method tracks the motion during the heart cycle and assesses global function.

programs for assessment of global cardiac function has been developed at NTNU in cooperation with GE Vingmed and has been implemented in a handheld unit.

Clinical benefit of use of pocket-sized ultrasound imaging in nursing homes

This project will evaluate the clinical benefit of automated detection of dehydration, fluid retention and urine bladder volume by pocket-sized ultrasound in a nursing home. This is common but difficult to assess clinically and can be treated at the point of care instead of hospitalization. The infra- structure and model for training of general practitioners in pocket-sized ultrasound have been established at Levanger Hospital during the project "Interreg Sweden–Norway". General practitioners in the municipality of Levanger and Verdal have been recruited for clinical studies in CIUS.

Automatic detection of signs of Rheumatic heart disease

Approximately 8 million children worldwide are affected by rheumatic fever and rheumatic heart disease. These are conditions that can lead to significant heart valve disease and finally heart failure. Rheumatic heart disease is endemic among Indigenous people in Australia. CIUS has established a colaboration with The University of Queensland in Australia and The Indigenous Cardiac Outreach Program. Indigenous health care workers have been trained in ultrasound imaging of the heart and will test fully automatic programs for assessment of global cardiac function developed by NTNU and GE Vingmed Ultrasound.

ICOP

Indigenous Cardiac Outreach Program

Professor Bjørn Olav Haugen in the middle instructing a student in the use of hand held ultrasound

WP7 CLINICAL FEASIBILITY AND VALIDATION – ISCHEMIC HEART DISEASE

WP leader Professor Bjørn Olav Haugen, NTNU

This work package covers clinical feasibility and validation studies for establishing the potential of new ultrasound imaging methods developed in CIUS. The focus is on ischemic heart disease, currently the leading cause of mortality in the Western world. More safe, accurate and efficient diagnostic tools are needed for early detection and patient selection for immediate intervention.

Currently, the diagnostic gold standard is coronary angiography with fractional flow reserve measurement that is an invasive technique with inherent risks. Coronary Computer Tomography (CT) is a less invasive method. However, both methods expose patients to radiation and potentially harmful contrast agents. Detection of significant coronary artery disease stenosis is important, but in the periphery of an occluded artery, the myocardial tissue will eventually die and leave a scar that is beyond salvage. New techniques are needed to visualize coronary stenosis, quantify them and assess viability of the myocardium in order predict who will benefit from medical treatment and revascularization.

Research goals:

1. Ultrasound coronary angiography – feasibility and validation
2. Ultrasound imaging and quantification of tissue at risk – feasibility and validation (Asbjørn Støylen and Bjørnar Grenne)
3. Ultrasound imaging of myocardial viability – feasibility and validation (Asbjørn Støylen and Bjørnar Grenne)

Highlights from 2016

Ultrasound coronary angiography – feasibility and validation

The main aim of this project is to assess the feasibility of new and safe 3D ultrasound methods for visualizing the blood supply of the heart muscle: the coronary arteries. Early trials in 2016 have shown that it is possible visualize proximal parts of the left coronary artery at 5000 frames/sec.

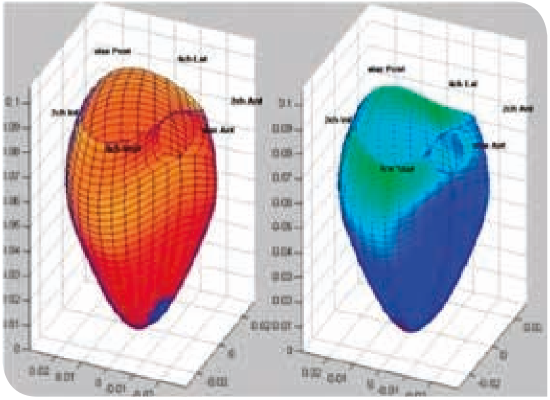
The technical developments here are currently under way in WP3 and WP5, please see WP3 and 5 for details on the technical development and implementation in the ultrasound navigated interventional suite. When these technical and methodological developments are ready for feasibility studies, the planned activity in WP7 will commence.

Ultrasound imaging and quantification of tissue at risk – feasibility and validation.

An acute occlusion of a (proximal) coronary artery will induce a large area of dysfunctional myocardial tissue. This area can be quantified with 3D reconstructions of 2D recordings of Tissue Doppler Imaging / Strain rate imaging. The PhD project "Ultrasound based markers of ischemia and viability in patients with myocardial infarction" was designed by Professor Asbjørn Støylen to identify the best marker of myocardial dysfunction and which one that best detects ischemia and predicts an occlusion of a coronary artery.

Ultrasound imaging of myocardial viability – feasibility and validation

The main aim of this project is to evaluate the feasibility of ultrasound methods developed in CIUS for detection of fibrosis. In the designed PhD project "Ultrasound based markers of ischemia and viability in patients with myocardial infarction", tissue Doppler recordings of patients after myocardial infarction will be compared to MRI , that is the current gold standard for detection of scar tissue, in order to identify the best ultrasound markers of non-viable fibrotic tissue.



Left ventricular myocardial velocities during contraction and filling faze of the heart cycle. Courtesy of Professor Asbjørn Støylen.

WP8-9 FEASIBILITY AND VALIDATION IN MARITIME AND OIL & GAS APPLICATIONS

These work packages cover the validation and feasibility of new US methods developed in CIUS to reach the proposed innovation goals in maritime and oil & gas.

Projects in this WP will be defined prospectively as new technologies emerge within CIUS.

Associated personell

PhD, postdoc and other researchers connected to CIUS activities, but not financed over the CIUS budget

WP1:
Trond Ytterdal, Professor electronics, NTNU
Harald Garvik, PhD student, NTNU
Knut E. Asmundstveit, Professor micro/nano systems technology, USN
Tung Manh, Postdoc, USN

WP2:
Hefeng Dong, Professor acoustics, NTNU
Roy Hansen, Principle Scientist, FFI and Associate prof II, UiO
Andreas Austeng, Professor signal processing, UiO
Alfonso Molares, Senior engineer, NTNU

WP3:
Ingvild Ekroll, postdoc , NTNU
Jørgen Avdal, postdoc, NTNU
Solveig Fadnes, postdoc, NTNU
Morten Wigen, PhD student, NTNU (WP3 and 4)
Stefano Fiorentini, PhD student , NTNU (WP3 and 4)

WP4:
Siri Ann Nyrnes, Senior researcher, pediatric cardiologist (WP4 and 7), NTNU/St. Olavs Hospital
Thomas Grønli, Summer student, NTNU

WP5:
Catharina de Lange Davis, Professor biophysics, NTNU
Andreas Åslund, Senior researcher, NTNU
Sofie Snipstad, PhD student, NTNU
Tormod Selbekk, SINTEF
Gabriel Kiss, Senior researcher, NTNU/St. Olavs Hospital (WP4 and 5)
Svend Aakhus, Professor cardiology, NTNU/St. Olavs Hospital
Torvald Espeland, PhD student, NTNU/St. Olavs Hospital
Anna Karlberg, PhD student, NTNU/St. Olavs Hospital
Live Eikenes, Associated professor PET-MRI, NTNU

WP6:
Cameron Palmer, PhD student, NTNU
Håvard Dalen, Associated professor cardiology, NTNU/St. Olavs Hospital
Ole Christian Mjølstad, St. Olavs Hospital/NTNU
Bjørnar Grenne, Associate profefssor, St.Olavs Hospital/NTNU

WP7:
Asbjørn Støylen, Professor cardiology, St. Olavs/ NTNU
Bjørnar Grenne, Associate profefssor, St.Olavs Hospital/NTNU

SFI CIUS collaborates with several international academic institutions scientifically. In addition, CIUS academic personnel is involved in international scientific societies, organizes and chairs international conferences, and takes on editor and reviewer responsibilities.

CIUS is also involved in internationalization of higher education through the Research Council of Norway INTPART program.

Professor Lasse Løvstakken (WP4) with his lab attending an international scientific meeting in France in 2016.

INTERNATIONAL COLLABORATIONS

Main international collaborators

WP1

Professor Kirk K. Shung, University of Southern California, US

Jean Francois Gelly, GE Parallel Design, Sophia Antipolis, France

WP2

Professor Alan Hunter, University of Bath, UK

Professor Ingolf Sack, Charité Hospital, Berlin, Germany

WP3 and WP4

Professor Jan D'hooge, KU Leuven, Belgium

Professor Olivier Bernard, CREATIS, INSA-Lyon, France

Professor Herve Liebgott, CREATIS, INSA-Lyon, France

WP5

Professor Thomas Beyer, Medical University Vienna, Austria

WP6

Associate Professor John Atherton, Director of Cardiology at the Royal Brisbane and Women's Hospital and Department of Medicine, University of Queensland, Australia

Rohan Corus, state manager of the Indigenous Cardiac Outreach Program, Prince Charles Hospital, Australia

Research unit of Health Region Jämtland Härjedale in VälTel – Mixed Zone för Välfärdsteknologiske Testlabs, Sweden

WP7 and WP4

Professor Luc Mertens, Hospital for Sick Children, Toronto, Canada

INPART Program for internationalization of higher education

Collaboration on the education of master and PhD students in the field of ultrasound transducer design between USN (WP1) and the *Ultrasonic Transducer Resource Center* (UTRC) at the *University of Southern California and Berkeley Sensor and Actuator Center* (BSAC) at the University of California, Berkeley.

Everyday life at the ultrasound lab at NTNU. From the left Postdoc Solveig Fadnes, PhD student Morten Wigen, Associate professor Tonni Franke Johansen and Professor Hans Torp.

CIUS EMPLOYEES

PhD students

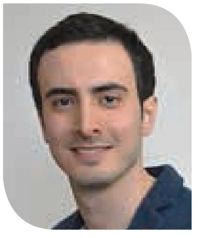
Kenneth K Andersen (WP1)

Ultrasound transducer design
Working with an optimized method for ultrasound imaging transducers. New ultrasound imaging and therapeutic modalities may require or benefit from ultrasound transducer that can operate at two, or more, significantly different frequencies. Such transducers are referred to as dual-frequency transducers. The design and optimization of dual frequency transducers are not trivial, and conventional design guidelines do not necessarily apply. To handle the complexity of dual-frequency transducers, we have developed a numerical design and optimization method for ultrasound imaging transducers based on linearizing the spectral phase. A publication on the method is expected within 2017.

Erik Andreas Berg (WP5)

Refine and validate a computerized algorithm for 3D transthoracic (TTE) and transesophageal (TEE) echocardiographic measures for reconstruction of aortic root morphology.
Develop and validate a semi-automatic computerized algorithm for semi-quantification of aortic and mitral valve regurgitations based on ultrasound data
Develop and investigate the clinical value of an algorithm for continuous ultrasound monitoring of LV function during major surgery.
Develop and validate an application for 3D echocardiography of coronary arteries.

Seyed Ali Mohammad Fatemi (WP2)



State-of-the-art echocardiography allows to correctly diagnose most of cardiovascular diseases. An unknown source of clutter, however, hinders the visualization 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
Working with adaptive clutter filtering in Doppler ultrasound for coronary arteries.

Thong Tuan Huyhn (WP1)

Non-ideal effects in transducers.
Novel medical ultrasound imaging utilize the nonlinear properties of the tissue. This requires a good control of the nonlinear behavior of the transmit system, i.e. electronics and transducer. 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 cannot be described by an impulse response. The ultimate goal 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.

Andreas Sørbrøden Talberg (WP2)

Working in the CIUS work package 2, the focus is on using ultrasonic non-destructive testing methods in applications related to the oil and gas industry. Currently work is being conducted together with people from work package 3 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.

Marcus Wild (WP1)

As part of my PhD, I will be investigating the heat generation and transfer within ultrasound transducers. Heating can cause performance and efficiency issues in modern transducers so it would therefore be of interest to be able to accurately model the temperature rise for a given design before prototyping. The initial part of my PhD consists of characterising the loss mechanisms in the piezoelectric component accurately for various external conditions such as driving voltage or temperature. I will then be using the determined losses to predict the temperature rise in a piezoelectric component.

Andreas Østvik (WP4)

The goal of my PhD project is to utilize and further develop machine learning methods to improve stateof-the-art solutions in the field of ultrasound image analysis and visualization. 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.

Postdocs

David Bouget, PhD (WP5)

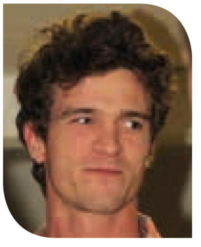
In order to measure blood pressure and flow through a specific coronary artery, catheter insertion in the body is the current diagnosis approach. In order to perform the same measurement in a non-invasive manner, a solution is to use a US probe to image the flow inside the coronaries. One critical drawback is then the difficulty for the surgeon to properly target a specific coronary using only the US data. To that end, 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 for reaching more easily regions of interest.

Fabrice Prieur, Post Doc (WP2)

My contributions to the CIUS project deal with three main areas:
The first area is the use of nonlinear propagation in underwater acoutics. This task is done in collaboratin with Kongsberg Maritime and aims at exploring how the nonlinear effecs of sound propagation in water can contribute to improve image quality in sonars. This idea is investigated through theoretical modelling as well as experimental validation using Kongsberg Maritime facilities.
The second research area deals with guided waves. In the context of non-destructive testing, guided acoustic waves are often used to inspect tank walls, pipe surface, or boreholes for weakness signs such as corrosion, cracks, or bonding faults. Acoustic waves travelling along this structure can be analysed to discover and position these weaknesses. These complex theme is investigated through simulations using finite element methods and possibly through lab experiments. Oil and gas companies within the consortium are all potential partners.

Finally, I will use my experience in simulations both using finite element modelling method, such as COMSOL AS, and finite time difference methods, such as K-wave, to improve our understanding of the propagation of elastic waves. Elastic waves are present in medical ultrasound both in diagnostic and therapeutic applications. Being able to predict how they propagate arms us with an important tool.

Sebastien Salles, PhD (WP3)



Development of acquisition strategies and processing algorithms for high frame rate 3D tissue deformation imaging, utilizing 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).

Erik Smistad, PhD (WP4 and WP5)

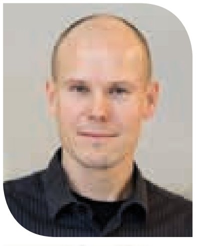
Image processing, analyzis and visualization Erik Smistad is a post doc primarily working on image segmentation, and exploring the new developments in the field of machine learning and neural networks. The work has so far been on classification of images as well as identifying structures, such as blood vessels and the left ventricle. Erik has 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 (FAST).

Associate/guest professors

Martijn Frijlink, MSc, PhD (WP1)

Tasks: supervise MSc- and PhD students, and assist in the acoustic transducer lab at the Department of Micro- and Nanosystem Technology, which is part of the Faculty of Technology and Maritime Science of the University College of Southeast Norway at Campus Vestfold in Horten. This work is performed in close collaboration with Professor Lars Hoff.

Bjørn Olav Haugen (WP6-7)



Cardiologist and PI of WP6-7.

Tonni Franke Johansen (WP2-3)

Works on ultrasound in oil&gas applications.

Scientific programmer

Tore Bjåstad (WP5)

Scientific programmer for faster translation of academic results to product.

Position	Employed in 2016	Norwegian/international
PhD	8	5/3
Postdoc	4	1/3
Associate/guest professors	3	2/1
Scientific programmer	1	1

SOFIE SNIPSTAD won the national "Forsker Gran Prix" final in Bergen with a presentation about ultrasound-mediated delivery of nanomedicine.

DISSEMINATION, MEDIA AND OUTREACH ACTIVITIES

Throughout the year, CIUS researchers are active participants at conferences and seminars around the world, but we are also conscious of our duty to disseminate our research outside of academia.

Twice a year, CIUS researchers, partners and collaborators are gathered for a full day seminar. In 2016 we had the CIUS Spring Conference Day in April, and the Fall Conference Day in November.

Furthermore, we had a stand at Technoport in March, and to celebrate the National Science Week (Forskningsdagene), we collaborated with the MR Centre at NTNU on a stand about medical imaging at Forskningstorget in Trondheim in September.

As we are in our first full year of operation, we have focused our dissemination efforts on presenting research that has led up to the establishment of CIUS, and what we hope to find the answers to in the course of CIUS. All blog posts published at the Faculty of Medicine and Health Sciences' blog "NTNUmedicine" are also shared at the Faculty's Facebook page "NTNU Helse", which has 3118 followers. The blog has on average 1500 readers. Below we have listed media coverage and blog posts from the year past:

Ultrasound - Teknologihovedstaden Trondheim	YouTube: Teknologi-hovedstaden Trondheim	04.01.2016
Seks områder Norge bør satse på	Adressa	08.01.2016
Først i Europa med nytt ultralydapparat	NRK Kveldsnytt	13.01.2016
CIUS at Technoport 2016	CIUS News	10.03.2016
Visit from Norwegian Minister of Health	CIUS News	01.04.2016
CIUS spring conference day 2016	CIUS News	14.04.2016
Studie: Cellegift levert rett i svulsten kurerer kreft hos mus	VG	26.05.2016
Bubbles and ultrasound destroy tumours in lab animals	Gemini	07.06.2016
Interpreting ultrasound images with neural networks	NTNU Medicine – blog	01.09.2016
Naturfilosofi på en våt strand	Titan.uio.no - blog	14.09.2016
Avoiding unnecessary coronary angiograms	NTNU Medicine – blog	16.09.2016

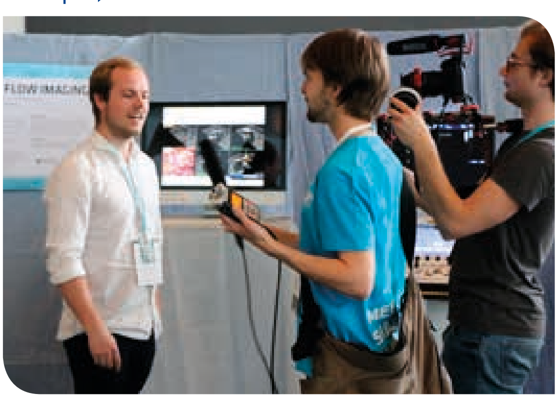
Improving quality of cardiac ultrasound images	NTNU Medicine – blog	28/10/2016
Boblende nanomedisin mot kreft	NTNU Medicine – blog	16/11/2016
CIUS fall conference day 2016	NTNU Medicine – blog	29/11/2016
Exploiting nonlinear distortion to switch from black and white to colour in underwater acoustic imaging	NTNU Medicine – blog	16/12/2016
Finalen i Forsker Grand Prix 2016	NRK Kunnskapskanalen	16/12/2016
Ultrasound-mediated drug delivery presentation won Forsker Grand Prix	CIUS News	16/12/2016

Examples from some of the outreach activities that CIUS has participated in during 2016

CIUS Spring Conference Day

CIUS Fall Conference Day

Technoport, March 2016



Ministerial visit

Examples of media coverage of CIUS activities in 2016

30 | ØKONOMI — Fredag 8. januar 2016 | Adresseavisen

Norsk industri og teknologi: Konsernsjef i Sintef, Alexandra Bech Gjørv, snakker om Norges vekstmuligheter og satsningsområder på NHOs årskonferanse torsdag. Foto: BERIT ROALD, NTB scanpix

Fallende oljepriser og automatisering av arbeidsoppgaver vil føre til tapte arbeidsplasser, men også gi nye vekstmuligheter i Norge.

Seks områder Norge bør satse på

»Oslo

Teknologi

Alexandra Bech Gjørv, konsernsjef i Sintef, snakker om hvordan teknologien endrer norsk industri og om nye vekstmuligheter for Norge på NHOs årskonferanse torsdag.

Her er seks områder der norsk økonomi kan oppleve vekst hvis det satses, ifølge Bech Gjørv:

1. Avansert materialvitenskap

Ett område med store muligheter for vekst i Norge er anvendelse av avansert materialvitenskap i vareproduserende industri.

– Etter mange år med leveranser av støtfangere til bilindustrien, har Benteler på Raufoss nå klart å innta rollen som global eneleverandør for hjuloppheng til Audi. Dette er en kjempestor kontrakt, forteller Bech Gjørv.

– Årsaken til at Benteler fikk denne kontrakten i havn er ikke bare at de har spesialisert seg på høyautomatisert produksjon, men vel så mye at de kan trekke veksler på et helt norsk landslag i teknologi.

Et toppet team med professorer fra NTNU, Sintefs atomskalamikroskop, metallurger i Oslo og Trondheim, og lokale ingeniører og verktøymakere, sprinter mellom laboratorier og produksjon, sier Bech Gjørv.

2. Avansert IKT

– Det høye lønnsnivået i Norge har krevd at vi har gått langt i omstilling gjennom digitalisering av samfunnet vårt. Det har gitt oss en befolkning med høy grad av generell digital kompetanse. Men også innen forskning og utvikling har Norge betydelig styrke innenfor IKT, ifølge Bech Gjørv.

– Vi hevder oss blant de ypperste i konkurransen om EUs forskningsmidler. Allerede i dag er avanserte IKT-løsninger kjernen i mange av våre viktigste næringer. Og etter hvert som næringslivets bruk av «big data» virkelig tar av, ligger det forretningsmuligheter i digital tjenesteproduksjon, sier Bech Gjørv.

3. Elektriske samfunn

Også i den norske kraftnæringen og den videre elektrifiseringen av samfunnet gjennom såkalte «smart grids» er mulighetene for vekst store, mener Bech Gjørv. Smart grid er et samlebegrep på fremtidens bærekraftige, elektriske kraftsystem.

– Med vannkraft som utgangspunkt, har norske bedrifter utviklet teknologi, styringssystemer, markedsstrukturer og digital innsikt i verdensklasse.

– Det er «big data» som ligger til grunn for de store modellene for kraftsystemanalyse, som er etterspurt globalt, både av dem som produserer kraft og av dem som tar finansielle posisjoner i markedet, sier Bech Gjørv, og nevner ABB i Skien som en fremtidsrettet teknologibedrift:

– De investerer i forskning og utvikling, og klarer derfor å levere bryteranlegg som tåler de ekstreme belastningene som oppstår i et fleksibelt smart grid-system. Internasjonal ekspansjon innen digitale tjenester og fysiske produkter til det elektriske storsamfunnet er åpenbart en stor mulighet for Norge, sier Bech Gjørv.

4. Velferdsteknologi

Sensorteknologi, robotisering og digital kommunikasjon vil gjøre det mulig for pasienter å oppleve større trygghet og utføre mange oppgaver uten hjelp.

– Her er mulighetene store for effektivisering, forbedring av tjenestene og tilrettelegging for at eldre og pleietrengende kan bli boende hjemme hos seg selv. Målet må være at dette skal frigjøre kapasitet til omsorgsoppgaver med høy verdi, tid til den varme hånden og den viktige praten over kaffen, og til mer målrettet behandling av helseproblemer, sier Bech Gjørv.

5. Fra olje og gass til medisin

Norges IKT-miljø innenfor olje og gass er i verdensklasse. Bransjen er inne i en dyp krise, men nye teknologier vil også måtte være en stor del av løsningen, mener Bech Gjørv.

– Da jeg kom til Sintef, ble jeg slått av mulighetene til å utveksle modeller for systemforståelse og konkret teknologi mellom olje- og gassbransjen og medisin.

Til tross for de mange åpenbare forskjeller på biologi og geologi, ser vi at teknologi som blant annet bygger på oljebransjens erfaringer tas i bruk på medisinområdet, forteller Bech Gjørv.

Hun nevner som eksempel utveksling av kunnskap mellom flerfasestrømming av olje og gass og blodomløpet, og mellom GPS-styrte inngrep i oljeutvinning og kirurgi.

– Dette er en av grunnene til at Forskningsrådet valgte Center for innovative ultrasound solutions for health care, maritime, and oil & gas industries, som er ledet av NTNU, som ett av sine storsatsingsområder for de neste åtte årene, sier Bech Gjørv.

6. Havbruk og mikroorganismer

– Fisk, skjell, tare og mikroorganismer i havet fremstår kanskje som den største muligheten vi i Norge har til virkelig å være med og løse klimaproblemet og ernære klodens voksende befolkning.

Verdiskapningspotensialet i denne bransjen er enormt, sier Bech Gjørv.

– For å lykkes med bærekraftig utnytting av mulighetene havrommet gir, må hele paletten av teknologier og fagdisipliner i arbeid: Fartøyskonstruksjon, mikrobiologi, robotikk, droneteknologi, big data-analyser, oseanografi, regelverksutvikling og diplomati, for å nevne noen.

Alt dette må fases inn i næringer som ikke er bortskjemt med forskningsavdelinger og teknologistaber. Her må folk fra laboratorium ut i merder og opp på dekk, som et bærekraftig «økosystem», sier Bech Gjørv.

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3 ledere i norske teknologibedrifter, interesse- og utdanningsorganisasjoner om de store endringene i norsk arbeids- og næringsliv:

– Nordmenn har vært i komfortsonen for lenge

NHO-sjef Kristin Skogen Lund mener nordmenn har vært i komfortsonen for lenge, og at arbeidslivet står foran teknologiske endringer vi knapt forstår rekkevidden av. Ikke alle vi snakket med er helt enige i det.

Michael Jacobs, Microsoft Norge

Jacobs mener NHO treffer spikeren på hodet med navnevalget for årets konferanse. «Remiks» er hentet fra musikkbransjen, som har gjennomgått ekstreme endringer som følge av digitaliseringen.

– Næringslivet blir nødt til å remikse arbeidsmåter og forretningsmodeller de nærmeste årene. Statistikken viser at en fjerdedel av deltagerne på NHO-konferansen er i gang med omstilling, og gratulerer til dem med det. Men de siste tre fjerdedelene taper enten penger eller risikerer å være borte innen fem år. Jacobs ser allerede store gevinster av digitalisering i helsevesenet.

Maalfrid Brath, Manpower

Konsernsjefen ser lyst på fremtiden ved siden av og etter oljen.

– Vi må utnytte vår høykompetanse innenfor nye fagområder, sikre innovasjon av ny energi, innenfor havbruk og applaudere gründere som tør å se nye muligheter. Selskapets undersøkelser viser at 30 prosent av norske arbeidsgivere sliter med å finne riktig kompetanse. Globalt er tallet enda høyere – hele 38 prosent.

– Både i Norge og globalt er det yrkesfaglærte som troner på topp med tanke på hvor det er mangel på kompetanse. Som en god nummer to kommer ingeniører. Selv om vi i Norge i dag ser at flere ingeniører mister jobben, er de innenfor flere områder fortsatt en stor mangelvare, særlig infrastruktur.

Gerd Kristiansen, LO

LO-lederen mener det er behov for en ny, norsk industripolitikk, som tar hensyn til behovet for automatisering.

– Det er liten tvil om at det kommer til å bli færre industriarbeidere som følge av den teknologiske utviklingen. Noen måter å jobbe på, vil bli borte. Men samtidig vil det dukke opp mange nye måter å arbeide på, blant annet vil vi trenge mange nye operatører. At Norge har «sovet i teknologitimen», er hun ikke helt enig i.

– En liten nasjon med fem millioner innbyggere kan ikke være best i alt. Vi må peke på hva vi er best på, og satse enda mer på det, sier hun.

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20 — TORSDAG 26. MAI 2016 — VG

Svulst — MED ULTRALYD

Svulst — UTEN ULTRALYD

***FORSKJELL:** Hos musen til venstre har det selvlysende teststoffet trengt inn i svulsten etter behandling med ACT og ultralyd. Hos musen til høyre har man ikke brukt ultralyd, da trenger ikke teststoffet inn i svulsten. Musene er påført prostatakreft, men i benet.* Foto: NTNU

Ny metode kan bli kreftkur

Forskere leverer cellegiften rett i svulsten

***GJENNOMBRUDD:** Her er teamet bak forsøket ved NTNU i Trondheim; fra v. professor Catharina de Lange Davies, postdoktor Annemieke van Wamel og forsker Andreas Åslund. Musene som var med i forsøket er, som reglementet krever, avlivet. Musen på bildet var ikke med i forsøket.* Foto: STEIN ROAR LEITE, NTNU

Av STELLA BUGGE

Med treffsikker levering av cellegift ved hjelp av bobler og ultralyd, har norske forskere klart å kurere kreft hos mus.

Nå håper de å kunne prøve den oppsiktsvekkende metoden på mennesker i 2018.

I en forsøksstudie ble samtlige dyr enten kvitt kreftsvulsten fullstendig, eller den sluttet helt å vokse. Det skriver Gemini.no som presenterer forskningsnytt fra NTNU og SINTEF, og som først omtalte saken.

Av de ni musene med prostatakreft som ble behandlet med ACT-metoden (Acoustic Cluster Therapy) ble seks mus helt kreftfrie mens svulsten sluttet å vokse hos de resterende tre.

– Det er veldig lovende resultater vi nå har fått. Metoden bidrar til at behandlingen blir mer spesifikk mot kreftsvulsten og dermed kan bivirkningene som cellegift gir, bli redusert, sier professor Catharina de Lange Davies ved Institutt for fysikk ved NTNU til VG.

Hun mener resultatene er så oppsiktsvekkende gode at pasienter må få denne behandlingen så raskt som overhodet mulig.

– Det er en lang prosess, men målet er at vi kan starte den første utprøvingen på mennesker i 2018, sier Davies.

Gemini skriver at forskningen er et samarbeid mellom NTNU, Phoenix Solutions AS og The institute of Cancer Research i London.

Slik går det til

Forskerne bruker mikrobobler av gass koblet med mikrodråper av olje i kombinasjon med fokusert ultralyd for å få cellegiften dit den trengs, nemlig inn i selve kreftsvulsten. En bitte liten negativt ladet gassboble kobles sammen med en like liten positivt ladet oljedråpe, og slike «clustere» eller klynger injiseres i blodet.

Når «klyngene» kommer frem til kreftsvulsten, utsettes de for ultralyd som får boblene til å vokse slik at de blokkerer blodårene. En ny runde ultralyd får boblene til å vibrere og når pasienten nå får cellegift vil denne kunne passere veggen i blodåren og ut i selve kreftsvulsten.

– Boblen trykker på åreveggen og gjør den mer «lekk» slik at legemiddelet går gjennom åreveggen og «dytter» den videre fram til kreftcellene, forklarer Davies.

Davies håper at metoden etter hvert kan brukes på kreft som ikke kan opereres i bukspyttkjertelen, bryst og prostata.

Hjernesvulster

Metoden ser også ut til å kunne brukes til å levere kreftmedisin til svulster i hjernen, noe som er veldig vanskelig fordi blodårene i hjernen danner en barriere for å hindre fremmedlegemer å komme fra blodårene til hjernecellene.

Forhistorien til ACT var kontrastmidler for medisinsk diagnostisering utviklet hos tidligere Nycomed.

Tre gründere opprettet firmaet Phoenix Solutions AS som nå i tre år har videreutviklet denne teknologien mot terapi bruk. Daglig leder er Per Sontum, kjemiker med en doktorgrad i farmasi, som i en årrekke jobbet med kontrastmidler hos Nycomed.

– Når kan dette bli et regulært tilbud til kreftpasienter?

– Ja, det er selve «kongespørsmålet», er det ikke? Dersom virkningsgraden er eksepsjonell, kan vi få en såkalt «fast track» hos legemiddelmyndighetene. Da kan vi slippe å gjennomføre en såkalt fase tre studie som gjerne tar to-tre år. Skjer det, kan vi ha dette på markedet i 2021 eller 2022 om vi er svært optimistiske, sier Sontum.

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Vil foreta utprøving på mennesker om to år

NTNU ultrasound research group combining research and physical activity at the annual strategic group meeting

CIUS ANNUAL ACCOUNTS FOR 2016

The annual account for 2016 deviated from the original budget, which can be attributed to slower start-up and less in-kind contributions from of the corporate partners.

FUNDING (in 1000 NOK)	Amount
Research Council Grant	4 979
Host Institution (NTNU)	2 008
Research Partners/Public funding*	7 828
Corporate Partners/Private funding**	13 532
Total	**28 347**

COSTS (in 1000 NOK)	Amount
Host Institution (NTNU)	11 737
Research & Development Partners*	5 233
Industry Partners**	11 377
Equipment	0
Total	**28 347**

* SINTEF, University of Oslo, University college of southeast Norway, Helse Midt Norge RHF, St. Olavs University Hospital HF, Nord-Trøndelag Hospital Trust

** Statoil Petroleum AS, GE Vingmed Ultrasound AS, Archer – Bergen Technology Center AS, Sensorlink AS, Phoenix Solutions AS, InPhase Solutions AS, Kongsberg Maritime AS, Halfwave AS, Aurotech Ultrasound AS, X-Fab Semiconductor Foundries AS, Medistim ASA

Ultrasound test phantom at the utrasound lab at NTNU

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