2016 2024

FINAL REPORT

CIUS

Centre for Innovative Ultrasound Solutions

sfi Centre for Research-based Innovation

cius

NTNU Norwegian University of Science and Technology

Academic Partners

NTNU Norwegian University of Science and Technology

SINTEF

UiO : University of Oslo

USN University of South-Eastern Norway

Industry Partners

equinor

Archer

AUROTECH ULTRASOUND

InPhase Solutions

GE HealthCare

MEDISTIM

Re{Lab}

KONGSBERG

NDT GLOBAL

Sensorlink

EXACT THERAPEUTICS

xfab

Health Sector Partners

HELSE MIDT-NORGE

HELSE NORD-TRØNDELAG

ST. OLAVS HOSPITAL TRONDHEIM UNIVERSITY HOSPITAL

SØRLANDET SYKEHUS

Levanger kommune

VERDAL KOMMUNE

Associated Partner

FFI Forsvarets forskningsinstitutt
Norwegian Defence Research Establishment

Host

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

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Svein-Erik Måsøy

Centre Director

Norwegian ultrasound industry and academia is world leading within its application areas in medicine, maritime (sonar), and oil & gas. The Centre for Innovative Ultrasound Solutions (CIUS), a Centre for Research Based Innovation (CRI) under the aegis of the Research Council of Norway (RCN), has been a great success. A large portion of the Norwegian ultrasound community, encompassed by the center partners and external collaborators, have strongly increased their collaboration across industry, academia, and the public sector. The center and its collaborators have generated more than 500 research articles (peer reviewed and conference papers), developed 48 specific innovations, and industrialized and commercialized several of these into the global market or as tools used within our partners operations. We have licensed 8 of our innovations to our partners, several (beyond those already finalized) of which are currently being developed into new products.

We have developed and built a strong community and culture focusing on innovation from research, which for us, means anything any partner in CIUS can use in their products, processes, or services. Innovation can be defined as gathering a group of people to solve real-world problems. Thinking innovation in everything we do has been at the core of our success. We have achieved this by developing our projects in strong collaboration with our industrial and public partners, focusing on their needs and how we can solve these through focused research and translation of research to innovations. This means that the innovation aspect must be part of the thinking and the process from the very start of all projects.

Fostering a culture of this sort requires continuity and time, and 8 years goes fast. It took some time to truly master this skill and to develop a culture of innovation and sharing across the CIUS teams. Now as the final phase of the project is over, it is clear that we really started to get the hang of this, we unfortunately have no time left. Still, what we have developed does not go away, the 43 PhDs and Post Docs we have funded and trained in the center, the additional 68 PhDs and Post Docs affiliated with center activities, the 109 master and research students that has been coupled to CIUS, the many researchers and research and development (R&D) personnel from our partners have acquired a taste of what such collaboration can foster. We will all bring this with us as we are continuing to innovate for the future.

Thank you so much to everyone that in one way or the other has been involved in CIUS and made such a great impact and lasting mark on our fantastic Norwegian ultrasound community.

CIUS is dead, long live CIUS!

Siri Forsmo

Dean

Brita Pukstad

Vice Dean

It has indeed been an exciting journey to be host for CIUS all these years, and we are proud to have been a part of the huge amount of research, innovation and knowledge that has emerged from this outstanding center.

It has indeed been an exciting journey to be host for CIUS all these years, and we are proud to have been a part of the huge amount of research, innovation and knowledge that has emerged from this outstanding center.

Knowledge for a better world is NTNU's strategy, and our strength lie in our competence in science and technology. Great results are achieved through interdisciplinary and collaborative work. Centers for research-based innovation, such as CIUS, have been an important part of this.

Health for a better world is the strategy of the Faculty of Medicine and Health Sciences. Our aim is to develop knowledge, skills and solutions that contribute to good health through research, education, innovation, and dissemination while staying true to the UN Sustainable Development Goals. As war in Europe threatens democracy, we see more than ever how important it is to have a global perspective and awareness of ethical responsibilities and integrity in our activities. We need to find ways to enable a fairer distribution of knowledge and resources, fight inequality and strengthen our commitment to address the challenges in global health and climate change. Continuing our focus on innovation and collaboration between academia, industry and the public sectors will be important to achieve this.

CIUS have embraced the strategies at NTNU, and with this created impact and great value in working with ultrasound technologies across different academic fields in collaboration with industrial partners. Many thanks to everyone in CIUS who has contributed, and best of luck with future plans to continue this journey.

Eva Nilssen
Board Leader

The intention of the CIUS research program was to create innovations. Innovation is not just an invention; it is an invention that is of use for some-body, in this context primarily the Norwegian industry. Which means that there is a need for close collaboration between academia and industry, we need to work together to solve challenging problems. It requires some effort: The participants need to be aligned about what it is we want to achieve. So how to do this successfully? Does the industry present their problem to the university and the researchers goes back to their desk at the university and come back after some months (years?) with a solution? This may work, but it is probably not going to create the best innovations. In CIUS we have tried to work as an integrated team, with seamless discussions between the researchers in academia and industry. And with the users, such as for example medical personnel at St. Olavs hospital. The research results are prototyped into products and tried out in real life situations during the invention of the new methods: does it work, does it need some tweaks and optimizations, or is it a failure?

It does takes time to understand and to realize the value of CRI cooperation. There is what we can call a "collaboration competency" in these types of projects. This competency is developed over time, in the partner institutions and for the individual participants. As such, the members of CIUS have gained quite a lot of experience over the past 8 years, experience which can be used for other collaboration projects in the future.

At the start of CIUS in 2016, the industry partners had different starting points; Healthcare partners had participated in the MiLab CRI, and CIUS was to some extent a continuation project, while O&G and Maritime partners were new to the consortium. One lesson learned from MiLab, was that we need early user evaluation of the research results. We in GE HealthCare therefore started early collaboration with St. Olavs hospital, and thanks to great engagement and involvement by the clinicians who actively prioritizing evaluation of CIUS research results, we have been able to realize inventions earlier and with better results than what otherwise would have been possible.

For Oil & Gas and Maritime, it took some time to get to know and understand the structure and the organization, but gradually CIUS has become quite beneficial also to the non-Healthcare partners, with closer loop between research results and user utilization. The CIUS consortium is also great for network building, both with the academic institutions and with the ultrasound businesses in Norway, facilitating technology and business models discussions and to find new collaborators inside and outside CIUS research projects.

One of our key goals with CIUS was to utilize synergies between the different partners, in Oil & Gas, Healthcare and Maritime business areas. This has worked quite well in both WP1 and WP2, for electronics, transducer, and beamforming techniques with benefits for partners from all business areas. Examples: Common electronic components for healthcare and maritime, at NTNU. Common transducer technology for Healthcare, Maritime and

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

Oil & Gas at USN. Common beamforming technology for Healthcare and Maritime at UiO. And for all of us, the introduction of AI, of course.

The socioeconomic value of trust is discussed a lot these days. We are operating in Norway, a country with high degree of trust so we have a good starting point. But, in a project such as CIUS, this is not trivial and requires constant attention. We must make sure that the partners in a project understand and respect that there are different needs in academia than in industry and that sometimes these needs are conflicting. Such conflicts need to be discussed and resolved, always keeping in mind the mutual benefit of the CIUS activity. Academia may want to publish "everything" as this is one of the primary goals for a PhD candidate. However, the company survival may be dependent on keeping some of its core technology secret. Also, some of the technology we in the industry want to keep secret, is often the technology which is most interesting for research. And has the highest potential for success, both research wise and commercially. Which means that we must find a solution for both parties if we are going to succeed. It is my experience that although these discussions can be difficult and quite challenging, having these discussions often bring us to the next level of understanding and respect, done in an atmosphere of trust and respect for the other part's needs.

CIUS has also been good place for recruitment. Through the close collaboration in CIUS, the industry learns to know candidates for potential employment. And the candidates get to know the industry and potential future colleagues. The dissemination of knowledge is of great value, researchers in CIUS have access to state-of-the-art equipment, tools, and highly competent industry personnel thus being able to make the right trade-offs and to choose the solutions which has the greatest impact in real life situations. And this it the biggest commercial value benefitting Norwegian industry. Many CIUS researchers have been hired by the industry partners. This is proof that competency from the CIUS project is relevant and of great value to the industry partners. These researchers also create a bridge between academia and industry which is a foundation for continued cooperation in the future.

The development of competency and contacts between industry partners and academia in a project such as CIUS, is important for the Norwegian ultrasound industry. There is great potential for innovative solutions securing continued activity in existing companies as well as creation of new industry companies. The flat organization and easy access to expertise as we see example of in CIUS, is one of our greatest assets in Norway. Let's utilize this for improved competitiveness, for all of us.

Summary

The Centre for Innovative Ultrasound Solutions has brought together key Norwegian ultrasound environments in medicine, maritime, and the oil and gas industry. These are industrial areas where Norway has globally leading technology companies. These are also areas where Norwegian academia is internationally recognized and world leading, largely because of the connection between industry and academic institutions (including research institutes and public institutions such as hospitals and government institutes). Engineers and technical personnel working in these domains regularly switch jobs between the different areas, showing that the basic technological competence required is the same in all areas, although the application areas are very different.

The goal of CIUS has been to build on this to maintain and further the Norwegian ultrasound industry and academic environments position in a fierce competitive global market. It is not given that Norway, being such a small country, can uphold its international standing without closer collaboration and a strong focus on research and innovation (R&I). The support of the CRI program has been instrumental for this effort, and CIUS has definitely served its main goals which has been:

1. To be a world-leading center 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 center for ultrasound technology to ensure sufficient competence and recruitment needed by Norwegian industries, academia, and the health care sector.

The total CIUS budget has been 380 MNOK, where 160 MNOK represents cash contributions (96MNOK from the Research Council of Norway) and 220 MNOK in-kind contribution from the partners. CIUS and its collaboration partners have published more than 500 research articles (both peer reviewed and conference papers), many of these co-authored with international collaborators and our industry partners. 43 PhDs and Post Docs have been trained by the center directly and 63 PhDs and 5 Post Docs externally funded have collaborated with activities in CIUS. The center has had 28 researchers on its payroll, and 12 visiting and related researchers to center activities. From 2019 to 2023 an average of 80 R&D personnel from our industry partners have been in daily, weekly, or monthly contact with our projects. 109 master and research students have been associated with the center. We have developed 117 new or improved methods, models or prototypes. Many of these concepts have been tested by our partners and many will also be continued beyond the center time frame. Our researchers and partners have reported 48 Declaration OF Invention's (DOFIs). Currently 8 of these are licensed by our industrial partners for potential commercial

use. Two of these licenses are already commercialized in 6 products with a global reach. One license is used by a company in an internal process. CIUS have registered 2 patents, but our partners have not generally been interested in patents. The spin-off company ReLab was co-founded by one of our PhD candidates but did not succeed in their business venture and has been closed down.

More detailed testimonies about our projects and successes can be found in the Stories section of this report.

Our results are a clear answer to our primary goals as stated above; CIUS represents a world leading center for research and innovation in ultrasound, as documented by the sheer amount of publications we have made; we have strengthened and furthered the innovation culture within the Norwegian ultrasound community with a clear focus on innovation from research; we have succeeded with innovations already in the market, and several more are on their way; we have recruited and trained a large amount of people to work within our areas of interest, a critical factor for us continuing to maintain the position as an international leading environment; our partners have believed in this effort committing 284 MNOK to CIUS in in-kind and cash contributions.

International collaboration has been important for the center and is clear from our many publications co-authored with international researchers. The center has collaborated with many universities and international subsidiaries of our partners around the world (see International cooperation section). Several of these collaborations have been developed to deep relationships which will endure long after the center has finished its activities. One example is the collaboration with The Hospital for Sick Children in Toronto and the University of Toronto, Canada, where the projects are centered around heart disease for both the unborn and small children. The research from CIUS in this area has the potential to develop new diagnostic tools for children which are born with heart disease. This may also lead to innovations coming to the marked long after the center has finished, but still, crucially dependent on the activities that has taken place in CIUS. Such is the game of research and innovation; it may take a very long time due to all the challenges that must be solved.

Working with innovation from research is a risky endeavor. It is by no means sure that it will succeed, and a critical part of the CRI scheme, as we see it, is to reduce this risk. This is a collaborative effort between the public and private sector.

Having a large center with a long horizon provides the time to develop strong collaborative ties, which are based on trust, and a culture for innovation. This is by no means a simple feat and requires constant attention and a great deal of involvement from the participating partners and people working in the center. This represents the strongest feature of the center model as we see it.

CIUS would like to thank the Research Council of Norway for developing this visionary model of innovation collaboration, and for supporting us in our endeavor, and we believe that the bonds made between the partners during our 8 years of operation will endure and strengthen going from here. We already see several bonds developed being continued in new partnerships and collaborative efforts. Crucially, the people trained from the center has started working with our partners and comes back to collaborate with the academic environments they once were part of. Also, many of our partners are following up on innovation ideas from the center and are actively seeking new projects together, and we are planning to apply for a new CRI grant.

CIUS and its collaboration partners have published more than 500 research articles, many of these co-authored with international collaborators and our industry partners

Sammendrag

Centre for Innovative Ultrasound Solutions har samlet sentrale norske ultralydmiljøer innen medisin, maritim og olje- og gassindustrien. Dette er områder hvor Norge har verdensledende teknologibedrifter. Dette er også områder hvor norsk akademia er internasjonalt anerkjent og verdensledende, mye på grunn av sammenhengen mellom industri og akademiske institusjoner (inkludert forskningsinstitutter og offentlige institusjoner som sykehus og statlige institutter). Ingeniører og teknisk personell som jobber i disse domenene bytter jevnlig jobb mellom de ulike områdene, noe som viser at den grunnleggende teknologiske kompetansen som kreves er den samme på alle områder, selv om bruksområdene er forskjellige.

Målet til CIUS har vært å bygge videre på dette for å opprettholde og videreføre norsk ultralydindustri og akademiske miljøers posisjon i et hardt konkurranseutsatt globalt marked. Det er ikke gitt at Norge, som et lite land, kan opprettholde sin internasjonale status uten tettere samarbeid og et sterkt fokus på forskning og innovasjon (FoI). Støtten til SFI-programmet har vært avgjørende for denne innsatsen, og CIUS har definitivt oppnådd hovedmålene som har vært:

1. Å være et verdensledende senter for forskning og innovasjon innen neste generasjons ultralydavbildning, forbedring av pasientbehandling, høsting av havressurser, og for miljøovervåking og sikkerhet.

2. Å forlenge og styrke innovasjonskulturen med vekt på rask translasjon fra idé til praktiske anvendelser og løsninger som trengs for å legge til rette for ny vekst i næringene.

3. Være det viktigste utdannings- og kunnskapssenteret for ultralydteknologi for å sikre tilstrekkelig kompetanse og rekruttering til norsk industri, akademia og helsesektor.

Totalt har budsjettet i CIUS vært på 380 MNOK, hvor 160 MNOK representerer kontantbidrag (96 MNOK fra Norges forskningsråd) og 220 MNOK «in-kind» bidrag fra partnere. CIUS og samarbeidspartnerne har publisert mer enn 500 forskningsartikler (både fagfellevurdert og konferanseartikler), hvor mange er skrevet sammen med internasjonale samarbeidspartnere og våre industripartnere. 43 PhD og Postdoktorer har vært internt finansiert av senteret, mens henholdsvis 63 og 5 PhD og Postdoktorer har vært eksternt finansierte og samarbeidet med aktiviteter i CIUS. Senteret har hatt 28 forskere på lønningslisten, og 12 besøkende og relaterte forskere. Fra 2019 til 2023 har i snitt 80 FoI personer fra våre industripartnere vært i daglig, ukentlig eller månedlig kontakt med våre prosjekter. 109 master- og forskerlinjestudenter har vært assosiert med senteret. Vi har utviklet 117 nye eller forbedrede metoder, modeller eller prototyper. Mange av disse konseptene har blitt testet av våre partnere og mange vil bli videreført utover senterets tidsramme. Våre forskere og partnere har rapportert 48 oppfinnelse, eller «Declarations of Inventions» (DOFI'er). For tiden er 8 av disse lisensiert av våre industrielle partnere for potensiell kommersiell bruk. To av disse 8 lisensene er kommersialisert i 6 produkter med global rekkevidde. En lisens brukes av et selskap i en intern prosess. CIUS har registrert 2 patenter, men våre partnere har generelt ikke vært interessert i patenter. Spin-off selskapet ReLab ble medstiftet av en av våre PhD kandidater, men lyktes ikke i sin forretningssatsing og har blitt lagt ned.

Mer detaljerte historier om våre prosjekter og suksesser finner du i «Stories» delen av denne rapporten.

Resultatene våre er et klart svar på våre primære mål som nevnt ovenfor; CIUS representerer et verdensledende senter for forskning og innovasjon innen ultralyd, som dokumentert av den store mengden publikasjoner vi har fått frem; vi har styrket og videreført innovasjonskulturen i det norske ultralydmiljøet med et tydelig fokus på innovasjon fra forskning; vi har lykkes med innovasjoner som allerede er i markedet, og flere er på vei; vi har rekruttert og trent en stor mengde mennesker til å jobbe innenfor våre interesseområder, en kritisk faktor for at vi skal fortsette å opprettholde posisjonen som et internasjonalt ledende miljø; våre partnere har bidratt til denne innsatsen ved å forplikte 284 MNOK til CIUS i form av «in-kind»-støtte og kontantbidrag.

Internasjonalt samarbeid har vært viktig for senteret og fremgår tydelig av våre mange publikasjoner i samarbeid med internasjonale forskere. Senteret har samarbeidet med mange universiteter og internasjonale datterselskaper av våre partnere rundt om i verden (se avsnittet «International cooperation»). Noen av disse samarbeidene er utviklet til dype relasjoner som vil vare lenge etter senteret er ferdig med sin virksomhet. Et eksempel er samarbeidet med The Hospital for Sick Children i Toronto og University of Toronto, Canada, hvor prosjektene er sentrert rundt hjertesykdom for både ufødte og små barn. Forskningen fra CIUS på dette området har potensiale til å utvikle nye diagnostiske verktøy for barn som er født med hjertesykdom. Dette kan også føre til at innovasjoner kommer til markedet lenge etter at senteret er ferdig, men de har likevel vært avhengig av aktiviteten som har funnet sted i CIUS. Slik er spillet med forskning og innovasjon, det kan ta veldig lang tid på grunn av alle utfordringene som må løses.

Å jobbe med innovasjon fra forskning involverer høy risiko. Det er på ingen måte sikkert at prosjektene vil lykkes, og en kritisk del av SFI-ordningen, slik vi ser det, er å redusere denne risikoen. Dette er et samarbeid mellom offentlig og privat sektor. Å ha et stort senter med lang horisont gir tid til å utvikle sterke samarbeid, som er basert på tillit, og en kultur for innovasjon. Dette er på ingen måte en enkel oppgave og krever konstant oppmerksomhet og stort engasjement fra partnerne og menneskene som jobber i senteret. Dette representerer den sterkeste egenskapen til sentermodellen slik vi ser det.

CIUS ønsker å takke Norges Forskningsråd for å ha utviklet denne visjonære modellen for innovasjonssamarbeid, og for å støtte oss i vårt arbeid, og vi tror at båndene mellom partnerne i løpet av våre 8 år vil bestå og forsterkes herfra. Vi ser allerede at flere bånd som har blitt utviklet videreføres i nye partnerskap og samarbeid. De som er utdannet fra senteret har begynt å samarbeide med våre partnere og kommer tilbake for å samarbeide med de akademiske miljøene de en gang var en del av. Mange av våre partnere følger også opp innovasjonsideer fra senteret og søker aktivt nye prosjekter sammen, og vi planlegger også å søke om et nytt SFI senter.

CIUS og samarbeidspartnerne har publisert mer enn 500 forskningsartikler, hvor mange er skrevet sammen med internasjonale samarbeidspartnere og våre industripartnere

RESULTS

CIUS KEY FIGURES 2016-2024

44 new/improved products/ processes/services finalized

117 new/improved methods/ models/prototypes finalized

2 patents registered

48 number of DOFIs reported

2 new business activity

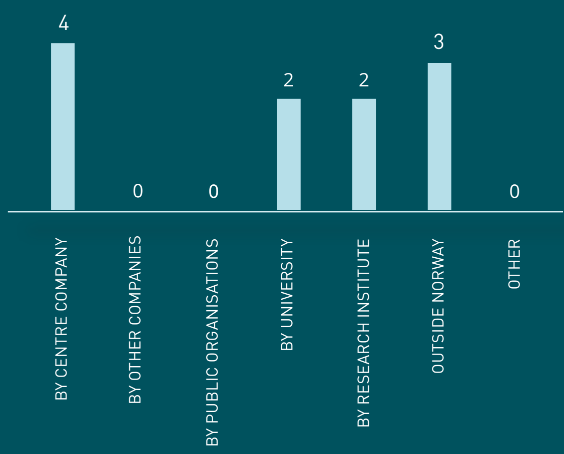
8 signed licenses with industrial partners

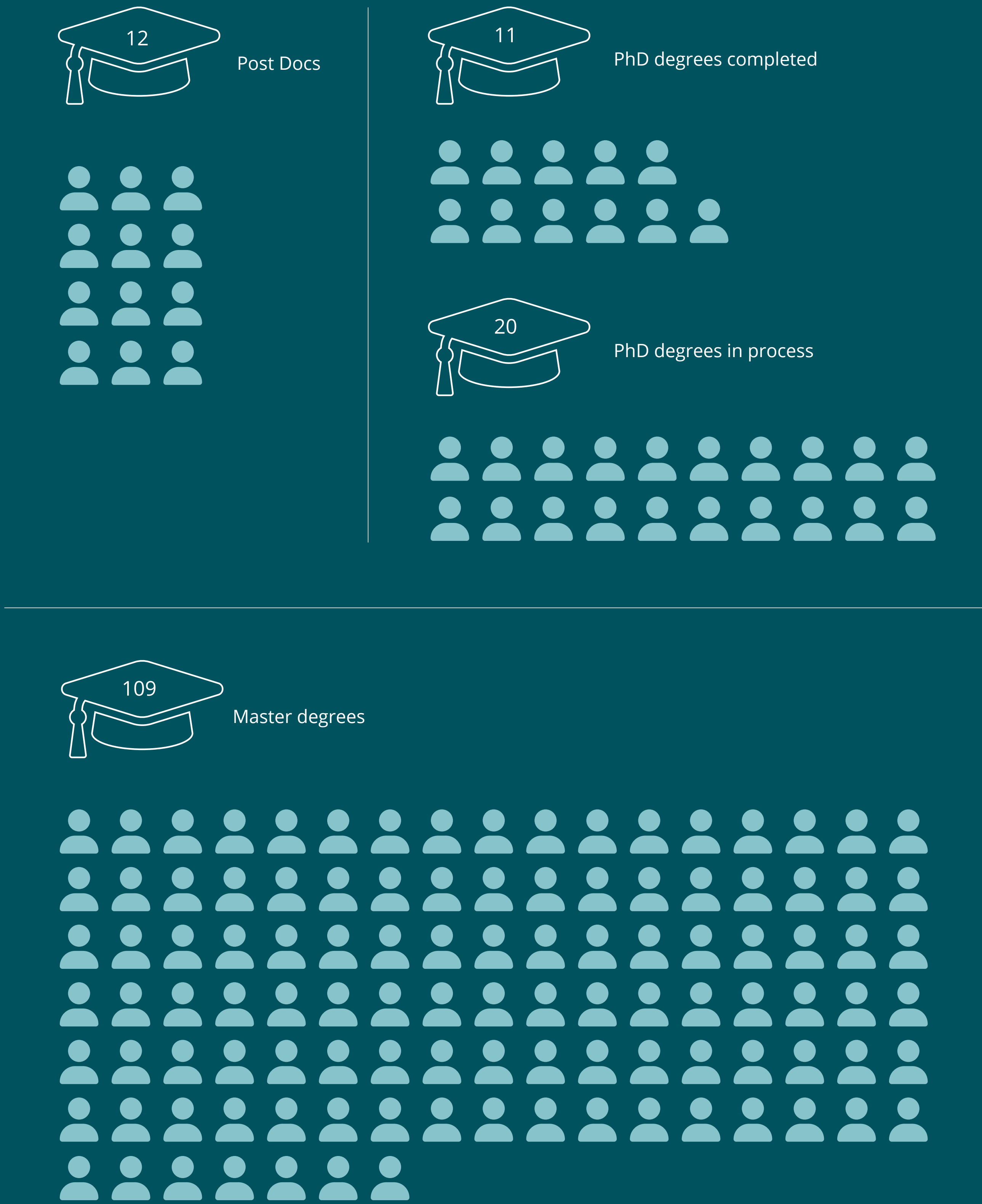
533 scientific publications (article, article in book, book/report)

473 dissemination measures for users

265 dissemination measures for the general public

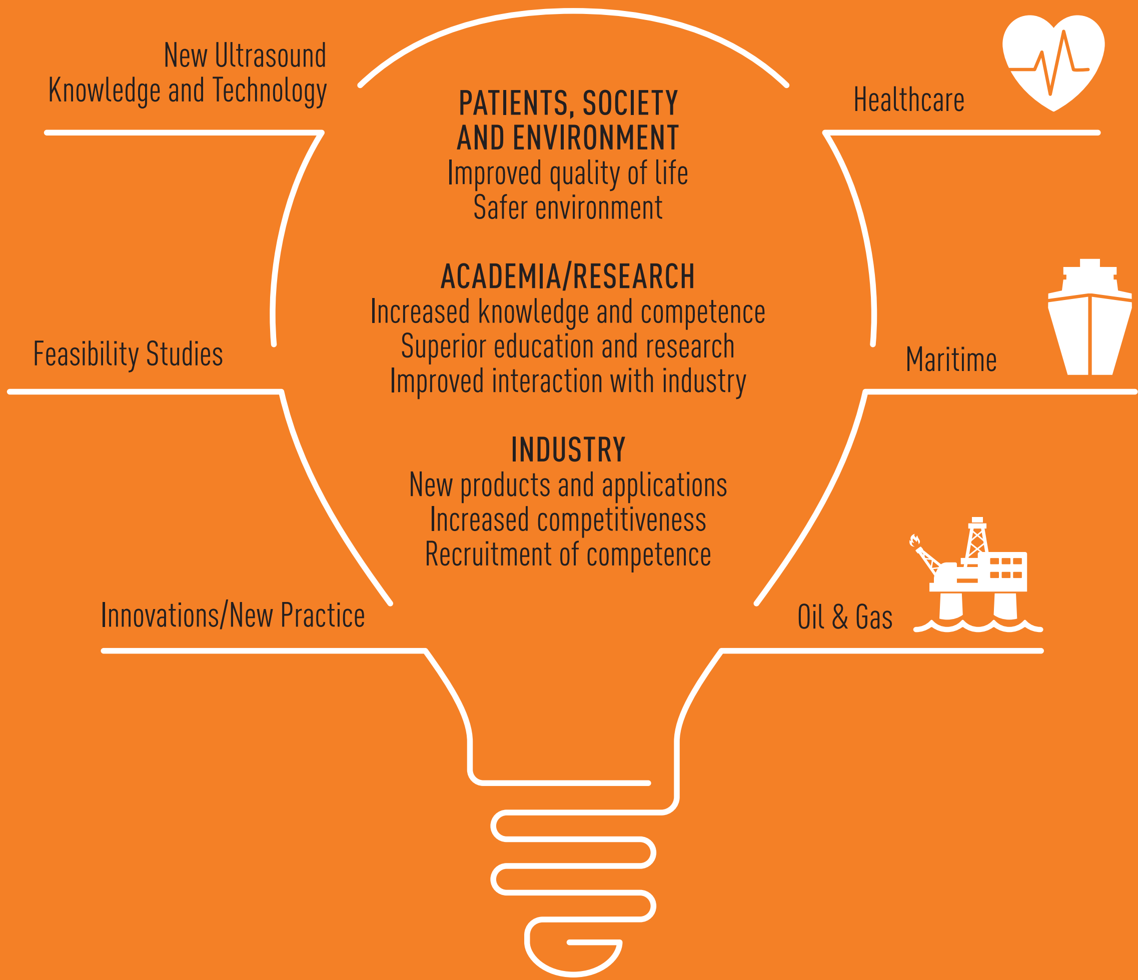
Employment of PhD candidates - Total 11




12
Post Docs
11
PhD degrees completed
20
PhD degrees in process
109
Master degrees

CIUS Idea

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



Vision and objectives

The motivation for CIUS was to join forces and explore synergies across disciplines, leveraging next-generation ultrasound technology within healthcare, maritime, and oil & gas applications. Key ultrasound research tasks were focused within transducer design, acoustics and image formation, Doppler, and deformation imaging, as well as image analysis and visualization. CIUS would by unique competence and innovations, secure long-term competitive advantage within areas where Norway is internationally recognized for excellent research, innovation, and product deliveries.

The main aims of CIUS have been

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.

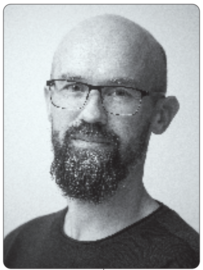
CIUS MANAGEMENT AND BOARD 2023/24

MANAGEMENT

Board Leader Eva Nilssen, GE Vingmed Ultrasound

Vice Dean Brita Solveig Pukstad, NTNU

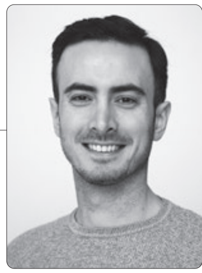
Centre Director Svein-Erik Måsøy, NTNU



ELECTED BOARD REPRESENTATIVES AMONG THE CORPORATE PARTNERS

Erik Swensen, Medistim

Hanne Martinussen, Sensorlink



Ali Fatemi, Sensorlink

APPOINTED BOARD REPRESENTATIVES

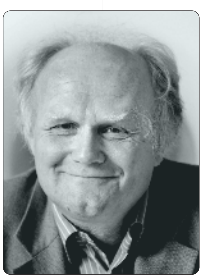
Kjell Salvesen, NTNU

Trym Holter, NTNU

Helge Haarstad, St. Olavs hospital

Pål Hemmingsen, Equinor

Frank Tichy, Kongsberg Maritime



Olav Haraldseth, NTNU

Kerstin Bach, NTNU

CIUS MANAGEMENT AND BOARD 2016–2024

MANAGEMENT

Board leader Eva Nilssen, GE Vingmed Ultrasound (2016-2024)
Dean Bjørn Gustafsson, NTNU (2016-2019)
Dean Siri Forsmo, NTNU (2020-2024)
Vice Dean Brita Solveig Pukstad, NTNU (2020-2024)
Centre director Asta Håberg, NTNU (2016-2021)
Centre director Svein-Erik Måsøy, NTNU (2022-2024)
Industry Liason Svein-Erik Måsøy, NTNU (2017-2024)

ELECTED BOARD REPRESENTATIVES AMONG THE CIUS CORPORATE PARTNERS

Dag Håkon Frantzen, Archer BTC (2016-2018)
Petter Norli, Halfwave (2019-2021)
Hanne Martinussen, Sensorlink (2022)
Ali Fatemi, Sensorlink (2023-2024)
Erik Swensen, Medistim (2016-2024)

APPOINTED BOARD REPRESENTATIVES

Fredrik Varpe, Statoil (2016-2017)
Petter Aadahl, St.Olav (2016-2017)
Berit L Stand, NTNU (2016-2021)
Dag Økland, Equinor (2018-2019)
Gunnar Morken, St.Olav (2019–2021)
Pål Hemmingsen, Equinor (2019-2024)
Frank Tichy, Kongsberg Maritim (2016-2024)
Olav Haraldseth, NTNU (2016-2024)
Helge Haarstad, St.Olav (2021-2024)
Trym Holter, NTNU (2021-2024)
Kjell Salvesen, NTNU (2022-2024)
Kerstin Bach, NTNU (2023-2024)

SCIENTIFIC ADVISORY BOARD

Dr. Iacob Mathiesen, CSO, Otivio, Oslo (2017-2024)
Professor Jenny Dankelman, MISIT Group, Delft University of Technology (2017-2024)
Dr. Philippe Blondel, Senior Lecturer, University of Bath (2017-2024)
Anna Shaughnessy, previous Director of Earth Resources Laboratory, MIT (2017-2024)

WORK PACKAGE SUPERVISORS

Hefeng Dong, NTNU (2016-2024)
Trond Ytterdal, NTNU (2016-2024)
Tonni Franke Johansen, NTNU/Sintef (2016-2024)
Catharina de Lange Davies, NTNU (2016-2024)

WP LEADERS

WP1: Lars Hoff, USN (2016-2024)
WP2: Sverre Holm, UiO (2016-2024)
WP3: Hans Torp, NTNU (2016-2021),
Jørgen Avdal, NTNU (2022-2024)
WP4: Lasse Løvstakken, NTNU (2016-2024)
WP5: Asta Håberg, NTNU (2016-2024)
WP6: Bjørn Olav Haugen, NTNU (2016-2019),
Ole Christian Mjølstad, NTNU/St.Olavs (2020-2024)
WP7: Bjørn Olav Haugen, NTNU (2016),
Asbjørn Støylen, NTNU (2017-2022),
Bjørnar Grenne (2023-2024)
WP8-9: Svein-Erik Måsøy (2017-2024)

INNOVATION TEAM

Svein-Erik Måsøy (2017–2024)
Tormod Njølstad (2018–2021)
Svein-Erik Gaustad (2022–2024)

ADMINISTRATION

Project coordinator:
Christina Kildal (2016-2019)
Marthe Charlotte Solbu (2019)
Line Skarsem Reitlo (2020-2024)

Project economist:
Eirik Dønjar (2016)
Vegard Nyhus (2017-2020)
Alexandra Skorobogataia (2020-2023)
Urszula Mochocka (2021-2022)
Ask Angellsen (2024)

Web & Communication:
Karl Jørgen Mathinsen (2018-2021)
Kari Williamson (2016-2023)

Research Partners

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

ACADEMIC PARTNERS

Norwegian University of Science and Technology (NTNU) (2016-2024)
SINTEF (2016-2024)
University of Oslo (UiO) (2016-2024)
University of South-Eastern Norway (USN) (2016-2024)

INDUSTRY PARTNERS

AUROTECH ultrasound AS (2016-2024)
Archer - Bergen Technology Center (2016-2024) Equinor ASA (2016-2024)
EXACT Therapeutics (2016- 2024)
GE HealthCare, GE Vingmed Ultrasound AS (2016-2024)
GE Healthcare, Women's Health Ultrasound (2021-2024)
InPhase Solutions AS (2016-2024)
Kongsberg Discovery AS (2016-2024)
Medistim ASA (2016-2024)
Sensorlink AS (2016-2024)
X-FAB Semiconductor Foundries GmbH (2016-2024)
ReLab AS (2020-2021)
NDT Global (2016-2024)

HEALTH SECTOR PARTNERS

Helse Midt-Norge (Central Norway Regional Health Authority) (2016-2024)
Helse Nord-Trøndelag (Nord-Trøndelag Health Trust, Levanger Hospital) (2016-2024)
St. Olavs hospital (Trondheim university hospital) (2016-2024)
Innherred-samkommune (Innherred joint county primary health care) (2016-2024)
Sørlandet sykehus HF (Sørlandet Hospital health authority) (2019-2024)

ASSOCIATED PARTNER

Forsvarets forskningsinstitutt (Norwegian Defence Research Establishment) (2019-2024)

Sensorlink has success with their subsea corrosion monitoring systems based on ultrasound, and their products is continuously improved with the help from CIUS contributions. Photo: Sensorlink

Cooperation within the centre

To create innovations, people must come together to solve real-world challenges. This has been the main motivation behind all the projects within CIUS; to gather people in multi-disciplinary projects addressing challenges requiring a solution. This is to be framed within a research context, potentially leading to a commercialization.

The main point is to have the partner(s) involved in a CIUS project from the very beginning, and make sure they participate in both the design and development of the research project. This dramatically increases the potential of a possible commercialization as it both creates ownership and detailed understanding about the project. We have also linked this process to Technology Readiness Levels (TRL's), as a suggestion on the level of maturity of the projects.

When a CIUS project is started, we urge all involved parties to have regular meetings, no less than once a month. In CIUS we have had projects with partner involvement on a weekly, bi-weekly and monthly basis. Some projects have had overlapping interests with teams from several academic and partner institutions joining bi-weekly meetings encompassing 10-20 people. Other projects have had smaller concentrated teams meeting once a month to discuss status and updates. The partners in CIUS have also involved themselves in training of researchers, as many of the technologies and processes used are very specific to a partner, or industry, and where key competence and knowledge is to be found in the partners organizations. As an example, we have had several courses and seminars at Equinor about down-hole drilling and logging with many presentations from different experts. Also, CIUS researchers have given courses to industry partners, e.g., about AI and the newest developments. So, this effort has gone both ways.

When a project reaches maturity and step 2 and 3 in the CIUS innovation process, there is never a hand-off of the project to the partners. In our experience, the best result for piloting and further commercialization still requires involvement from the researchers. There are many unresolved issues and research tasks also required during commercialization. Also, when commercialization is a reality, this represents version 1.0 of a concept. Quite often, there is much research to be continued to improve the concept to a version 2.0 and 3.0 and so on.

The crown jewel of this process is the bi-yearly CIUS conference, which over the center period has had an average attendance of about 80-100 people at each meeting. This has been a unique forum where researchers, CEOs, CTOs, PhDs, MScs, developers, marketing teams, invited speakers, etc., have come together to present results, mingle, and discuss project opportunities and results. This meeting has been a huge success for the center as it has created a sense of a common goal, a "we are in this together" feeling. This has been particularly important for PhD and Post Doc candidates as they have been able to see and feel that their work is part of something bigger and may create actual impact in the world. Also, this has been a great arena for our partners to follow and recruit candidates.

THE CIUS INNOVATION PROCESS

1

Defining research-based innovation projects in collaboration with partners at PhD, Post Doc, and researcher level.

Lead: Principal investigators and researchers in collaboration with partners.
TRL: 1-6

2

Piloting and validating reported innovations

Lead: Industry partners in collaboration with researchers.
TRL: 7

3

Commercializing innovation

Lead: Industry partners, researchers providing input when required.
TRL: 8-9

All these efforts have led to a team feeling where projects can grow and cross between partners and researchers where opportunities arise. Many projects in CIUS still mostly have contained one partner at a time, some have had several, but the inspiration from all the small meetings, the seminars and workshops, and the bi-yearly meeting has fostered a CIUS family feeling where everyone can be inspired and motivated about the ongoing work. The core result of this is people getting to know one another well, again developing trust, the secret ingredient in making innovative collaboration between organizations work.

Photo: Kari Williamson

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.

To exemplify some of the collaborative efforts and fascinating projects that have been going on in CIUS we have collected a few examples in this section. If you are interested in reading more stories from CIUS, you may do so here: ntnu.no/blogger/cius/

Selected research projects

- Support for Improved Diagnostics by the use of Hand-held Ultrasound Device
- Ultrasound and AI improve salmon breeding and welfare
- Real-time project and real-life experience
- We built an AI tool to help avoid environmental disasters
- Researchers can thank gamers for better ultrasound images of the heart
- The hole story

How we have worked with innovation

- Innovation work in CIUS, see pages 42-47 in CIUS Annual report 2017
- The CIUS Innovation Game, see pages 44-45 in CIUS Annual report 2018
- Developing an Innovation to a Product – the CIUS Innovation Pathway and the Pilot, see pages 50-51 in CIUS Annual report 2019
- Translation from Academic Research into Practical Applications – fuelled by the CIUS licencing strategy, see pages 46-47 in CIUS Annual report 2020
- Blue skies innovation (2022), see CIUS blog

PhD Candidate, CIUS

Malgorzata Isabela Magelssen

Support for Improved Diagnostics by the use of Hand-held Ultrasound Device

Photo: Karl Jørgen Marthinsen

> Ultrasound can be hard to use for people without training, and today it has been an imaging technology reserved for dedicated sonologist and cardiologists. However, new technological progress can make ultrasound imaging more accessible for other medical personel. This can make the health care system much more efficient.

Malgorzata Isabela Magelssen is both a cardiologist at St. Olavs hospital in Trondheim and a PhD candidate at CIUS: "Our group has a clinical focus. We are evaluating new functions implemented in hand-held ultrasound devices in order to improve diagnostics in heart diseases," she says.

Evaluating Hand-held Ultrasound

"We are researching new possibilities for general practitioners to diagnose heart failure using hand-held ultrasound devices. In addition to a clinical examination, other diagnostic tools may be helpful in order to make a correct diagnosis."

170 patients with suspicion of heart failure have been included into the study. They are being examined by five general practitioners in addition to specialized nurses and specialists in cardiology. Their task is to determine whether the patients have heart failure. Magelssen explains that they are examined by the medical staff in three steps:

"First, the doctors and nurses examine the patient with a regular ultrasound image, using a handheld device.

"The next step is to enable the automatic measuring functions on the devices. This can guide inexperienced users to make a better decision whether the patient has heart failure."

The images taken by general practitioners are also sent to specialists in cardiology for evaluation. They give written feedback with a possible diagnosis.

"The general practitioners must consider the diagnosis after each step. Ultrasound by cardiologist has been used as a reference."

Research is important

Malgorzata went to medical school in Warsaw, Poland and graduated in 2006. After an internship, she first worked in Gothenburg, Sweden for a couple of years before permanently moving to Trondheim in 2010. Since then, she has worked in internal medicine at St.Olavs hospital.

"I've always had an interest in Cardiology and have worked as a MD at the clinic of Cardiology since 2015," she says.

"Research is a big part of the Clinic of Cardiology at St. Olavs hospital and we are always encouraged to get involved in research programs. I was interested in a clinical project with clear goals. This project suited me perfectly since it potentially can lead to an improvement in the diagnostic process of heart failure."

Utilization of Handheld Ultrasound can have Large Benefits

Patients with suspicion of heart disease are referred to a specialist for further diagnosis. Waiting lists are usually long and sometimes patients have a long way to travel to get to a specialist. However, Malgorzata is optimistic about the future of handheld ultrasound.

"The devices can potentially aid in the evaluation of patients suspected of having heart disease. The patients who need urgent care can be correctly prioritized and others might not need a referral. Also, hand-held ultrasound devices are a great asset in specialist health care, especially in the acute cases when you need a quick overview of the patient's clinical status.

The use of technology must be validated

"I think I'm a tech optimist, but I feel that it is very important that new technology is properly validated before it's used by the "masses". I'm convinced that in the future, medical imaging is used by more inexperienced users. It is therefore important that the tools available are reliable and that specialists are used for consultation when needed. I think that telemedicine will be used in a larger scale to assist in the diagnosis of heart diseases.

"I hope that our research will lead the way for further research in the area and possibly increased use of handheld ultrasound devices by general practitioners. Also, I hope it will lead to more research in more rural areas where the access to healthcare is scarce."

ULTRASOUND AND AI IMPROVE SALMON BREEDING AND WELFARE

Ultrasound combined with machine learning provides a new, smart, and more reliable way of estimating the maturation states of salmon with the aim of predicting the optimal timing for egg harvesting.

Ultrasound applied to fish is a new venture in CIUS. Yasin Yari is doing his PhD on ultrasound and machine learning for smart monitoring of maturation states in Atlantic salmon in collaboration with AquaGen, Mowi, and CIUS partner InPhase Solutions. His work builds on that of Dr. Ingun Næve (AquaGen), who developed several methods to screen Atlantic salmon maturation states using state-of-the-art medical ultrasound equipment.

Yasin Yari scanning a fish using ultrasound.

Estimating the Weight of the Ovary

The first task of Yari's PhD project is to measure the length and volume of the fish ovary and estimate its maturation state. The size gives an indication of the weight.

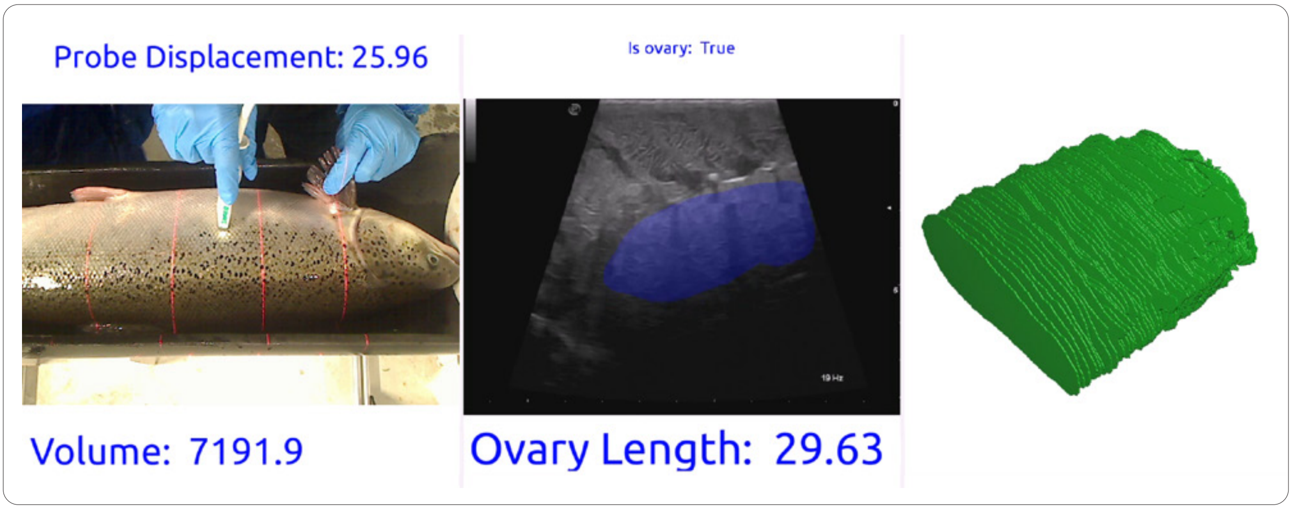
"We need to know the weight of the ovary in the fish. What we can do now is to use ultrasound to get a very good estimation of the weight of the ovary, and having that, we can predict when the fish will be ready for stripping," says Yari. Stripping is the removal of the eggs for further farming.

Current methods use an ultrasound probe along with a ruler to measure the length of the ovary manually, but Yari is combining machine learning and ultrasound to automate and improve the accuracy of these methods.

"We are developing a method that can recognise the ovary, measure its length and volume, and estimate the relative weight of the ovary to the fish weight," says Yari.

To use the automatic maturation estimation method more efficiently, there is a need for the automation of ultrasound image acquisition. So, the long-term plan is to scan the fish whilst in water.

"Scanning underwater removes both the need to take fish into the air and the stress associated with the scanning, which benefits fish health and welfare. Moreover, it simplifies the work and reduces the workload for the staff in the production department," Yari points out.



The figure shows real-time quantification of the ovary for predicting the maturation state: Fish being scanned (left); Real-time segmentation of the ovary in ultrasound (middle); 3D reconstruction of ovary (right). Illustration: Yasin Yari/NTNU.

Monitoring the Development of the Eggs
The second task in the PhD project involves smart screening of the development of the eggs. Using ultrasound scanning, it is possible to watch as a dark spot appears in the egg, grows bigger and, in the end, almost fully covers the egg. The fish is ready for stripping at this stage, and the belly will now become soft as the fish ovulates.

"Scanning underwater removes both the need to take fish into the air and the stress associated with the scanning, which benefits fish health and welfare."

"At the moment, the procedure is to take the fish out of the tank and check the belly by palpation. The fish is ready for stripping if the belly is soft, meaning the eggs are released. This must be done for each individual," says Yari.

He is optimistic that they can find a way of using the ultrasound image to see if the eggs have been released, avoiding the need for the demanding palpation procedure.

Ultrasound also enables them to see if there is a problem in the ovary. If there is blood in the ovary or eggs are not maturing as expected, the ultrasound image will reveal this, and the fish can be removed from the cage.

Measuring the Fat Content
Finally, the third task is to monitor the fat content of the muscle using ultrasound image analysis.

"The fat content of the fish determines whether the fish will go into the maturation process in that year or if it needs to wait another year to grow and produce more fat before entering the process. The muscle and deep-lying abdominal (visceral) fat content before maturation could perhaps say something about which individuals are more likely to mature, and it can be a selection criterion for broodfish candidates. As maturation progresses, energy stored as fat in muscles and viscera is used in the building of the eggs," explains Yari.

One challenge that Yari faces is the ultrasound probes, which are not customised for this task. Although common standard transducers are good enough to achieve reliable information, the ideal would be to have an ultrasound transducer that is customised for fish scanning.

Yasin Yari started his PhD in December 2020 and is set to complete it towards the end of December 2023. His supervisors are Professor Lasse Løvstakken at CIUS, Dr. Ingun Næve from AquaGen, Dr. Marco Marien Voormolen from InPhase Solutions, together with Dr. Per Helge Bergtun, who is a veterinarian from Mowi and Dr. Svein-Erik Måsøy who is the Director of CIUS.

By: Wenche Margrethe Kulmo

REAL-TIME PROJECT AND REAL-LIFE EXPERIENCE

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

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

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

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

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

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

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

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

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

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

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

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

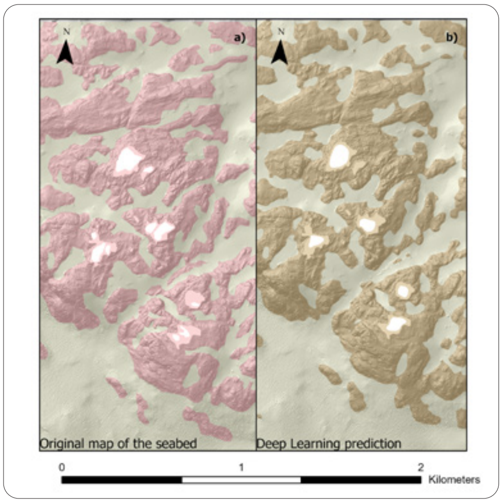


Image showing:
a) Example of the original map for the study area;
b) Deep Learning prediction. This shows the similarity between the original annotations and the predictions confirming the suitability of Deep Learning to perform automatic classification of the seabed.
Image: Rosa Virginia Garone/NTNU.

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

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

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

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

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

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

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

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

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

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

By Kari Williamson/NTNU

WE BUILT AN AI TOOL TO HELP AVOID ENVIRONMENTAL DISASTERS

Artificial intelligence helps us more and more with decision-making in fields such as medicine, transportation, and information retrieval. In collaboration with Equinor, Norway's biggest oil and gas company, we have now added another field to the list: Interpreting integrity logs from oil and gas wells. Together, we built an AI-based assistant for Equinor's log interpreters that they are now using in their daily work.

In short, well integrity interpretation is a safety-critical task to make sure that oil and gas reservoirs cannot leak. Well integrity interpreters analyse complex sonic and ultrasonic measurements made in the well to determine whether it is properly sealed or not. Failure to do this task can lead to serious disasters such as the Deepwater Horizon explosion which led to one of the largest environmental catastrophes in history.

Our assisted interpretation tool
The tool acts as a helpful colleague who, at the click of a button, can offer an interpretation of a given well integrity log. The interpreter can then use this automatic interpretation as a basis for their own. In the end, however, the human interpreter makes the final judgements and takes responsibility for the result.

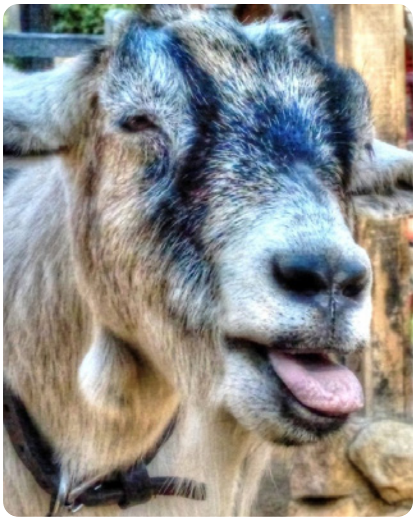
Building this tool was a joint project between CIUS and Equinor involving researchers from both sides, with extensive experience with machine learning on well integrity logs, and experienced well log interpretation experts with lots of domain knowledge, who would also be among the end-users of the tool.

Our machine learning problem
Building this tool was not straightforward. To explain why, I first need to explain the machine learning technique it is based on. We use a *supervised* machine learning algorithm that learns its task by looking at matching examples of input and output. The process is analogous to a very naïve child with no understanding of the world being trained to recognise animals by looking at pictures of individual animals while being told which animal is which.

With no understanding of the world around it, this child can easily end up learning associations that work for the training pictures but don't work in general — for example, *any animal sticking its tongue out with its mouth open is a dog*. The problem gets even harder if some of the animal pictures are unclear, or if the child occasionally gets told the wrong animal for a picture (see picture 2 and 3).

For our tool, the input is not animal pictures, but previous well integrity logs, and the 'answer key' is not animal names, but expert interpretations of those logs. As in every complex interpretation task, different interpreters will disagree to some degree. Even individual interpreters are not perfectly consistent from day to day. Hence, the machine learning algorithm will get a somewhat inconsistent answer key. To train the algorithm better, it is important to improve the consistency as much as possible.

Furthermore, the input well log data is complex — it contains a lot of different types of information, and much of it is often not predictive of what the interpretation should be. Some of the data is even junk, with a regular pattern



1: Firefighting ships after the Deepwater Horizon explosion. Photo: United States Coast Guard.
2 og 3: Animals I found at home (left) and on the Internet (right). With their tongues out and their mouths open, both are obviously dogs — right? Photos: Quynh Trang Nguyen/NTNU, Linnaea Mallette via publicdomainpictures.net.

that lets human interpreters easily identify and disregard it. However, machine learning algorithms are naïve, and can't disregarding the junk data as easily!

Improving the machine learning
In this collaboration project between CIUS and Equinor, we made some major strides compared to our previously published work, which significantly improved the quality of the automatic interpretations. On the input side, we developed a simple and sufficiently robust method to identify and filter out the junk data. Furthermore, we improved our methods to break down the log data before feeding it to the machine learning algorithm.

On the output side, however, the close collaboration with Equinor's well log interpretation experts unlocked some major improvements over previous CIUS work based on older Equinor logs. Since those logs, Equinor has developed and adopted a much better interpretation system than what is commonly used in the industry, where interpretations are made using an inherently subjective rating scale. While this approach works, the subjectivity leads to inconsistencies that can trip up the machine learning. Equinor's new annotation system, however, specifies what is behind the casing. This allows for more precision and objectivity, which reduces inconsistencies and benefits the machine learning.

Furthermore, the project's well log interpretation experts constructed a very high-quality set of logs for training and testing the machine learning. They took previously interpreted Equinor logs, excluded logs that were too ambiguous to serve as training examples, and performed an extra quality control to improve the internal consistency of the dataset.

The tool today
During the project, we integrated the assisted interpretation tool into the software used by Equinor's well log interpreters so that they could easily use it as part of their daily workflow. As a result, Equinor's interpreters now makes extensive use of the tool, which Equinor is currently maintaining and expanding.

Equinor also plans to release the source code of this tool for the use of other companies. Their aim is to benefit the entire industry by providing a tool to improve safety.

By Erlend Viggen/NTNU

RESEARCHERS CAN THANK GAMERS FOR BETTER ULTRASOUND IMAGES OF THE HEART

The gaming industry's rush for super-fast microprocessors has helped Norwegian researchers solve a 40-year-old ultrasound problem.

The problem is called aberration, or imaging error. And because it has now been resolved, the next generation technology for cardiac ultrasound is on its way out into the world carrying technology from NTNU and GE Vingmed Ultrasound. The innovation has been named Adapt. It is essentially an algorithm, which uses raw data from ultrasound to estimate and compensate for the effect of body tissue in each individual patient. "It provides sharper and clearer heart images than we have seen before," Svein-Erik Måsøy explains. He is a researcher, medical ultrasound expert, and director of SFI CIUS (Centre for Innovative Ultrasound Solutions) at NTNU.

18 million deaths annually
According to the World Health Organization (WHO), around 18 million people die from cardiovascular disease every year. The numbers have doubled in 30 years and top the list of the world's biggest health challenges. More than 100 million heart examinations are carried out using ultrasound every year. Cardiovascular disease often comes with age. Here at home, the trend of an ageing population has only just begun. "The numbers say something about the size of the challenges we are working on, and about the market that our technology is now a part of," Måsøy says.

From SFI to licence – to world market
"We are the first in the world to come up with this solution. In our niche, this is definitely a breakthrough. Time will tell what it means in the heart clinic," he says. SFI CIUS is one of 12 Centres for Research-Driven Innovation (SFI) hosted by NTNU. Adapt is commercialized by the Horten company GE Vingmed Ultrasound, and is based on one out of a total of 30 licences originating from NTNU in 2022. Among these were 9 licences from the Faculty of Medicine and Health Sciences.

Main challenge: Different bodies
Ultrasound is sound that is converted into images. The biggest challenge for heart diagnostics with ultrasound is that people have different bodies. We have different muscles and different connective tissue, and both the amount and distribution of subcutaneous fat is different. The distance between our ribs varies with height, age, and gender. All of this results in different speeds of the sound waves, and it is precisely the speed that determines the quality of the ultrasound images.

Calculates and compensates
Svein-Erik Måsøy compares sending ultrasound waves through body tissue to photographing with a layer of vaseline on the lens. The contrasts disappear, and the image becomes blurry. The problem is called aberration. What Adapt does is to estimate the effect of the vaseline, compensate for it, and give us a sharper and clearer image.

Aid to more accurate diagnoses
Real-time image quality is particularly important for myocardial infarction. Very small changes in the way the heart muscle moves can tell the doctors something about the extent of and damage from an infarction.

Senior consultant Bjørnar Grenne at the Echo-lab, Clinic of Cardiology at St. Olavs hospital, confirms that Adapt in general contributes to better ultrasound images. "We see a difference – especially in patients where it is challenging to get good enough images. And it is precisely in those cases that we need such an improved method."

Easier to distinguish structures
"For example, the heart valves become clearer. This also applies to the outline between the heart muscle and the heart chamber. This makes it easier to distinguish the structures of the heart, which can provide more accurate measurements and improved diagnostics. This is important to be able to give each individual patient the best possible treatment," Grenne says.

The cardiologist is also a researcher at SFI CIUS and head of the Norwegian Cardiological Society's working group on echocardiography.

Image quality in many people is poor
When the ultrasound probe is placed on the patient's chest, sound waves are directed towards the heart. On their way into the tissue, the waves are reflected back as an echo. The probe has thousands of sensors that function both as speakers and microphones. These help the machine to determine exactly where the sound is coming from. All the data is fed into a gigantic mathematical formula, which turns the sound into an image. When the tissue or material through which the sound passes is the same everywhere, this goes smoothly. But the diversity of bodies means that for 10-15% of all patients examined, the image quality may be too low. That again, could mean 10-15 million patients who do not receive the best possible treatment - every year.

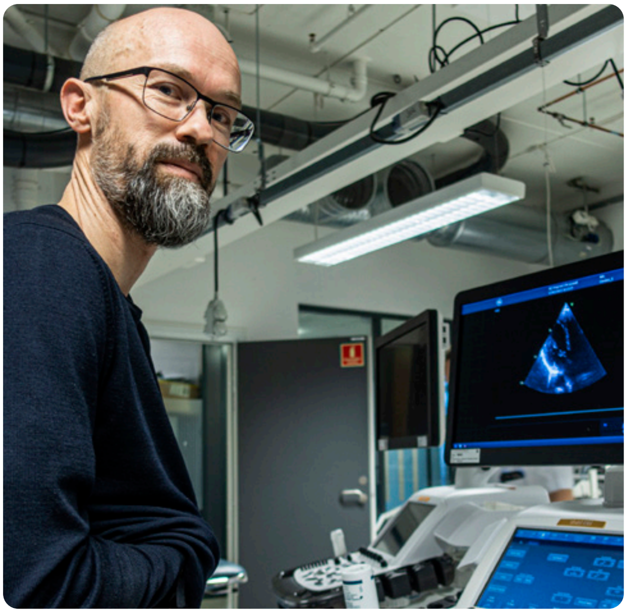
Extreme amounts of data
In the early 2000s, Svein-Erik Måsøy worked on his PhD and new methods to improve the calculation of aberrations. The methods worked, at least in theory. "GE had a demonstration of the technology in 2000. The computer used was just as big as the ultrasound machine itself, and thousands of cables ran between them," Måsøy remembers. They were able to correct 1-2 images per second. Today, it is possible to correct up to 150 images per second. "At the time it all became rather unmanageable, and also far too expensive, and the venture fizzled out," Måsøy, who defended his doctorate in 2004, explains. And now, it is time to introduce those who eventually became the ultrasound researchers' new friends: the gamers and the gaming industry.

Gaming became a game-changer
In recent years, developments in the gaming industry have progressed tremendously. Micro-processors, or GPUs (Graphics Processing Units) which were originally designed to display images on a screen, have greatly improved. They work unbelievably fast, have enormous computing power and corresponding memory capacity. The GPUs come in increasingly better versions and have become off-the-shelf products for more than one industry. The gaming industry now has an annual turnover of USD 150 billion. "Now the image processing is so fast that all the seasons of your favourite series on Netflix can rush through the ultrasound machine in 1-2 seconds," Svein-Erik Måsøy says.

Dedication to better imaging
Within the framework of SFI CIUS (2015-2024), a core team of 10 researchers from NTNU, the University of Oslo, GE HealthCare and St. Olavs hospital again tackled the problem of imaging errors. Hardware from the gaming industry took care of the heavy processing of the raw data, while researchers could concentrate on how the ultrasound images of the heart could be improved. Meanwhile, developments in 3D medical imaging have also taken great strides.

Cardiologists in pilot study
All this led to Adapt. Four cardiologists at St. Olavs hospital tested the new technology in a pilot study. In 97% of the cases, they preferred Adapt over what was then the best available equipment in the clinic. Bjørnar Grenne participated in the study. He has also done many of the ultrasound recordings and analysed images. "If given the choice between recording with Adapt or without, I will almost always prefer using Adapt. It is because the quality of the ultrasound images of the heart is improved, which is crucial for the analyses and diagnostics I perform," he says. Svein-Erik Måsøy explains how SFI CIUS has worked to correct image errors in this video.

40 years of collaboration
GE started the development of Adapt in 1989. NTNU has been working on the problem since the early 90s. Professors Bjørn Angelsen and Liv Hatle were among the pioneers of medical ultrasound development in Norway, including the development of Doppler technology in the late 70ties. "The close collaboration between GE Vingmed and NTNU in recent decades has been crucial in ensuring that GE Healthcare remains the best in the world in terms of ultrasound imaging quality," says Bastien Dénarié, development engineer at GE HealthCare. "The collaboration contributes to developing unique technologies such as Adapt, but also to creating a network of engineers in Norway who are specialized in ultrasound imaging and signal processing," Dénarié adds.



New, Norwegian technology that provides clearer and sharper ultrasound images of the heart is on its way to the world market. "For us, it is enormously satisfying to see that ideas are being used globally," says Svein-Erik Måsøy, expert in medical ultrasound and head of SFI CIUS at NTNU. Here he scans his own heart.
Photo: Sølvi W. Normannsen/NTNU.

By Sølvi W. Normannsen/NTNU

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THE HOLE STORY

What do leaky heart valves, leaking borehole walls and oil and gas extraction through perforated 'straws' have in common? Holes. Holes that are too small to be imaged clearly by standard ultrasound imaging, but where the information of the size and shape of the hole can be crucial. Thanks to the openness within the SFI and shared coffee machines, CIUS has an AI-based solution.

It all started with a project on leaky heart valves trying to quantify the amount of blood leaking through – crucial information for cardiologists.

The then PhD-candidate Stefano Fiorentini was already working on this problem with partner GE Vingmed Ultrasound when Sigurd Vangen Wifstad started his PhD. Fiorentini's approach was to search through a predefined set of possible hole-shapes to find the best match with the ultrasound image.

"Stefano was working on this leaky heart valve hole project when I started my PhD. The poor resolution was one of the core challenges in that project, and Stefano worked on another (non-AI) approach to deal with it," Wifstad explains.

"Starting my PhD, I jumped aboard and decided I would try to work on the same problem, only using an AI-based approach instead. In the end, we published both approaches as separate papers. There are pros and cons of both."

Fiorentini's approach has the advantage of being more transparent and less prone to the quirks of AI, whereas the AI-approach has the advantage of not being restricted to a set of predefined shapes.

The coffee machine effect

Some may wonder how CIUS can work as an SFI spanning such wide topics as echocardiography to using ultrasound for non-destructive testing of cement and steel pipes. But in what some feared could be CIUS' weakness in being spread too thin, lies the key to this success story – the bringing together of different fields and discussing seemingly different topics over the coffee machine.

At the same time as Wifstad started working on an AI solution to measuring leaky heart valves, another PhD, Shivanandan Indimath, started on a project involving leaking borehole walls for the oil and gas sector with CIUS partner Equinor: "Shivanandan started his PhD about the same time as me, and it quickly became apparent that we were working on very similar topics from meetings within the ultrasound group (at NTNU) and CIUS. We also sat right across from each other in the office space, so it was inevitable that we would find out soon enough," Wifstad muses.

"We would probably never have been aware of each other's projects if we were working in separate SFIs. I would likely not have ventured out into co-authoring a paper about oil and gas (which deviates quite a bit from my PhD project) hadn't it been for us working in the same office, having coffee breaks and lunch together."

Indimath adds: "The scope of my PhD did not originally include this work. It was primarily aimed to evaluate the use of Doppler for quantification of fluid flows through fractures in borehole walls. It was only during some meetings and regular coffee interactions with Sigurd in late 2021, that we realised that his work could also be applied to my project to improve the segmentation of fracture shapes.

"The discussions were mostly informal for a long time until about June 2022, when we actually started working together."

Blurry images give blurry answers

It soon transpired that both Indimath and Wifstad were trying to quantify the flow of liquids through holes so small that ultrasound and Doppler could not "see it" clearly. The contours become blurry, or pixelated, making it near impossible to determine the exact shape and size of the hole. This again affects the calculations used to quantify flow:
Flow rate (m3/s) = velocity (m/s) * surface area (m2)

When you do not know the exact surface area (size and shape of the hole), this becomes a consequential error. With an inaccurate surface area, the flow rate "answer" also becomes inaccurate. This is bad news both for cardiologists and for borehole operators. How urgently does the patient need surgery? Will the oil well blow out?

This is where collaboration became very fruitful.

AI "image filter"
Anyone who was around before digital cameras will marvel at how newer smartphones automatically detects faces, adjust for poor light and camera shake, and how most video-calls can add funny faces mirroring the speaker's facial expressions. Some of the same thinking can now help us "sharpen" the images of holes.

What Wifstad has been working on, is crudely put – an AI image filter compensating for the low resolution. "The AI-tool is a convolutional deep neural network. This is a type of machine learning model which works especially well on image data. In simple terms, it is essentially a cascade of mathematical operations (image filters) which are applied to the blurry image, and the output is an image without blur, and with better resolution (more pixels). "The parameters of the models are tuned by training the model to learn from image pairs of blurry images, and the corresponding 'ground truth' image of the hole. "Wifstad and Indimath did for obvious reasons not have access to 'ground truth' images – it is hard to photograph small holes in a borehole wall, or heart valves moving in a living heart – and in both cases, Doppler images were blurry due to too low resolution. "In order to circumvent this, we instead simulated a bunch of leaky holes and what the corresponding blurry ultrasound image would look like. We could then train or model using this dataset, and apply it to real images," Wifstad says.

Wifstad's project on leaky heart valves resulted in the paper "Quantifying Valve Regurgitation Using 3-D Doppler Ultrasound Images and Deep Learning". Moreover, Indimath's project on leaky boreholes has resulted in the paper "Subpixel segmentation of borehole fractures from low resolution Doppler ultrasound images using machine learning".

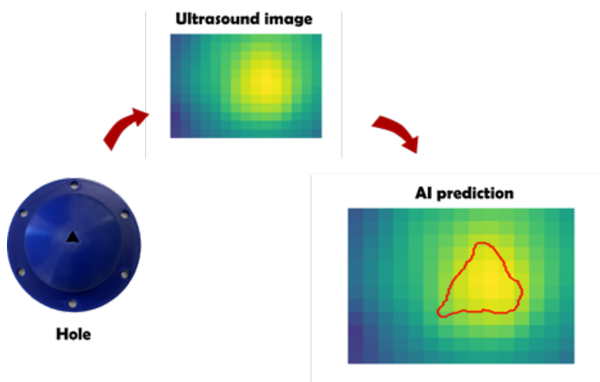
Another hole
As Wifstad and Indimath's projects started to wrap up, Indimaths' co-supervisor and CIUS researcher Erlend Magnus Viggen started working on a project to estimate the size and shape of the pipe holes that oil and gas passes through so that their wear and tear can be monitored, especially for shale gas extraction — or fracking. Think of a large, metal straw with perforations at the bottom. To extract shale gas, so-called 'proppants' are pushed out of the holes to the shale formation outside to prop open cracks and let the gas through. These proppants cause wear and tear that needs to be monitored, in addition to off course being able to optimise production by knowing the size of the holes the gas will flow through. Through talks with Indimath and meetings in the oil & gas work package in CIUS, Viggen became aware of Wifstad's AI solution to optimising images of holes. And luckily, within the framework of an SFI, it is possible to share code much more freely without long, and often tedious, approval processes.

So Viggen had the advantage of an AI setup that could learn how to optimise images. In addition, he had the lucky advantage of having access to 'real' ground truth images. The CIUS partner for Viggen's project, Archer, could provide both 3D ultrasound images of holes alongside camera-based images from another Archer partner, EV. "Thus I can directly use the photo-based hole outlines as ground truth when training the neural network. This means that I am training the network to reproduce similar outlines to those found from the camera tool. This also saves me from having to simulate artificial cases with ground truth, like the others do," Viggen explains.

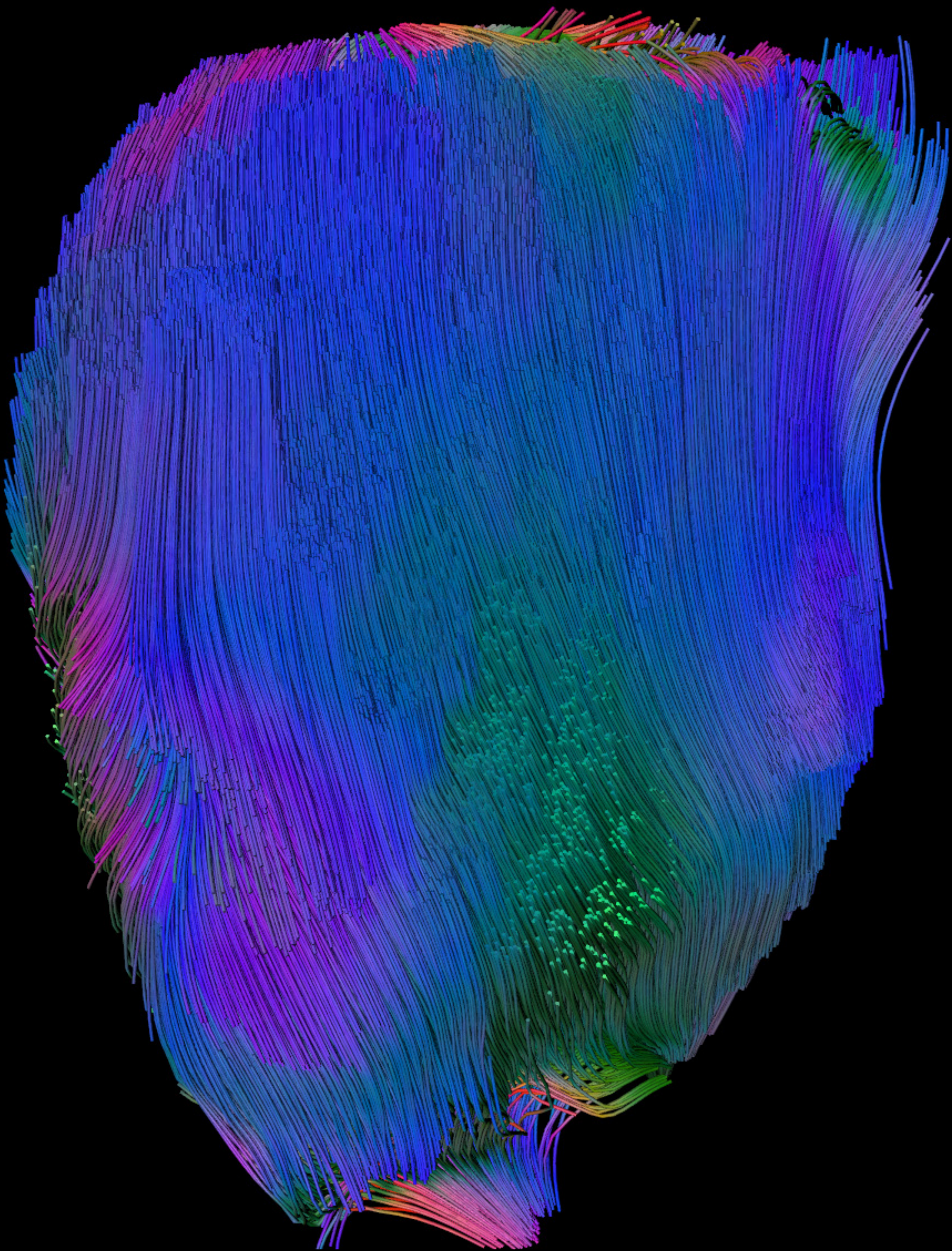
The camera images can of course get accurate images – but only in clear liquids. As soon as liquids become less transparent, ultrasound is the preferred imaging mode. So far Archer has implemented their own approach based on traditional signal processing. "But its accuracy could be better, and it requires extensive manual intervention, which makes it both slow and subjective. We are trying to use machine learning in place of this manual workflow," Viggen adds.

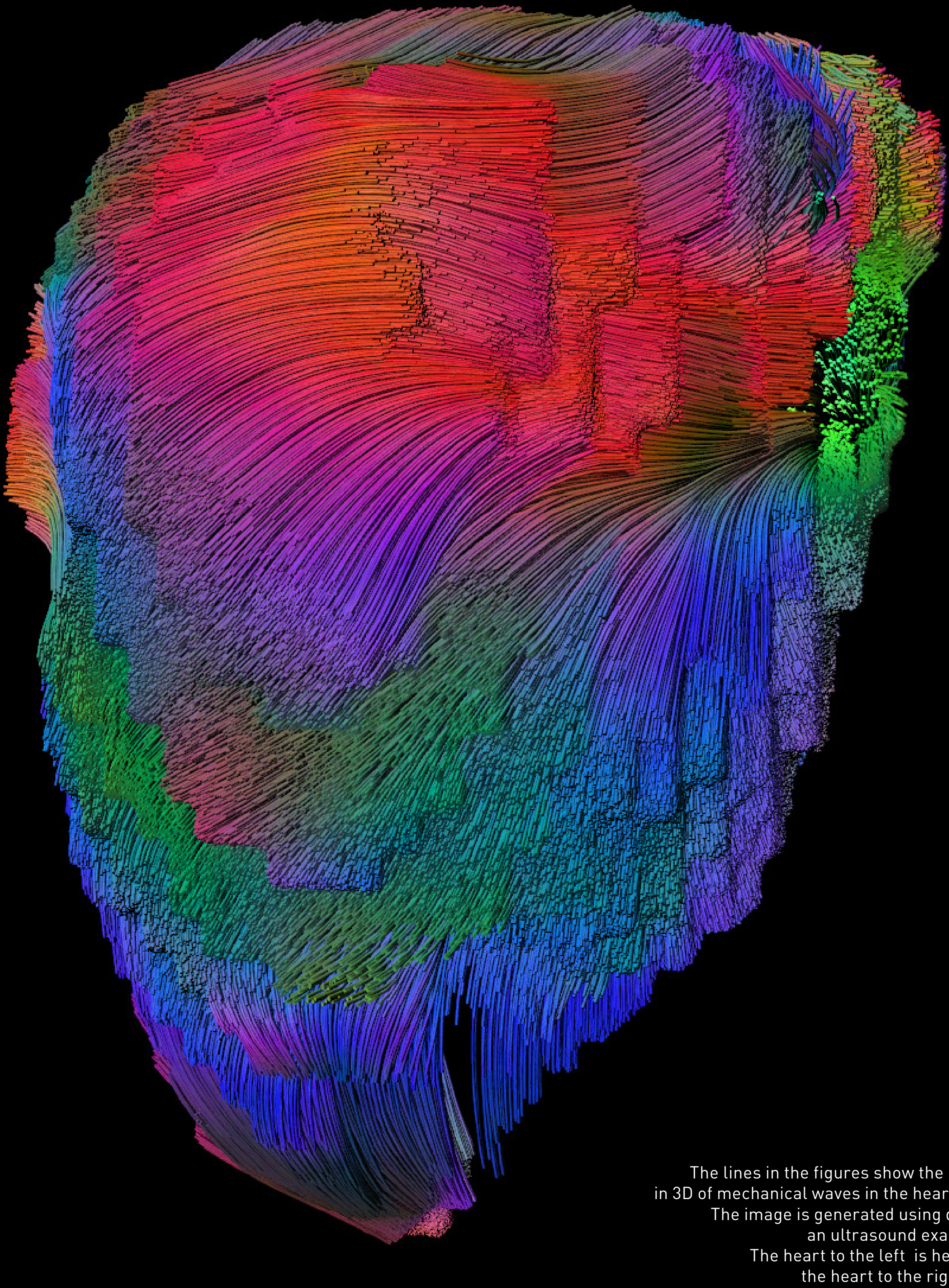
Statements from Archer and GE
"Perforation evaluation in petroleum wells has become a natural step in the process of preparing a well for production. By determining the perforation sizes and shapes using data captured by optical or ultrasound imaging systems, the operators can improve the efficiency of the wells and achieve greater performance. Erlend has developed a machine learning model that accurately predicts perforation dimensions and shapes from the ultrasound data by assuming that the corresponding optical measurements are benchmark results. Integration of this model into perforation analysis workflows promises enhanced accuracy, objectivity, and substantial reduction in processing time of the ultrasound data." Sondre Grønsberg, Lead Engineer, Software and Sustaining, Archer

"Echocardiography is routinely being used to quantify many parameters describing the human heart. But still, there are no really good approaches for quantifying regurgitations (heart valve leakages). Sigurd's approach of quantifying the regurgitation orifice (size and shape of the "hole") by AI is a valuable contribution to solve this challenge and illustrates the importance of NTNU's long line of investigations in this area." Svein Arne Aase, Staff Software Engineer, GE HealthCare



A triangular hole imaged using Doppler ultrasound, resulting in a poor resolution image where it is challenging to discern the shape and size of the hole. Using the AI "image filter" it is possible to retrieve the information from the image.





The lines in the figures show the pathways
in 3D of mechanical waves in the heart muscle.
The image is generated using data from
an ultrasound examination.
The heart to the left is healthy and
the heart to the right is sick.

Illustration: Sebastien Salles

Original research plan and development of research plan

The original research plan of CIUS centered around 4 basic Work Packages (WPs) of technologies that are common to the center's application areas (see figure next page). The next level of WPs concerned piloting and testing of developed technologies in more relevant scenarios. For the health care sector, this was divided into three separate work packages, whereas for the oil & gas and maritime domain, one pilot WP was created for each of these domains.

All the WPs were aimed towards 11 innovation goals (IG), listed below.

Innovation Goals – Health care:
Med-IG-1: 3D ultrasound coronary anatomical and functional imaging
Med-IG-2: 3D ultrasound quantification of valve and shunt pathologies
Med-IG-3: Affordable, functional and user-friendly solutions for ubiquitous ultrasound
Med-IG-4: High-resolution US imaging for image-guided surgery and targeted drug delivery
Med-IG-5: Multimodal imaging and therapy follow-up in brain and heart disease with a main focus on hybrid PET-MR.

Innovation Goals – Maritime
Mar-IG-1: Sea bed classification
Mar-IG-2: Long term monitoring of the ocean environment
Mar-IG-3: Automatic detection of fish species

Innovation Goals – Oil & Gas
Oil-IG-1: Well integrity monitoring
Oil-IG-2: Monitoring of pipelines and risers
Oil-IG-3: Sensors for the Subsea Factory

Just after the start of CIUS in 2016, the oil & gas sector experienced a dramatic reduction in the oil price causing a major upheaval in the industry. This forced the industry to rethink all R&I, re-work their organizations and change priorities. It also affected the maritime field, as a significant portion of the business in this sector was also related to the oil & gas domain (e.g. seabed mapping of subsea pipelines). This affected CIUS in the sense that projects were not started up, and it was challenging to engage the partners.

This was commented by the RCN during the mid-term evaluation of CIUS in 2018, and CIUS had to re-work its research and pilot plans for both the oil & gas and maritime sector. After this change, the innovation goal number 3 within each of these fields was dropped, and the focus was on IG goals 1 and 2.

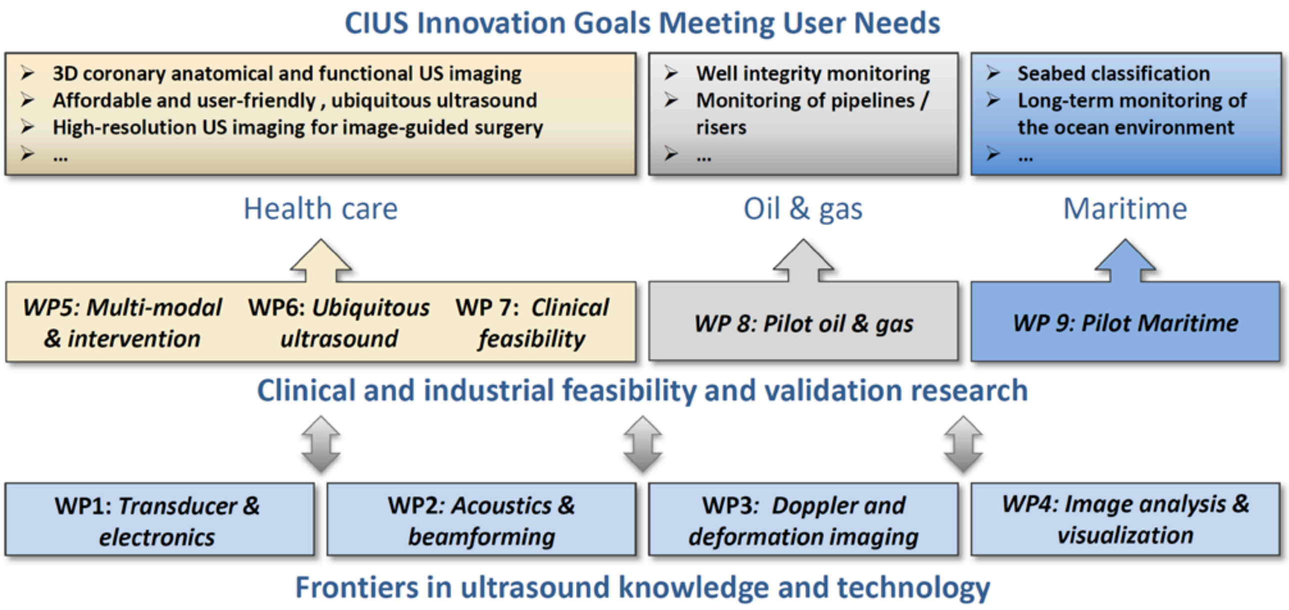


Figure: CIUS research method and approach, innovation goals and work packages.

Another significant impact on the research plans for the center was the breakthrough in AI, and particularly Machine Learning (ML) which came to the fore early in the center's period. This was even not part of the goals in the application for CIUS, but was recognized as very important, and the center pivoted a lot of research into this field. This was particularly so in WP4 and did also affect all the application domains of CIUS.

The Corona pandemic was of course a challenging time for society and the world, with shutdowns and home office regulations being imposed in most organizations. Some clinical trials were delayed due to the pandemic, and a project collaboration with Australia on rheumatic heart disease in rural areas was cancelled. Another impact for CIUS was probably a that newly recruited PhD candidates in this period, many from abroad, had a hard time during the startup of their project. They were subject to strict travel and testing regimes to come to Norway, delaying and challenging visa application times, also facing quarantine and empty offices upon arrival. Making sure the candidates had a psycho-social environment and enough inter-personal interaction became important for their well-being.

A reduction of physical meetings was also sub-optimal for networking and sharing of information, one CIUS by-yearly conference was cancelled, and one held digitally. Still, in total, the pandemic did not set back CIUS R&I wise, and we were able to finalize all the projects we started during this period in a reasonable way.

Research achievements,highlights and awards

Researchers from and affiliated with CIUS have together published more than 500 research articles (both peer reviewed and conference papers), many of these co-authored with international collaborators and our industry partners. Many CIUS researchers have also been invited to give lectures and as keynote speakers at international conferences, indicating the status of the scientific work carried out in the center. The research activities in the center have spanned across the WPs, with researchers formally assigned to a project within one WP, also working in teams with researchers and partners across multiple WPs. In several projects this has also crossed between the domains, as "The Hole Story" is one example of. Here, we summarize the research achievements of the center in relation to each WP for consistency. Only selected results are presented in order to illustrate projects that has been ongoing in each WP.

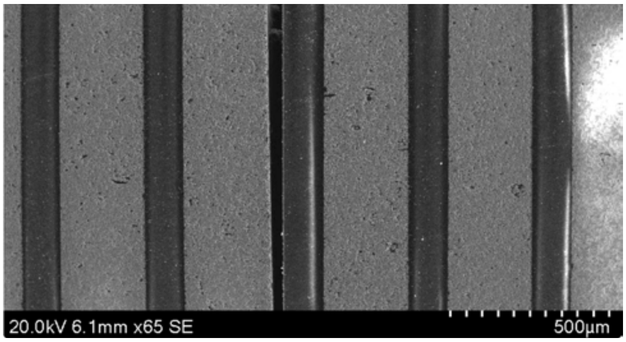
WP1: TRANSDUCERS AND ELECTRONICS

This work package covered joint research for design, fabrication, characterization and modelling ultrasound sensor 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 deemed fundamental and highly overlapping for all applications.

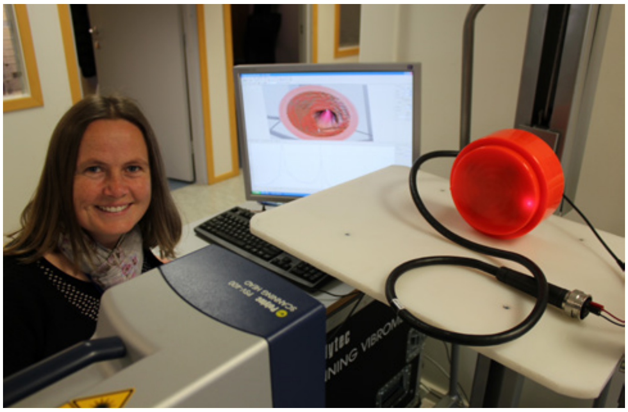
Highlights of Scientific results

CIUS funded 7 PhD students and 1 postdoc researcher in the transducer part, and 2 PhD-students on the electronics part. In addition, 5 PhD students were associated to CIUS with funding from other sources. All these projects cannot be described in this overview, we have selected to highlight two: *Kenneth K. Andersen* did his PhD on multi-bandwidth transducers for ultrasound mediated drug delivery, working with Exact Therapeutics and WP5 led by prof. Catharina Davies at NTNU. His task was to develop novel transducer concepts for their research on cancer treatment. He developed a transducer operating at the 1st and 5th harmonics, this was produced and used in preclinical testing of Exact's products at locations in USA, UK, and Norway. Kenneth also founded a startup-company (ReLab) to commercialise his research. After having finished his PhD, Kenneth now works for CIUS partner Medistim, developing new probes for their ultrasound systems.

Ellen Sagaas Røed was funded as industrial PhD from Kongsberg Discovery, working closely with and benefitting from the transducer research at USN supported by CIUS. The emergence of small autonomous underwater vessels puts new requirements to size and power consumption of the onboard sonar systems. Ellen's research demonstrated how novel piezoelectric materials could be used to create transducers with extended bandwidth, enabling one single transducer to cover what previously required several units. After having finished her PhD, Ellen continues her work as transducer designer in Kongsberg Discovery. The most important result of this work package is the highly skilled candidates we have delivered to the industry. Our candidates are very attractive, demonstrated by 6 PhD candidates from WP1 continuing their work as R&D engineers in CIUS industry partner companies, and at least 2 more in Norwegian high-tech companies outside CIUS. In addition, at least 18 MSc students have completed their thesis within this work-package and are now either working in the industry or continuing in academia.



A scanning electron microscope (SEM) image of an in-house made piezo-polymer 2-2 composite with a defect: The piezo ceramic (wide posts) has separated from the polymer (narrow posts). With a SEM, defects are possible to examine using destructive testing. Photo: Courtesy of Kenneth Kirkeng Andersen



Ellen Sagaas Roed and her developed new transducer.

WP2: ACOUSTICS AND BEAMFORMING

This work package covered the fundamentals of acoustic wave propagation and image formation common to all applications with a focus on improving image resolution and contrast across all application areas. During the project period some of the original plans in this work package was changed and focused from medical to sonar imaging. Overall, most of the original plans were followed through.

Highlights of Scientific results

One of the successful projects in this WP was the development of the Adapt patient adaptive imaging technology, correcting for variations in the speed of sound in medical ultrasound imaging. The project is described in more detail in the Researchers can thank gamers for better ultrasound images of the heart. The technology has now been commercialized in two different GE HealthCare imaging systems, the Vivid E95 (Adapt released in 2022) for cardiology examinations, and the Voluson Expert 22 (Adapt released in 2023) for fetal ultrasound. Adapt is now available and in use in several thousand systems globally. Research on this concept has been ongoing for more than 40 years, and a team of researchers in CIUS (collaboration between GE HealthCare, NTNU, and St. Olavs hospital) succeeded in finalizing and commercially launching, for the first time, this methodology in a pulse-echo medical ultrasound system. In a clinical pilot trial, 4 trained cardiologists preferred the Adapt technology, over to state-of-the-art imaging, in 97% of the cases.

Another significant result from this WP is the development and launch of the open-source software the UltraSound ToolBox (USTB). The toolbox is used to process data from medical ultrasound systems and synthetic aperture sonar imaging. The original paper (from 2017) presenting the toolbox has recently passed 115 citations, thus demonstrating that the toolbox has been well received and is widely used in the ultrasound community. As an example, there were eight presentations at the 2022 IEEE Ultrasonics Symposium (IUS) in Venice from UiO/NTNU using the USTB. The USTB has also been important for a recent start-up company, Sonair AS (who has hired researchers who have been affiliated with CIUS) in Acoustic Detection and Ranging (ADAR) in air. USTB has been downloaded from all over the world, and is also used by many ultrasound companies in the world. The GE HealthCare Women's Health Ultrasound (GEHC-WHUS) team (which is a CIUS partner), has collaborated with CIUS researchers to adapt the tool to data from its systems. This code can then be used by collaborators of GEHC-WHUS for research and development purposes. This WP has also focused on improved imaging using sonars and several PhDs have concentrated on topics such as multibeam sonar with nonlinear acoustics and improved mapping rate in seabed mapping sonar. Some of the developed methods have been tested in sonar during sonar data collection surveys for evaluation for further prototyping and potential commercialization.

WP3: DOPPLER AND DEFORMATION IMAGING

Technology to improve methods for detecting and measuring flow and displacements in ultrasound images was covered in this work package. This ability is considered one of the main strengths of ultrasound compared to other image modalities and has been essential for several of the CIUS innovation goals.

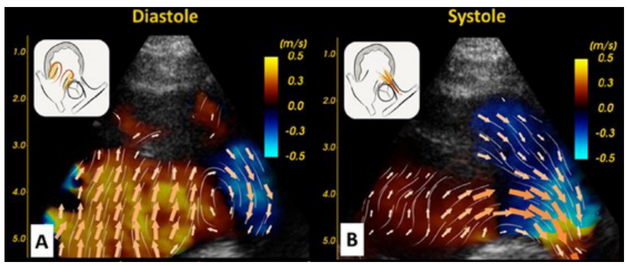
The original research plan for WP3 included ambitious research goals within a wide range of ultrasound applications including

· Coronary flow imaging
· 2D and 3D vector velocity imaging
· Cardiac jet flow quantification
· Detection and quantification of flow in oil & gas borehole and logging applications.

The bulk of projects in WP3 have proceeded as planned with minor adjustments based on intermediate results and variations in available personnel. The Coronary flow imaging project turned out to be challenging, as expected, and after the first two subprojects, the focus was directed towards the more general goal of separating blood signal from surrounding tissue signal. This evolved into a close collaboration with GE Healthcare on this topic. Similarly, the research topics in the oil & gas projects were adjusted based on intermediate results and feedback from industrial partners Archer and Equinor.

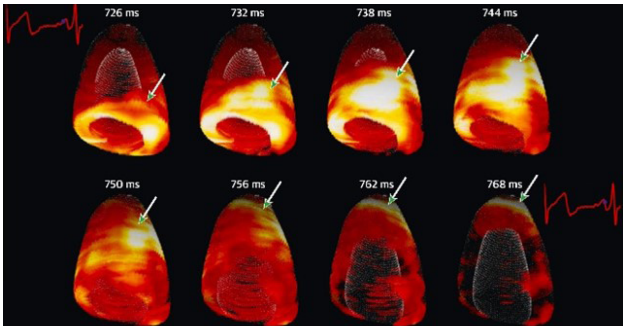
Highlights of Scientific results

Vector velocity imaging of blood flow using ultrasound is under continuous development, and collaborations between clinicians and technical researchers have resulted in several studies showing the potential of such methods in assessing the functionality of fetal and adult hearts. Clinical PhD student Wadi Mawad has evaluated the clinical usefulness vector velocity imaging for pediatric cardiac imaging in a series of studies in a collaboration between NTNU, St. Olavs hospital, Ålesund Hospital and the Sick Children Hospital in Toronto, Canada. With the current pace of development, this may become a standard feature on clinical ultrasound scanners in the near future.



2D rendering of heart flow, excerpted from publication analyzing flow dynamics in children's hearts, by Wadi Mawad et al.

Sébastien Salles, a Post Doc in CIUS, who now continues to collaborate with the center as a researcher in France, has developed a new method for detection and visualization of mechanical waves in tissue. This is significant leap forward in the ability to measure stiffness in the walls of the heart and blood vessels and may facilitate early detection of common diseases such as fibrosis in the heart walls (scar formation) and atherosclerosis. This concept has been followed up in several technical and clinical PhD projects. Further technical research and clinical validation studies are ongoing and will continue after the center has finalized its activities. Through GE HealthCare, and in collaboration with KU Leuven in Belgium and NTNU, this project has also received EU funding. CIUS is indirectly contributing to this project.



Propagation of mechanical wave through the heart wall, excerpted from publication by Sebastien Salles et al.

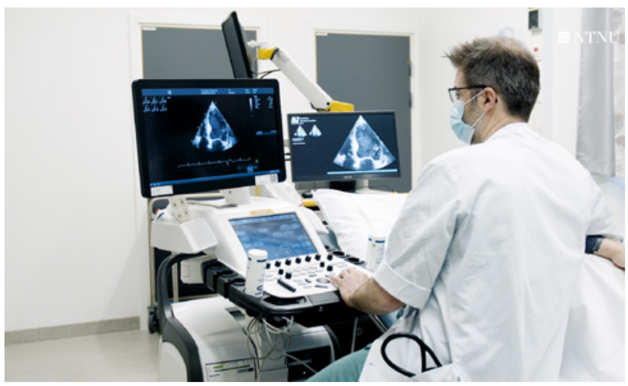
WP4: IMAGE PROCESSING, ANALYSIS, AND VISUALIZATION

WP4 focused on image analysis and visualization aspects of ultrasound imaging, which reached over all application domains. Image analysis has been in rapid development the last decade, and really took off with the introduction of deep learning-based methodology for image classification tasks. The timing of CIUS was in this sense excellent, as we were able to exploit these new baseline technologies in our projects in an early stage. The original research plan was somewhat adapted according to these new possibilities. The task on image segmentation was extended to involve automated measurements and to explore new possibilities in image guiding and motion estimation (cardiac strain imaging). Further, a project on seabed mapping was defined in the later stage of CIUS based on our progress in deep learning for medical applications. Machine learning / deep learning continues to be the future of image analysis, and we have in CIUS WP4 established a solid group in the forefront of these technologies in ultrasound imaging.

Highlights of Scientific results

CIUS WP4 have achieved solid scientific results in all application domains of CIUS, together with many industrial partners. In healthcare we contributed with some of the first publications on image segmentation in echocardiography based on deep learning, including our international collaboration with CREATIS (Lyon, France) which led to a landmark paper in this field that includes the open access CAMUS image database. This activity has since evolved from a small team of 4 people to a current team of 20 people (50/50% technical / clinical), based mainly on supplementary funding. We are now one of the main groups worldwide working with technical development and clinical exploration of machine learning / deep learning in echocardiography. This activity has also been a close collaboration with our industry partner GE Healthcare, who has licensed several innovations. We have many papers in key international journals (technical and clinical) and are regularly invited to speak at national and international conferences. In parallel, we have investigated the use of machine learning in well logging for oil & gas applications. This has been an effort leading to several publications and a planned open-source library for the community in collaboration with our industry partner Equinor. Finally, we have in a collaboration between Kongsberg Discovery and the Norwegian Geographical Survey (not a CIUS partner) developed new methods to map the seabed based on deep learning (see story about Rosa Garone's PhD project in the Stories section). This work has introduced new use cases for machine learning in this field and showed the potential of deep learning to be a supportive tool for seabed mapping, which currently is manual, highly time consuming, and subjective.

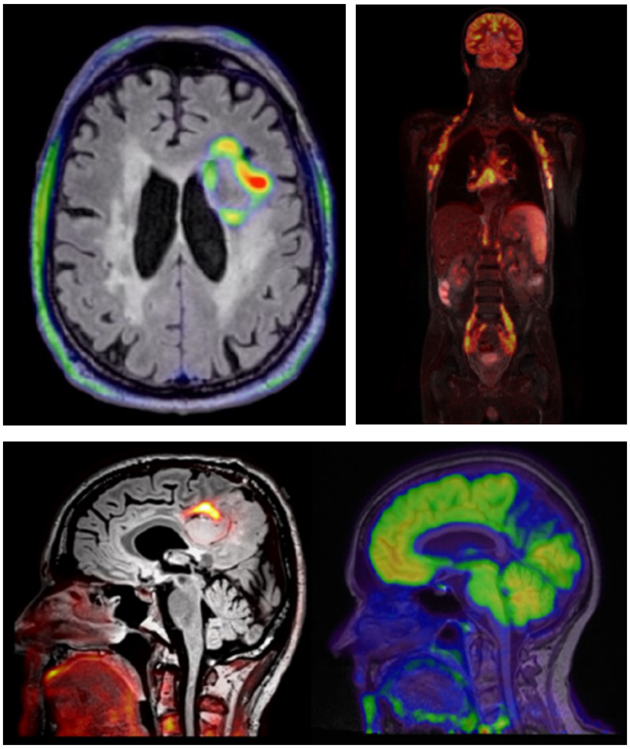
In general, CIUS contributed to the development of deep learning applications for image analysis based on ultrasound imaging in several domains. This includes several innovations on the technology side, and novel applications for automated tasks and measurements. We have focused on real-time processing aspects, and the integration of the technology into the workflow in the different domains. This includes the development of real-time processing and display for measurements that has been clinically evaluated, the integration between other sensors and image data for volumetric measurements in fish farming (see story about PhD candidate Yasin Yari in Stories section), and the development of open-source libraries for oil well logging in collaboration with industry partner (see blog by Erlend Viggen in Stories section). The projects have been well-rooted in the needs for the industry, and industry partners have been deeply part of forming and executing the projects.



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

WP5: MULTIMODALITY AND INTERVENTIONAL IMAGING

This work package covered development and application of multimodal and interventional imaging in preclinical models and humans. Multimodal imaging with the modalities US, CT, MR, and PET were used for novel and improved diagnosis and follow-up, guidance during surgery, targeted drug-delivery, and other therapeutic procedures. Fields or research included cancer-, cardiovascular- and brain diseases. The industry partners were GEVU, Medistim, EXACT Therapeutics while the academic and health care provider partners encompassed SINTEF, Helse-Midt Norge and St. Olavs hospital. Three main areas of research were multimodal imaging in cardiology, in human brain disease and targeted drug delivery in cancer. The innovations in this WP were predominately service innovations, but the WP contributed to innovations in GE HealthCare and EXACT Therapeutics.



PET MRI images
Top left: axial view of the brain with a glioma enhanced by the amino acid tracer 18F-FACBC, the center of the tumor is necrotic and is therefore not enhanced.
Top right: coronal view of the head and torso where yellow-red regions are those loaded with 18F-FDG (i.e. radioactive glucose) such as the brain, hearth, muscles, kidneys, liver and, in this person, the spleen (the enlarged, long structure on the right side on the image, left for the patient) due to lymphoma.
Lower right: saggital view of the brain of patient with glioma in the precuneus enhanced by the amino acid tracer 18F-FACBC.
Lower left: saggital view of the brain of a patient with dementia with classical loss of 18F-FDG uptake in the precuneus, a region affected early in Alzheimer's disease.

Highlights of Scientific results

Cardiology interventional procedures rely on 3D trans-esophageal echocardiography (TEE) imaging to guide the surgeon during instrument/device manipulation inside the heart. Manual registration of ultrasound to CT is commercially available. However, it is only valid if the position of the probe does not change. Tracking probe movement is highly desirable, to avoid manual re-labelling and to estimate probe motion for motion compensation during surgery. A fast method implemented on the GPU has been developed and tested on a dataset of 3D echo data acquired in the clinic simulating various degrees of probe movement. The method performed well on most cases and was deemed valuable for real-time operation. As a result, this approach was licensed by GE HealthCare (GE Vingmed Ultrasound) for integration into their scanners. This part of the project has continued working with new methods for evaluation of left ventricular function in critical care patients. Currently available tools are manual and thus too time-consuming. To resolve this issue, a method from CIUS researchers was proposed for the continuous and automatic quantification of LV function in these patients. A clinical PhD has evaluated the benefits of the method for short time automatic functional monitoring in an operating room setting or up to 2 hours. The results are promising, and research is continuing beyond the lifetime of the center. Collaboration was also started between this research team in CIUS and research groups in Milan and Lyon, which e.g. has led to the development of large dataset with known myocardial deformations. This can be used for evaluation of tracking methods of the heart and is planned to be published openly.

For brain diseases, the center has been involved in establishing PET-MRI methodology and relevant PET tracers for dementing disorders and brain cancers. Pilot studies of the feasibility and potential of theragnostic for treating brain cancers are underway leading to new treatment options for patients with limited options today. Traumatic brain injuries, one of the leading causes of disability, is another area of research interest where the center for instance have found biomarkers for outcome prediction and triaging to different types of neuroimaging modalities in the acute phase. The research group were part of the EU financed Center TBI study and led the ERANet TAI MRI study. Additionally, the group have worked on establishing norms for brain development, aging, and diseases. Taken together, the center has provided several novel and improved diagnostics and follow up methodologies using neuroimaging. One of these has led to a new diagnostic pipeline for degenerative diseases of the brain with a PET Tau-tracer for new and improved diagnostics. This methodology is unique to St. Olavs hospital in Norway.
For targeted drug-delivery the aim has been to achieve successful cancer therapy by delivering the therapeutic agents to all cancer cells in order to remove them. Focused ultrasound combined with microbubbles has been shown to improve the delivery of drugs and drug-loaded nanoparticles in tumors in mice, and the therapeutic effect is thus enhanced. To optimize the ultrasound treatment, there is a need to develop novel microbubbles made for delivery of drugs. The center partner Exact Therapeutics has developed a unique microbubble

having a diameter 5 times larger than regular microbubbles used in ultrasound imaging. Their concept is called Acoustics Cluster Therapy (ACT). Research in CIUS has demonstrated that ACT efficiently delivery various nanoparticles in human tumors growing in mice, and the therapeutic response is improved. Work from the center has also shown that ACT temporary and safely opens the blood-brain barrier and allows nanoparticles to reach the brain tissue.

To optimize treatment, it is important to understand the mechanism for ultrasound-mediated drug delivery. The research group in this domain has developed experimental setups allowing imaging through a microscope of ultrasound treatment with the ACT bubble in blood and nanoparticles crossing the blood vessel wall and penetrating different tissues. This has enabled imaging of both tumors growing and brain tissue and provided new knowledge on how nanoparticles cross different types of vessel wall during ACT. Two clinical studies have been completed at St. Olavs hospital, treating cancer patients with standard chemotherapy in combination with ultrasound and regular contrast agents. The number of patients included was too low to assess the therapeutic effect, but it was demonstrated that the treatment was safe, and the work provided valuable experience for participation in a planned multi-center clinical study.

WP6: UBIQUITOUS ULTRASOUND IMAGING

Pocket-sized ultrasound devices are extremely portable and can increase the use of ultrasound imaging as part of the diagnostic workflow in different groups of patients - from rural district hospitals to nursing homes in industrialized countries. This WP has been focusing on the clinical applications and technological advancements of pocket-sized ultrasound. The primary objective has been to develop and evaluate the use of handheld ultrasound devices for both experts and non-experts in clinical settings. The research emphasizes the potential impact on patient care, including quicker diagnosis and reduced hospital admissions.

The projects in this WP have been related to evaluation of handheld ultrasound for diagnosing heart failure by general practitioners in nursing homes. This involved training general practitioners (GPs) to use handheld ultrasound devices for patient evaluation, supported by automated measurements and telemedicine systems. There have been 3 PhD students related to this activity in the WP. This WP also had planned to develop a project on collaboration on automatic detection of Rheumatic heart disease in rural areas of Australia, but this had to be cancelled due to pandemic-related challenges.

Highlights of Scientific results

Studies in this WP have demonstrated the efficacy of handheld ultrasound in diagnosing conditions like heart failure, with GPs trained in its simplified use for patient evaluation. Automated measurements and telemedicine support have been integrated to enhance diagnostic accuracy. In collaboration with WP4, significant advancements have been made in real-time automatic guidance for operators during scanning, as well as fully automatic analysis of cardiac size and function using AI. These developments aim to streamline the diagnostic process and improve efficiency of pocket size ultrasound. Several manuscripts and abstracts have been published, highlighting the feasibility and reliability of automated measurements, user experience, and clinical impact. Notable studies include those related to telemedicine support, automatic decision-support software, and real-time guidance using deep learning algorithms.

Overall, the research performed in WP 6 has been very important to advance the use of pocket-sized ultrasound devices in clinical practice, particularly in improving diagnostic accuracy and accessibility, with a focus on both technical innovation and clinical impact.

WP7: CLINICAL FEASIBILITY AND VALIDATION – ISCHEMIC HEART DISEASE

This work package focused on the clinical assessment of new technical ultrasound modalities for evaluation of coronary artery disease. Coronary artery disease is still the main single cause of death worldwide. Early invasive treatment in patients with acute myocardial infarction has significantly reduced mortality and morbidity. However, timing of intervention, decisions on invasive versus pharmacologic treatment, and balancing risk and benefits of invasive procedures are important clinical challenges. WP7 sought to improve the clinical diagnostics in these patients by developing and exploring novel ultrasound solutions. Ultrasound is widely available, fast and relatively cheap, and improved diagnostic accuracy is important both to allow individualized treatment strategies and to enhance health care efficiency.

Highlights of scientific results

An initial aim in WP7 was to assess the feasibility of new 3D methods for visualizing coronary arteries and quantification of coronary stenosis with Doppler. However, early pilot studies demonstrated critical technical challenges. Coronary visualization was therefore not a priority during the last years of CIUS and the research focus was adapted to other areas, particularly the rapidly evolving field of implementing AI in heart ultrasound (see below).

The work package also focused on acute ischemia and viability detection using heart ultrasound and the work resulted in several research papers. Automated AI methods for measuring myocardial deformation and velocities in 2D and 3D were validated and tested in clinical cohorts. Moreover, technologies for imaging of rapidly occurring myocardial waves using high frame rate imaging in 2D and, for the first time in 3D, were developed and tested in patients with acute myocardial infarction. Furthermore, in cooperation with Sørlandet hospital, the PreACS study evaluated the use of prehospital assessment of patients with acute chest pain by a combination of on-site heart ultrasound acquired by paramedics in combination with blood tests and ECG. The first results have been published and further papers are under preparation.

Also, in collaboration with Sørlandet Hospital and the University of Oslo, the large prospective Improve study has enrolled >2500 patients. Our contribution has been in development of new technologies based on heart ultrasound and artificial intelligence to improve evaluation of the heart function. Several researchers, PhD students and master students are affiliated to this work, which already has resulted in publications in high-impact journals and is ongoing with high priority by our team.

An important field in WP7 has been blood flow vector imaging/ blood speckle tracking, both in adults and children (INPART-YOUNG and NeoDoppler studies). The work has resulted in a number of publications and affiliated PhD students.

A large number of abstracts and peer-review journal papers related to WP 7 have been published, including automated methods for myocardial velocity measurements, assessment of 3D high frame rate mechanical waves, blood speckle tracking, and deep-learning methods for deformation analyses in heart ultrasound. The WP has contributed importantly to the creation and advancement of novel heart ultrasound technologies in CIUS, both directly related to coronary artery disease and for the diagnostics in people with heart disease in general. The work covered all ages, from neonates to old patients. Also, we covered a spectrum of clinical settings, from prehospital diagnostics in the patients' home to urgent assessment in the cardiac intensive care unit. Solid research collaborations with hospitals and universities throughout Norway have been established based on WP7 and will be strong foundations for our continued efforts to improve heart ultrasound.

The results related to CIUS WP7 have been followed by several invited talks to national and international conferences, as well as research and invited journal review papers.

WP8-9 PILOTING IN THE MARITIME AND OIL & GAS DOMAIN

The main idea behind WP8-9 was that this should represent piloting of technologies carried out by the industry partners within the oil & gas and maritime fields. This piloting is different than in the health care sector, where validation of new technology happens on patients in a hospital setting and must be carried out by clinicians. Also, the equipment used by our partners within the oil & gas and maritime sector is expensive and challenging to operate and must be led by the partners in collaboration with the centers researchers.

Highlights of Scientific results

Work in this WP has been broad and covered many different fields within CIUS, from sensor development and experimental testing to field testing of improved image quality and mapping using multibeam echosounder sonars. Several of the projects have revolved around providing or constructing test facilities for PhD candidates at partner sites, and partners Archer, NDT Global, Sensorlink, InPhase Solutions, Kongsberg Discovery, and Equinor has funded or opened their lab facilities for such experimentation. This has both provided research results in the PhD projects and functioned as early prototyping experiments from these projects.
Two of the most successful projects from this WP are reported in the stories The Hole Story, and We built an AI tool to help avoid environmental disasters. These examples show how well collaboration in a center can work and has led to licenses with partners Equinor and Archer and led to technologies in use in Equinor and a potential commercialization together with Archer.

As another example in this work package, CIUS has also had a project which was not initially planned but came about during the center lifetime. This project has been aimed towards using ultrasound and machine learning to find the optimal time for harvesting eggs from Atlantic Salmon in the fish farming industry. PhD candidate Yasin Yari was hired for the project which was developed in collaboration between NTNU and InPhase Solutions, center consortium partners, and fish breeding and farming companies Aquagen and MOWI who were not partners to the center. A massive ultrasound image data collection effort was started in fish breeding facilities in Kyrkseterøra (Aquagen) and Bjugn (MOWI). This has led to 3 international journal papers in Yasin Yari's PhD work and a prototype system was developed for rapid and automatic imaging and measurement of salmon gonads (containing the eggs). Discussion about licensing and commercialization of this technology is ongoing. This represents an example where the activity in the center expands beyond its partners and obtain serious commitment and investment from companies outside the formal agreements of the center. Read more about this project in the story Ultrasound and AI improve salmon breeding and welfare.

AWARDS

Asta Håberg: 2017 Nansen neuroscience lecturer

Gerard Clarke: Bertil Romner Award (Prize for TBI research) 2023

Sofie Snipstad: Winner of the national contest Forsker Grand Prix in 2016

Sofie Snipstad: Communicator of the year 2020, NV-faculty, NTNU

Sofie Snipstad: Best PhD at Faculty of Natural Science 2017-2018

Sofie Snipstad: Poster award, European Symposium on Ultrasound Contrast Imaging, Rotterdam, Netherlands, 2017

Einar Sulheim: Chorafas prize 2019

Håvard Dalen was awarded the Norwegian Cardiac Society's Research Prize in 2017

International cooperation

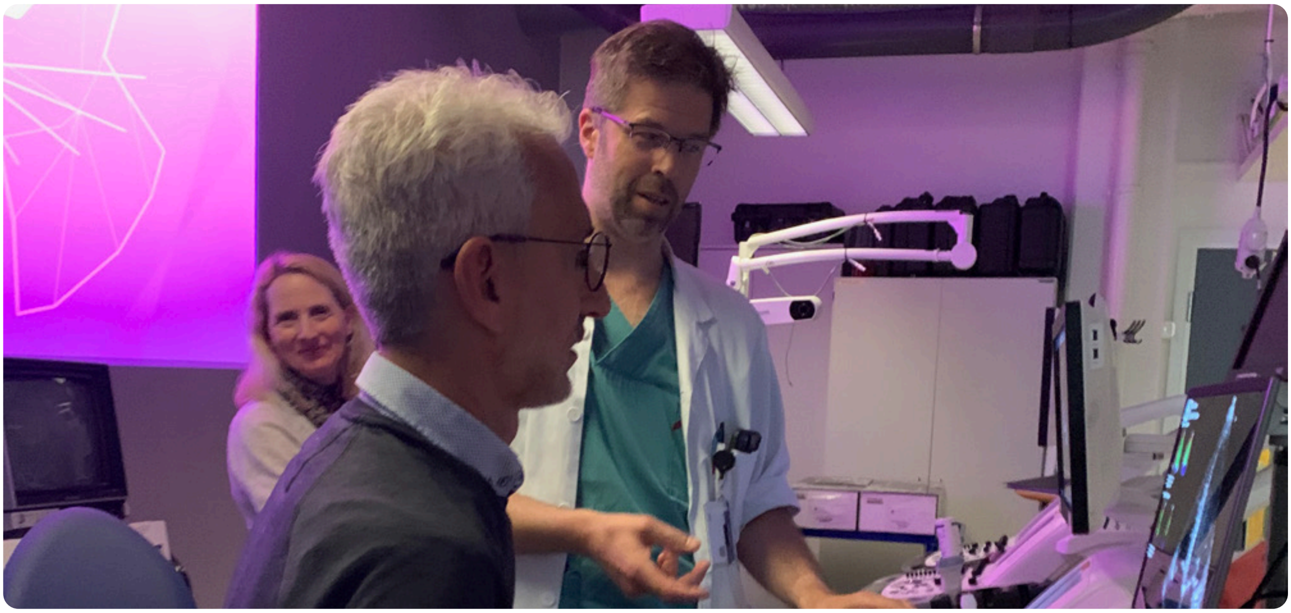
International collaboration has been important for the center and as we show in the collaboration map, CIUS has had collaboration with many different international environments over the years. This collaboration has resulted in a range of research articles (CIUS has more than 500 peer reviewed articles and conference proceedings) from CIUS with international collaborators, which is probably the core result of this effort. Also, being a research center with a long financial horizon, CIUS has been able to build up and maintain long-term relationships with certain groups. By adding additional funding (INPART and EU grants), such collaborations have become very important in developing a larger community for expertise, knowledge development, and potential for innovation, as trust can develop over the years and form deeper connections. In our experience, trust is a key factor in succeeding with collaborative innovation, and this takes time to build.

CIUS have also seen that international researchers return to their home countries and continue a collaboration with the center in new academic positions. Sébastien Salles, currently a Researcher at CNRS, Laboratory of Biomedical Imaging in Paris, France has been hired in a 10% position at the center within the medical field following up his activities as a Post Doc in the center. We expect more such events after the center has formally ended as some of our researchers obtain international academic positions and continue to collaborate with our researchers on topics developed in the center. CIUS has also attracted several international PhD, Post Doc, and researchers visiting for shorter or longer stays. Here the center's exposure in international research conferences and our posts in social media are believed to be key factors enabling the interest from the international community. Having a large center allows us to communicate a great deal of projects and research results under one umbrella organization, CIUS. This makes a large impact and draws the attention to our environment. This is a clear strength of the center model as we see it.

Below are more detailed examples of our collaboration projects.

Associated professors
CIUS has also had a policy of engaging international recognized researchers within different fields affiliated with the center. This has been handled by hiring 4 international Associated Professors, during parts of the center period. Jan D'Hooge (2017-2021) from KU Leuven in Belgium and Luc Mertens (2017-2023) from the Hospital for Sick Children (SickKids), Toronto Canada in the medical domain, Alan Hunter (2017-2021) from the University of Bath in sonar applications, and Martijn Frijlink (2016-2023) assisting in ultrasound sensor development projects.

The associated professors have taken part as co-supervisors for many PhD's, have participated in various projects, visited the centre partners for shorter stays, and taken part and presented at several CIUS conferences.



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

International Partnerships for Excellent Education and Research (INTPART) collaboration

CIUS has been an active partner in the following INTPART projects:

- Yield of Ultrasound -Heart and Brain Interactions in children (PI: Siri Ann Nyrnes, NTNU). Collaboration between NTNU, St. Olavs hospital, The Hospital for Sick Children in Toronto and the University of Toronto, Canada. Project period: 2021-2026. The goal of this project is to develop a highly innovative network for non-invasive pediatric imaging technology targeting the most vulnerable population of children, particularly aimed towards the heart and brain.
- Centre for Optical and Acoustical Sensor Technology (PI: Lars Hoff) between USN, Stanford University and University of Washington, USA. Project period 2020-2025.
- CIUS has participated in the INTPART project HBV, NCE-MNT, CRI CIUS US-Norway Collaboration on Ultrasound Technology and Harsh Environment Sensors, granted October 2015. Project period 2015-2018. Partners in the US were Ultrasonic Transducer Resource Center at University of Southern California, and Berkeley Sensor and Actuator Center, BSAC, UC Berkeley.

Collaboration with international departments of our industry partners

Some of our partners have international subsidiaries with special expertise which have benefitted the center. As an example, CIUS researchers at USN have worked in close collaboration with GE Parallel Design, Nice, France, a subsidiary of GE but not being a CIUS partner directly. GE Parallel Design develop and manufacture ultrasound sensors for the medical domain and has niche expertise in this domain not easily accessible in academia. One of the aims of this collaboration has been the design and fabrication of a hybrid CMUT/piezoelectric ultrasound probe. During the collaboration period, the teams have held regular meetings every two weeks.

EU Projects

- GE HealthCare Hercules project with KU Leuven, indirect collaboration with the centre.
- 2016-21: H2020 SC1-1-PM-04 – RECAP (Research on European Children Born Preterm) (WP leaders Asta Håberg, Kari Risnes, Marit Indredavik, NTNU)
- 2017-21: ERANET Confound NEURON - TAI-MRI (PI's: Anne Vik and Asta Håberg, NTNU).
- 2017-22: COST action - Fractional-order systems. (PI: Sverre Holm, UiO).

International
Collaboration


University of Oxford, UK
Sheffield University, UK
Kings College, London, UK
University of Twente, Netherlands
Århus University, Denmark
University of Bath, UK
Rigshospitalet, København, Denmark
Otivio, Oslo
Interreg Norway-Sweden
Linköping University, Sverige
Technical University of Denmark, Lyngby, Denmark
Charité Hospital, Berlin, Tyskland
MISIT, Delft University of Technology, Netherlands
Medical University of Vienna, Austria
M:V Lomonosov Moscow State University, Russia
Creatis Insa de Lyon, France
GE Parallell design, Sophia Antipolis, France
TDK Invense, Italy
University of Craiova, Romania
University of Rome, Italy
University of Rennes, France
Genth University, Belgium
Hohai University, Nanjing, China
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

Training of researchers

CIUS hired and trained 31 PhD students (24 male, 7 female) and 12 Post Docs (all male) during its period. There is clearly not a good gender balance in this cohort, and although there has been a focus on writing public announcements with care for gender specific language which may turn women applicants away, the center has still not succeeded in recruiting more women. This mirrors to a certain extent male dominance in the scientific fields required for a technical engineering PhD or Post Doc in CIUS based on historic attendance at universities in topics such as electronics, acoustics, and physics.

CIUS has not had a specific plan for recruiting talented Norwegian PhD candidates. We have announced our positions internationally but have also directly recruited Norwegian MSc students if the timing and candidate was right for a specific project. In the technical domains it has been somewhat challenging to attract Norwegian applications as unemployment rates in Norway have been very low during the entirety of the center.

Pay is significantly higher in the private sector in Norway for newly graduated MSc students, and it is a worrisome trend that PhD pay is lagging behind (up to 30% higher in the private sector) so much as it is today. In the medical domain, most PhDs have been Norwegian as it is required to have a medical degree accredited for work in the Norwegian health care system.

For testimonials from some of our PhDs on how it has been working in CIUS; read their own stories:

- Rosa Virginia Garone
- Simen Midtbø
- Josh Hoi Yi Siu
- Amirfereydoon Mansoori
- Ellen Katrine Sagaas Røed

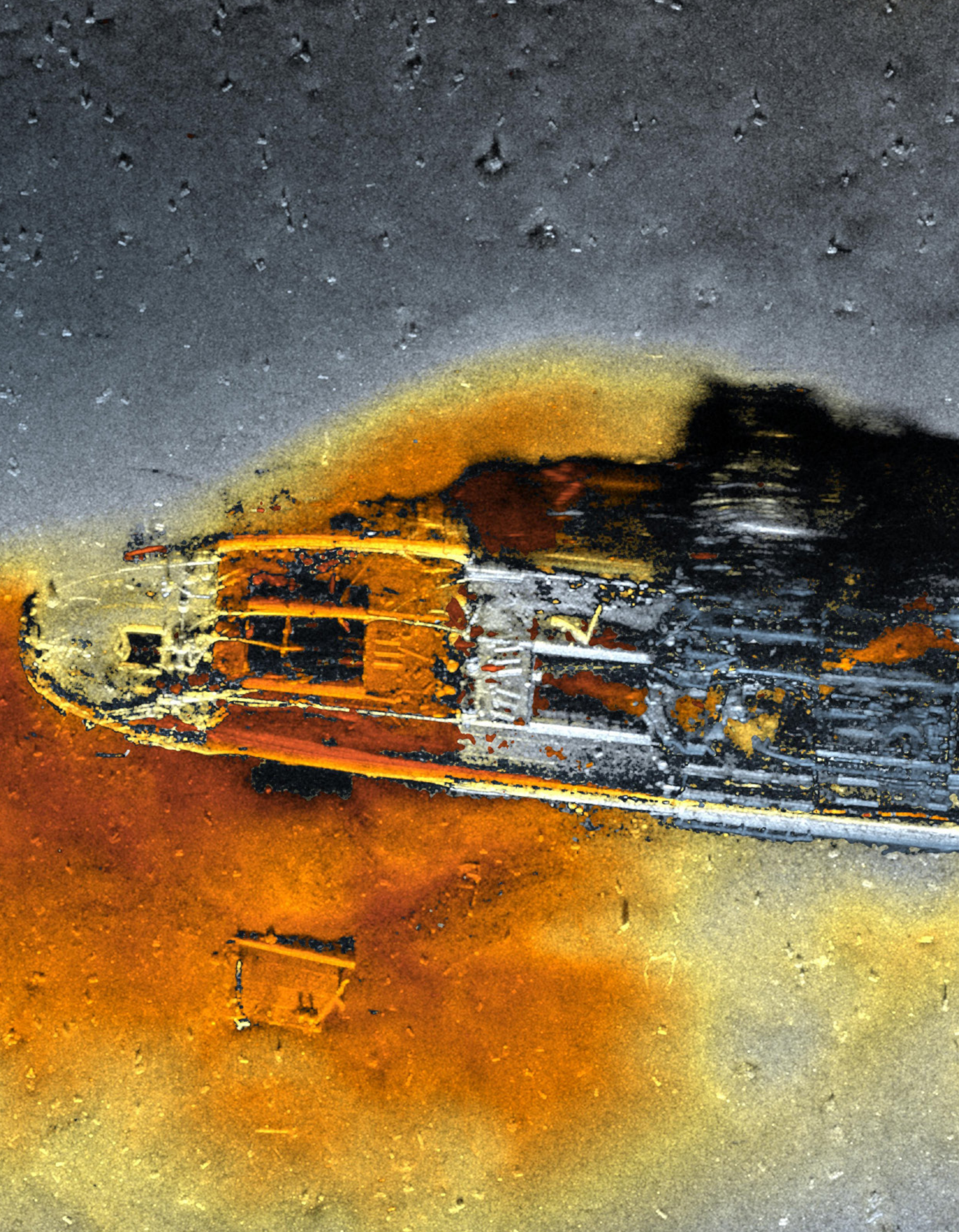
CIUS has also had 63 PhDs (41 male, 22 female) and 5 Post Docs (3 male, 2 female) affiliated with center projects with funding from other sources. The center has also recruited 109 (39% female) master and research students (clinical) to center related projects. Over the course of the center, all these candidates have generally been invited to the CIUS conferences, and to relevant courses when possible (PhDs and Post Docs).

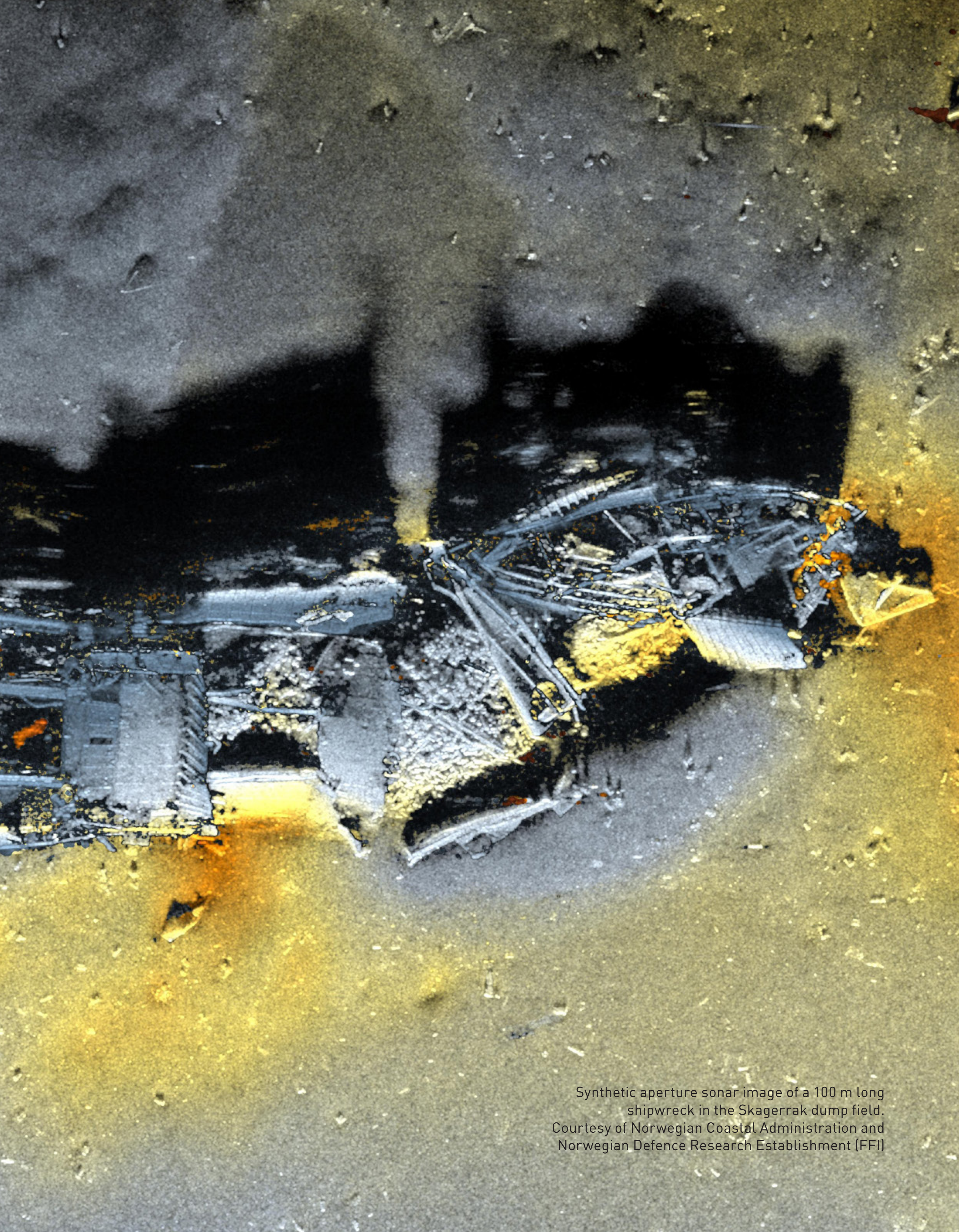
MSc and research students have also been invited to present their work for our partners, and their projects have usually been directly connected to an ongoing partner project in the center. Some are also co-inventors in reported Declarations OF Inventions (DOFIs) to the consortium.

Photo: Lasse Løvstakken

In addition to the standard training that all PhD students must do at their respective institutions, CIUS have also organized many courses and seminars over the years to provide additional knowledge relevant for work in the center and for future employers. Examples of such courses are:

- Pecha Kucha course (special technique for presenting work)
- Scientific writing courses
- Course in InDesign and figure making
- Supported attendance to national PhD courses
- Supported attendance to the School of Health Innovation, an initiative by University of Oslo, NTNU in Trondheim, University of Copenhagen, and Karolinska Institutet in Stockholm developed in collaboration with Nansen Neuroscience Network
- Course on patents and patenting
- Various seminars and training courses by our partners in their technologies and methodologies





Synthetic aperture sonar image of a 100 m long shipwreck in the Skagerrak dump field.
Courtesy of Norwegian Coastal Administration and Norwegian Defence Research Establishment (FFI)

Communication

CIUS acknowledges the importance of communicating our research to the public. The CIUS family has been very active on the media and has featured in a total of 163 media contributions ranging from local and national newspapers.

The CIUS family has been very active on the media and has featured in a total of 163 media contributions ranging from local and national newspapers (such as NRK, Finansavisen, VG, Aftenposten, Khrono, Shifter, Dagens Næringsliv, MN24, Adressavisen, Gemini.no, Forskning.no, Teknisk Ukeblad, Bergensavisen, Medwatch.no etc.) to social media channels such as LinkedIn, X (formerly known as Twitter) and Facebook.

CIUS have created 102 popular scientific articles, where most of these are blogs posted on our own blog page and shared in our social media channels. Some of these were also posted on Forskning.no under the tag "Alt om ultralyd". The blogs describe many of the research projects CIUS have undertaken and are written by our researchers. The center has had a policy and plan that all researchers directly funded by the center should blog about their work, and our public relations (PR) employee has followed this up.

Social media channels, which during the center's time have become very important, has been our main exposure for blogpost's written by our researchers and partners. These have a wide international audience, and many have received considerable number of views.

Social media channels have also developed to be an important way of communicating with the research community. Postings about new research articles and results can drive researchers to find the center's peer reviewed work. Such posting has increased in the later years, and particularly during the corona pandemic.


TØNSBERGS BLAD

Skal forbedre et produkt som dekker halve verdensmarkedet:

– Dette er helt unikt


Alt om Ultralyd

- en blogg om forskning hos SFI CIUS

(Ikke) science fiction på legekontoret


Ny teknologi kan hindre hjerneskade hos for tidlig fødte barn


Finansavisen

Skal hente 60 millioner før påske


MN24

Kompetansen har gradvis forsvunnet fra distriktene. Nå vil folk tilbake

Effects of centre for the host institution and research partners

Attendees at the CIUS Final Conference in March 2024. Photo: Mohammad Danial Mohajery

The formal host institution has been the Faculty of Medicine and Health Sciences (MH) at the Norwegian University of Science and Technology. The management of the center has been in the Ultrasound group at the Department of Circulation and Medical Imaging (ISB, its Norwegian acronym), which is a department at the MH faculty. The Ultrasound group at ISB was born in the early 70ties and has a 50-year history of ultrasound technology and clinical development.

Through its history, this group has mostly worked with medical ultrasound, but has from time-to-time also been involved in industrial related applications. With CIUS, a broader focus has come to the group, and in collaboration with other CIUS academic research teams and CIUS industrial partners, competence and projects have also been addressed with applications in the fields of maritime, oil & gas, and fish farming. This has markedly broadened the scope and knowledge in the group, e.g., exemplified by researcher Erlend Viggen writing a book about ultrasound in solid materials, and through supervision of many PhDs in all CIUS domains. Also, the strong collaboration between NTNU, SINTEF, St. Olavs hospital, and the regional hospitals of Mid-Norway has also clearly benefited from CIUS as people from the various institutions have been hired by the center and these organizations have recruited several PhDs into researcher and clinical positions.

Generally, CIUS has required the technical academic teams at NTNU, SINTEF, UiO, and USN to collaborate in more detail, as several competencies are required within each project, and we have had to make sure to have relevant knowledge available for all the PhD projects across domains. The Norwegian Defence Research Establishment (FFI) has also participated in this effort as an affiliated partner in CIUS (not entering the consortium agreement), assisting in supervision of PhD candidates and research projects, with their specific knowledge in the maritime domain.

The academic partners have also shared information about potential candidates for projects, and examples of MSc students from one institution starting PhD projects in the center in another has occurred. PhD students in the center have also taken courses at different institutions, as the knowledge about relevant courses has been more easily spread throughout the CIUS network.

In total, this has strengthened day-to-day collaboration and collegiality in the participating academic institutions, and as such we believe this has brought the academic community in Norway related to ultrasound and acoustics much closer together. An example of this is all the academic partners of CIUS (also now including FFI) are participating in a new CRI application. This shows increased desire and will to collaborate on future projects as well.

Effects of centre for the company partners, public partners and society at large

For examples of the effects of the center for society, we refer to the example stories at the start of this report. In the following, we focus on partner feedback, testimonials from some of our partners and how people in the center have collaborated.

PARTNERS FEEDBACK

The general feedback from the partners (both company and public) is threefold. First, participating in CIUS have provided them with the opportunity of taking part in, or create research projects they either could not perform internally due to lack of equipment or resources, or would not risk starting up. All our company partners face very tough competition in the market, and being at the knowledge forefront and innovating is a key strategy for maintaining or increasing market share. Being at the knowledge forefront and innovative is also very important for our public partners. The company partners state that being part of CIUS has enabled them with more continuous collaboration with academia and public partners (where relevant) over time and the dissemination of knowledge between company and academic researchers represents an asset leading to innovations and value creation. Second, participating in CIUS has provided them with great arena for training and recruiting highly competent personnel, both directly from MSc level or from PhD and Post Doc levels. This is also a very important point in international market competition. Third, CIUS has created arenas for collaboration and meetings in a large environment working on similar challenges. The bi-yearly conference has been particularly important in this context. All partners state that this has been important and fosters an environment of inspiration and creativity.

TESTIMONIALS FROM PARTNERS

Testimonials from some of our company and public partners are provide below.

GE VINGMED ULTRASOUND

"We have been involved and engaged in all work packages (except for 8 and 9, O&G and Maritime Applications); these are aligned with our internal innovation strategy. Already, several research elements have been realized into our product(s). Other elements still need more research before they potentially can be realized into product(s). The dissemination of knowledge between academic and our researchers are of great value to our company and to CIUS as the researchers both have access to state-of-the-art equipment and tools, as well as world class industrial knowhow. Participating in CIUS has also been important for the recruitment of employees, both for permanent employment and for temporary assignments. There is a synergy effect from the different industry partners as some of the product needs are the same for one or more of the partners. The benefits are both knowhow exchange and increased bandwidth for the research as several of the partners contribute to the same, or similar, research topics.

The most important innovations from the CIUS project are the research results already implemented into our products and commercialized, making a difference to patients world-wide:

- Image quality: Very good collaboration and results, clinical effectiveness proved, commercial released and launched (see own story for more details: Researchers can thank gamers for better ultrasound images of the heart), as well as continued research building on these results.
- AI: The focus is to reduce inter-operator variation and improved accuracy in echocardiographic measurement, and to make the examination more efficient, thus diagnosing more patients for the same cost.

In addition, the research results in areas such as probe technology, Doppler and quantification methods, cardiac elastography and multimodal imaging are important for further research and development in these fields for future products."

KONGSBERG DISCOVERY

"Regarding R&D and Innovation, we have been very interested in what is going on in other similar fields (medical and oil & gas) that are using acoustic and other similar technologies in their products. We are testing new processes learned from the CRI and have strengthened the collaboration and "access" to the institutions we have collaborated with in CIUS. As an example, we have recruited several people (CIUS PhDs and researchers) from USN during the CRI. We have strengthened the collaboration especially with USN, NTNU and NGU in this CRI and we have especially accelerated the R&D work in seabed classification and new transducer materials thru CIUS PhD students. We are very satisfied by having been a participant of CIUS. We have investigated many new fields in our technologies and tested out new prototypes for possible new products that we could not have done alone during the CRI period. We were joining an already established network of industrial and academic partners, it therefore took some time for us to get to know the other partners and therefore be able to both become more involved and better understand opportunities. It took a long time to finalize the consortium agreement. Different industrial partners and universities had different wishes regarding IP generated in the CRI. It is important to understand the wishes of the various industrial partners and universities and how to meet their needs."

ARCHER

"In general, participating in the CIUS conferences and speaking to the partners and the academic personnel have given us the opportunity to stay up to date with the general use of ultrasound for imaging and testing. It is also good for us to know that we have a large and diverse expertise in ultrasound technology in Norway. We have obtained valuable insight in ultrasound transducer research, in particular work being done for transducers in high pressure/high temperature environments.

Being part of the PhD mentoring for Andreas Talberg, we had many useful discussions about beam forming and wave propagation through steel pipes and steel plates. We have gained insights in practical use of machine learning (ML) for applications in ultrasound imaging and data analysis. Many research projects in CIUS have been using ML in creative and effective ways, and Archer has learned from the achievements in other projects. The collaboration with Post Doc Erlend Viggen regarding use of machine learning for better hole size and shape estimation has been advantageous for Archer. The project resulted in a license agreement with CIUS, where we obtain access to the implementation strategy and as well as the program code for the ML model. It also resulted in an excellent journal paper, giving us positive publicity."

EXACT THERAPEUTICS

"The center has been integrated in the company's R&D strategy by enabling research we do not have resources to conduct in-house. The developments at the center have not resulted in commercialization directly, but for biotech startup most of its value is created on a pre-market level. One of the activities at the center, related to delivery of drugs to the brain, opened a new research field for the company, and has resulted in a partnership with a California based company (Cordance Medical). For a small company, recruiting qualified personnel is essential for effective operations. The company has recruited 4 people (currently 33% of our staff) from academic and industrial partners in CIUS, with relevant experience for the required needs, binding us together with other partners in the ultrasound community in Norway. The center has given an arena, through the bi-annual conferences, to meet with established and potential collaborators in a setting which improves interpersonal relations and enables exchanging ideas. The center has stimulated for continued collaborations with partners including NTNU and USN also after the center has ended.

Together with CIUS, we have developed a dual frequency transducer used in many pre-clinical experiments, essential for establishing evidence of the efficacy for our technology. This concept also resulted in a patent on treatment of pancreatic cancer. Further, experiments conducted within the CIUS family was the foundation for a patent on a treatment methodology for diseases in the central nervous system (CNS) which also enabled a partnership with the previously mentioned Cordance Medical. Participation in the center has given us the opportunity to continue and strengthen collaborations with partners in both academia and industry. Research conducted within this community have been essential to us as a start-up company with limited resources to collect evidence for our treatment method under development and build value for the company. Reaching the public media is important for start-up companies, to reach potential investors' interest. The center has been helpful in this regard. They have also supported our effort to build Norway's reputation as an "ultrasound country" internationally."

ST. OLAVS HOSPITAL, TRONDHEIM UNIVERSITY HOSPITAL (PUBLIC PARTNER)

"Research and innovation within technological advancement of diagnostic ultrasound have for years been a strong and highly successful collaboration between the technological staff at NTNU and the clinical staff at St. Olavs hospital. This is further strengthened throughout the CIUS period and fits well with a win-win scenario. As a hospital partner, we are involved in the entire chain of innovations from idea to clinical evaluation. As a result from the close collaboration, innovations that are relevant for us as a partner hospital and for the general clinical society, have been made available. We suggest that this also strengthens the competitiveness of Norwegian medical industry.

There is a consensus that both the collaboration between clinicians and technicians, as well as the collaboration with the medical industry, are essential to reach the milestones of the center. There are several examples of products and algorithms developed in CIUS which have effectively been evaluated and validated in the Clinic of Cardiology. Accordingly, a rapid path for implementing innovations into clinical practice to the best for treatment of the patients is provided.

CIUS has continued and refined the collaboration between partners with respect to all part of research and innovations, as well as research education. The majority of work packages in CIUS included close collaboration between technologists, clinicians and industry. Several employees from the hospital have been employed in part-time positions within CIUS, and two of the work packages have been chaired by physicians from the Clinic of Cardiology. The work in CIUS has resulted in numerous publications and has been crucial for education of several PhD students. Our hospital greatly appreciates that several of our younger colleagues are given the opportunity to pursue PhD education and write theses that will stand as solid and important contributions for many years to come. The collaboration between partners within translational research from technical to clinical medicine and cardiology have been very important. Beyond employees formally affiliated with CIUS, the collaboration within the center has provided opportunities for numerous hospital employees to participate in clinical research and innovation. As a hospital partner we have provided a significant in-kind contribution, which we think is crucial for the success of CIUS. From our point of view, this contribution is well balanced to the benefits we yield as a partner.

In conclusion, St. Olavs hospital has greatly appreciated being a partner in the CIUS collaboration. Our experiences as a partner contributing to research and innovation relevant for large groups of patients world-wide as well as for Norwegian industry, have been the very best. St. Olavs hospital would certainly consider taking an active role as partner in a similar partnership in a future CRI. We believe that the collaboration between technical professions, clinicians and medical industry as performed within CIUS, is the best way to promote and perform outstanding research taking new innovations into the everyday clinic to best for the patients. “

EXCHANGE OF PERSONNEL BETWEEN THE PARTNERS

The primary way of personnel collaboration in the center was described earlier in the section Cooperation within the center. In CIUS, this has been the most practical way of collaborating as meetings can be both physical and digital, and teams can meet up as often as possible or required. The bi-yearly conference secures a common meeting ground, also spurring a lot of pre- and post-meeting activites between different partner constellations. In a modern world with digital communications (having greatly improved during the pandemic), this is also how most of our partners works internally. Many have international teams collaborating over continents and time zones. Also, many of our PhD candidates are in the process of developing families and having children. It is then very impractical (and unreasonable) to ask them to leave town for 6 months.

Still, some of our PhD candidates have spent parts or full time with our partners (partially a result of the pandemic also), but this has mostly happened due to people desiring to live in the cities where our partners are located, for example in Oslo or Bergen, and being affiliated to a PhD program at NTNU in Trondheim. That being said, if the candidates do live in the same city as a partner, it is much easier to arrange physical exchanges over longer periods of time, and this has happened in CIUS. Some PhD and Post Doc candidates have also been hired for periods of time with our partners to work on specific projects. This is a win-win situation, as the candidates learn to know the partners better and work with their technology. Still, this has also been solved by digital communication, and physical co-location when practically possible. In the medical domain, most of the clinical research has happened at St. Olavs hospital, which is co-located with the Ultrasound group of the host institution. In this scenario, collaboration and flow of people between the institutions is continuous, but this is a special case.

In addition, many of our partners have arranged for short time seminars, workshops, and even summer schools, to train or equip academic researchers with required knowledge for their projects. All our partners have opened their facilities, if or when required, for researchers from the center to visit or use their specific lab or equipment facilities. Sometimes partners have approached the academic partners for the same purpose. The center has also arranged for company visits during our bi-yearly conference which has alternated between Trondheim, Oslo, and Horten.

All in all, in the modern work environment there are many ways to collaborate not requiring physical co-location. The center has encouraged this activity towards our candidates, but it is not always practical. We think the way this has been solved in CIUS still has been very good for everyone involved, that we have truly managed to develop powerful relationships and strong collaborating teams across all our partner organizations.

Future prospects

CIUS has reported 48 specific innovations during its time. Several of these are already available in products or in use in internal services with our partners. There will be continued development of these technologies for potential future products. This will happen both in collaboration between the partners that were part of this development in CIUS, or it can go on internally within the partner organizations. Also, many of the reported innovations are still in development and rising on the TRL level scale. All center partners involved in such R&I have stated an interest in following and contributing (at the right time) to these developments. This is particularly relevant for the innovations where CIUS partners have signed license agreements, but the concepts have still not reached the market. It is also clear that several reported DOFIs will not be continued due to lack of interest from our partners, or because the researchers driving these projects are done with their PhDs and continue on other projects (most of them as employees with our partners but some have also started working in other companies or institutions), but this is to be expected. Not all ideas turn out to be great.

Several of the projects started in CIUS are also continuing with funding from other sources. Activities in the center has been able to acquire funding for an additional 63 PhD and 5 Post Doc positions, and many of these have not finalized their work, and are continuing e.g. clinical validations of methods developed in the consortium. The partners are also conducting pilots to further analyze concepts for potential commercialization or further research.

As an example, GE HealthCare (both the cardiovascular unit and women's health unit) is continuing to fund the ultrasound research group at NTNU and have also secured an Innovation Projects for the Industrial Sector with the same group for the next 3 years. These projects will continue to develop technologies and concepts brought up through CIUS, but also explore new opportunities.

CIUS has currently developed and published 4 open-source software libraries. Two of these have become very popular in the scientific and industrial communities (AnnotationWeb, USTB) and have been downloaded from all over the world. These are also in in continuous use with many of our partners, both for internal R&I and as tools integrated with their products for further R&I with 3rd parties. This exemplifies how tools developed within a center like CIUS serve many purposes; first, as a research tool for the center; then as a tool for collaboration between center partners and external partners; and finally, for anyone requiring such a tool. CIUS has had a goal to launch all open-source software libraries with open licenses not restricting the potential use of the code in neither further research nor commercial developments.

In the medical domain, CIUS has developed a significant number of databases from clinical trials, encompassing both clinical images and raw-unprocessed ultrasound data. The center has also developed databases based on existing data at St. Olavs hospital for data mining and Machine Learning purposes. As these data are owned by St. Olavs and NTNU, they form a natural part of the continued research at these institutions, in collaboration with CIUS partners for which these data are relevant. As such, these databases are of immense value for many years to come. In the maritime and oil & gas domain, CIUS have also obtained access to databases from our partners, but these are owned by our partners and was granted under the consortium agreement as background IP. When the consortium agreement ends, it is not yet clear how these data will be used for potential future research, and this has to be cleared with the respective partners.

Finally, many of the CIUS partners (12 of our existing partners) are also joining in an application for a new RCI with the first call deadline on September 18th of 2024. This is exciting as it shows that the center has been a success for our partners, and they want to both participate and contribute with significant resources towards a potential new center.

Conclusions

We believe that the core strength of having been a Center for Research Based Innovation (CRI) is that it creates a large environment pushing for a common goal, innovation. Planning for, meeting and discussing, and having a focus on creating innovations within a community over a long period of time generates a mentality that everyone in this environment connects to. Some more than others, but it does something to all the participants. Having the resources of the center, both in the form of cash and in-kind contribution, is key, and the center commits the partners for an 8-year stint, which allows them to think strategically about their involvement and take the center into the plans of their organizations. In our view, this is unique in the innovation funding schemes available in Norway, and why we believe the CRIs have an especially important role within this area.

Organizing the bi-yearly conference in CIUS has been a great boon the center and partner collaboration. This has in effect been a large team-building effort and we see this possibly as the strongest power of the center. The conference represents the glue of the entire project, bringing all parties together, showing off the ongoing work, representing an area for networking, project updates and ideas for new projects. This has definitely strengthened and deepened the relations between all the partners and people of the center, and in the end, its people who form and run collaborations. The conference has been particularly valuable for the PhDs and Post Docs of CIUS looking for a future employer, but also as mean of creating a motivation and understanding for their project by meeting and hearing about their partners ongoing activities and future plans. Organizing such a conference is costly in today's Norway, and here the centers cash funding has been vital for this to happen.

The center also brings with it a formalized structure, with a board, a scientific advisory board, work package leaders, and an administration including the center leader, communication advisor, and an industry liaison. Still, the most important part of the center's activity is formalized through all the projects the center has driven, where the researchers and user partners meet regularly to discuss project advancement and exchange ideas and learn from each other. As described earlier in this report, the projects were driven along a 3-stage process; 1 - Projects were defined in collaboration with partners at PhD, Post Doc, and researcher level. At this stage (TRL 1-6), the projects were driven by the Principal Investigators (PIs) and researchers in collaboration with the partners; 2 - Piloting and validating reported innovations. At this stage (TRL 7), industry partners were in the lead but still in collaboration with researchers; 3 - Commercializing the innovation (TRL 8-9). Now, industry partners had taken over the project but communicating with researchers when required. Also here, research could continue working on future versions of the technology not yet ready for the market due to e.g. technical limitations in current systems.

This process was regularly revised through annual work plans and dialogue with partners. Although the centers main research topics were already defined in its application to the RCN, important scientific and market shifts allowed CIUS to pivot to new activities as exemplified by the breakthrough of AI and Machine Learning, and the fall in oil & gas prices early in the center's existence. In summary, we believe that this way of defining and working projects has enabled CIUS to secure active participation from all our partners and make sure the center is addressing challenges they are fully engaged in.

Finally, being a center has allowed us to communicate what we do as one entity, and this is a powerful tool in today's social media driven communication strategies. Being able to post with the hashtag of CIUS attached has really promoted the center, our community, our individual researchers, and Norway's' image as an internationally renowned powerhouse of ultrasound research and innovation. We also believe this has enabled us to attract researchers from all over the world to come and work for us. Having open calls for, e.g., 8 PhD positions in one go (as we did in 2020) is valuable as it also shows a large commitment and the opportunity to create a strong collective environment to take part in.

To us, CIUS has been a great success! We have generated large amounts of research, trained researchers, strengthened collaboration between Norwegian academic, public, and private institutions, innovated and commercialized technologies, brought a bunch of new ideas out to our partners and society, and we have communicated about this thoroughly to the public at large. CIUS is dead, long live CIUS!

Financing through the life of the centre

Summary sheet for the main categories of partners (NOK)

CONTRIBUTOR	CASH	IN-KIND	TOTAL
Host	18 508 000	55 474 370	73 982 370
Research partners	-	19 917 600	19 917 600
Companies	28 000 000	32 084 125	60 084 125
Public partners	18 000 000	111 352 866	129 352 866
RCN	95 975 000	-	95 975 000
Sum	160 483 000	218 828 961	379 311 961

Distribution of resources (NOK)

TYPE OF ACTIVITY	NOK
Research projects	351 311 961
Common centre activities	4 000 000
Administration	24 000 000
Total	379 311 961

Statement of accounts for the complete period of centre financing (NOK 1000)

COST	Host	UIO	HBV / USN	GE Vingmed Ultrasound	Equinor	Kongsberg Maritime	Archer - BTC	Medistim	Aurotech Ultrasound	X- fab	Sensorlink
WP1 - Transducer and Electronics	30 946	-	12 754	15 534	1 895	6 154	62	300	161	395	589
WP2 - Acoustics and Beamforming	29 341	7 155	-	16 445	3 018	5 483	251	-	109	330	316
WP3 - Doppler and deformation imaging	32 512	-	-	8 533	2 979	4 261	378	170	113	297	251
WP4 - Image analysis and visualisation	39 772	-	-	9 064	3 056	2 756	203	159	-	5	207
WP5 - Multimodal and intervention	25 855	-	-	4 975	200	-	-	36	-	-	-
WP6 - Ubiquitous ultrasound imaging	12 218	-	-	3 577	-	-	-	30	-	-	-
WP7 - Validation - ischemic heart disease	15 784	-	-	4 412	-	-	-	-	-	-	-
WP8 - Validation Oil & Gas	-	-	-	-	2 464	-	453	-	-	-	-
WP9 - Validation Maritime	-	-	-	-	-	3 587	-	-	-	-	-
SFI Equipment	-	-	-	-	-	-	-	-	-	-	-
SFI Administration	29 529	-	-	-	-	-	-	-	-	-	-
Total budget	215 957	7 155	12 754	62 540	13 612	22 241	1 347	695	383	1 027	1 363

COST	InPhase Solutions	HMN (Central)	St. Olavs University Hospital	Nord-Trøndelag Hospital Trust	Levanger municipality	Verdal municipality	Exact Therapeutics	NDT Global	Sørlandet Sykehus HF	SUM
WP1 - Transducer and Electronics	221	-	-	-	-	-	-	3 463	-	72 474
WP2 - Acoustics and Beamforming	221	-	-	-	-	-	-	813	-	63 482
WP3 - Doppler and deformation imaging	406	-	1 144	-	-	-	-	26	-	51 070
WP4 - Image analysis and visualisation	417	-	900	-	-	-	-	26	-	56 565
WP5 - Multimodal and intervention	305	-	6 160	-	-	-	1 436	-	-	38 967
WP6 - Ubiquitous ultrasound imaging	-	-	6 863	4 798	497	302	-	-	165	28 450
WP7 - Validation - ischemic heart disease	-	-	4 429	6 667	107	56	-	-	-	31 455
WP8 - Validation Oil & Gas	562	-	-	-	-	-	-	148	-	3 627
WP9 - Validation Maritime	106	-	-	-	-	-	-	-	-	3 693
SFI Equipment	-	-	-	-	-	-	-	-	-	-
SFI Administration	-	-	-	-	-	-	-	-	-	29 529
Total budget	2 238	-	19 496	11 465	604	358	1 436	4 476	165	379 312

FUNDING	RCN	Host	UIO	HBV / USN	GE Vingmed Ultrasound	Equinor	Kongsberg Maritime	Archer - BTC	Medistim	Aurotech Ultrasound	X- fab	Sensorlink
WP1 - Transducer and Electronics	18 290	7 156	-	12 754	15 534	7 395	6 154	62	300	161	395	589
WP2 - Acoustics and Beamforming	11 439	6 083	7 155	-	18 945	6 518	5 483	251	-	109	330	316
WP3 - Doppler and deformation imaging	4 667	13 345	-	-	12 833	7 979	4 261	378	170	113	297	251
WP4 - Image analysis and visualisation	15 401	12 921	-	-	10 114	8 656	2 756	203	159	-	5	207
WP5 - Multimodal and intervention	10 721	10 084	-	-	5 125	600	-	-	36	-	-	-
WP6 - Ubiquitous ultrasound imaging	7 214	4 104	-	-	3 577	-	-	-	30	-	-	-
WP7 - Validation - ischemic heart disease	8 817	6 367	-	-	4 412	-	-	-	-	-	-	-
WP8 - Validation Oil & Gas	-	-	-	-	-	2 464	-	453	-	-	-	-
WP9 - Validation Maritime	-	-	-	-	-	-	3 587	-	-	-	-	-
SFI Equipment	-	-	-	-	-	-	-	-	-	-	-	-
SFI Administration	19 426	10 103	-	-	-	-	-	-	-	-	-	-
Total budget	95 975	70 163	7 155	12 754	70 540	33 612	22 241	1 347	695	383	1 027	1 363

FUNDING	InPhase Solutions	HMN (Central)	St. Olavs University Hospital	Nord-Trøndelag Hospital Trust	Levanger municipality	Verdal municipality	Exact Therapeutics	NDT Global	GEWHUS	Sørlandet Sykehus HF	SUM
WP1 - Transducer and Electronics	221	-	-	-	-	-	-	3 463	-	-	72 474
WP2 - Acoustics and Beamforming	221	-	-	-	-	-	-	813	5 819	-	63 482
WP3 - Doppler and deformation imaging	406	5 200	1 144	-	-	-	-	26	-	-	51 070
WP4 - Image analysis and visualisation	417	4 800	900	-	-	-	-	26	-	-	56 565
WP5 - Multimodal and intervention	305	4 500	6 160	-	-	-	1 436	-	-	-	38 967
WP6 - Ubiquitous ultrasound imaging	-	900	6 863	4 798	497	302	-	-	-	165	28 450
WP7 - Validation - ischemic heart disease	-	600	4 429	6 667	107	56	-	-	-	-	31 455
WP8 - Validation Oil & Gas	562	-	-	-	-	-	-	148	-	-	3 627
WP9 - Validation Maritime	106	-	-	-	-	-	-	-	-	-	3 693
SFI Equipment	-	-	-	-	-	-	-	-	-	-	-
SFI Administration	-	-	-	-	-	-	-	-	-	-	29 529
Total budget	2 238	16 000	19 496	11 465	604	358	1 436	4 476	5 819	165	379 312

List of Candidates

PhD candidates who have completed with financial support from the centre budget

NAME	M/F	NATIONALITY	SCIENTIFIC AREA	YEARS IN THE CENTRE	THESIS TITLE	MAIN THESIS ADVISOR
Kenneth K Andersen	M	Norwegian	Transducer design	2016-18	Therapeutic dual-frequency ultrasound transducers	L Hoff
Marcus Wild	M	UK	Transducer design	2016-18	Heat generation in underwater transducers	KB Hjelmervik
Cristiana Golfetto	F	Italian	US image noise reduction	2016-19	Improving flow detection with Doppler ultrasound in medical and oil and gas applications	IK Ekroll
Ali M Fatemi	M	Iranian	Cardiac imaging, reverberation	2016-20	On the origin of clutter in echocardiography and possible solutions	A Rodriguez-Molares
Andreas Østvik	M	Norwegian	Segmentation	2016-21	Automatic analysis in echocardiography using machine learning	L Løvstakken
Antoine Blachet	M	French	Sonar imaging	2017-20	Swath sonar: Advanced waveform modulation and associated signal processing techniques	RE Hansen
Wadi Mawad	M	Canadian	Congenital cardiac disease	2017-23	Right ventricular energetics using blood speckle tracking in pediatric congenital heart disease	SA Nyrnes
Per Kristian Bolstad	M	Norwegian	Evaluation of Metallurgical Bonding for Ultrasound Transducers	2018-22	Evaluation of Metallurgical Bonding for Ultrasound Transducers	L Hoff
David Pasdeloup	M	French	Machine learning and cardiology	2019-23	Deep Learning in the Echocardiography Workflow: Challenges and Opportunities	L Løvstakken
Sigurd Vangen Wifstad	M	Norwegian	Non-invasive measurement of cardiac valve leakage jets	2020-23	Deep Learning Applications for the Assessment of Valvular Heart Disease using Transthoracic Echocardiography	L Løvstakken
Shivanandan Indimath	M	Indian	Quantification of influx	2021-24	Doppler ultrasound for quantification of fluid influx/ efflux from borehole fractures using LWD tools	S-E Måsøy

PhD students with financial support from the centre budget who still are in the process of finishing studies

NAME	M/F	NATIONALITY	SCIENTIFIC AREA	YEARS IN THE CENTRE
Andreas S Talberg	M	Norwegian	Oil well integrity	2016-20
Erik Andreas Berg	M	Norwegian	Cardiology: aortic valve and fibrosis	2016-22
Thong Tuan Huynh	M	Norwegian	Nonlinear probes	2017-19
Aslak L Holen	M	Norwegian	Transducer electronics	2017-22
Amirfereydoon Mansoori	M	Iranian	Probe design	2018-22
Malgorzata Magelssen	F	Swedish	Handheld ultrasound primary care	2018-23
Marlene Halvorsrød	F	Norwegian	Cardiac disease	2018-23
Simen Hammervold Midtbø	M	Norwegian	Oil and gas pipe inspection	2019-22
Jessica Lage Fernandez	F	Cuba	Preclinical models, ultrasound therapy	2019-23
Olivia Mirea	F	Romanian	Ultrasound electronics	2019-23
Harald Garvik	M	Norwegian	US electronics	2020
Yasin Yari	M	Iranian	Maturation states in Atlantic salmon	2020-23
Mikael Y. Esuariwinarno	M	Indonesia	Advanced processing of data from existing well logging tools	2021
Rosa Virginia Garone	F	Italian	Machine learning for seabed classification in SONAR	2021-23
Duy Hoang Le	M	Vietnam	Probe design	2021-23
Anders Emil Vrålstad	M	Norwegian	US imaging and analysis in Ob/gyn	2021-24
Mailys Hau	F	French	AI during inteventional cardiology with US	2021-24
Josh Hoi Yi Siu	M	China	Transducer design	2021-24
Gerard Clarke	M	Slovenia	Traumatic brain injury	2022-24
Magnus Wangsteen	M	Norwegian	Pipes using ultrasound	2023-24

Postdoctoral researchers with financial support from the centre budget

NAME	M/F	NATIONALITY	SCIENTIFIC AREA	YEARS IN THE CENTRE
Sebastien Salles	M	French	Cardiac deformation Imaging	2016-18
Fabrice Prieur	M	French	Seabed mapping, ultrasound elastography	2016-19
David Bouget	M	French	Deep learning, image analysis, multimodal imaging	2016-19
Erik Smistad	M	Norwegian	Deep learning, image analysis cardiac	2016-22
Yucel Karabiyik	M	Turkish	Ultrasound novel methods (elastography)	2018-20
Hoai An Pham	M	Vietnamese	Intervention	2018-21
Erlend Viggen	M	Norwegian	AI for O&G well data analysis	2018-21
Morten Wigen	M	Norwegian	Flow measurements	2019-21
Ole Marius Rindal	M	Norwegian	Image optimalization	2020-23
Jahn Frederik Grue	M	Norwegian	Pocket ultrasound	2020-23
Mansoor Khan	M	Iranian	Transducer design	2022-23
Stefano Fiorentini	M	Italian	Cardiac US	2020-24

Post-doctoral researchers working on projects in the centre with financial support from other sources

NAME	M/F	NATIONALITY	SOURCE OF FUNDING	SCIENTIFIC AREA	YEARS IN THE CENTRE
Jørgen Avdal	M	Norwegian	MI LAB	Blood flow measurements and imaging	2016-20
Hong Pan	M	Chinese	NFR	The intelligent Cardiovascular ultrasound system	2016-18
Sofie Snipstad	F	Norwegian	The Liaison Committee for Education, Research and Innovation in Central Norway	Drug delivery cancer treatment	2018-23
Anna Karlberg	F	Swedish	St.Olavs Hospital, Fondsstiftelsen	PET MRI brain tumor	2020-24
Petros Yemane	M	Eritrean	NFR	Drug delivery cancer treatment	2023-24

PhD candidates who have completed with other financial support, but associated with the centre

NAME	M/F	NATIONALITY	SOURCE OF FUNDING	YEARS IN THE CENTRE	THESIS TITLE	MAIN THESIS ADVISOR
Karoline Aker	F	Norwegian	Department of Paediatrics, St. Olavs Hospital, The Liaison Committee for Education, Research and Innovation in Central Norway	2014-22	Perinatal asphyxia in a global perspective: how can we improve outcomes	R Støen
Tor Inge Birkenes Lønmo	M	Norwegian	Industrial-PhD, Kongsberg Maritime	2015-20	Adaptive Beamforming and Autocalibration for swath sonars	A Austeng
Sofie Snipstad	F	Norwegian	The Liaison Committee for Education, Research and Innovation in Central Norway	2016-17	Ultrasound-Mediated delivery of nanomedicine across biological barriers – for improved treatment of cancer and disease in the brain	C Davies
Yucel Karabiyik	M	Turkish	Umoja (Helse Midt)	2016-17	Quantitative Doppler analysis using color flow imaging and adaptive signal processing	L Løvstakken
Ole Marius Hoel Rindal	M	Norwegian	UiO	2016-18	Software Beamforming in Medical Ultrasound Imaging – a blessing and a curse	A Austeng
Anna Karlberg	F	Swedish	St. Olavs Hospital	2016-18	PET/MRI: Performance Characteristics and Diagnostic Assessment in Cerebral Gliomas	L Eikenes
Petros Yemane	M	Eritrean	NFR	2016-19	Ultrasound for the delivery of a nanocarrier across biological barriers in tumors: impact of cavitation and acoustic radiation force	C Davies
Einar Sulheim	M	Norwegian	NFR	2016-19	Nanomedicine and sonopermeation in the treatment of cancer	C Davies
Stefano Fiorentino	M	Italian	NTNU, DMF	2016-19	3D Doppler imaging in cardiac applications using high frame-rate sequences	J Avdal
Thu Thuy Nguyen	F	Vietnamese	USN	2016-20	Layer-specific strain and strain rates: Estimation using miniature transducers attached to the epicardium	L Hoff
Marieke Olsman	F	Netherland	NFR	2016-21	Ultrasound and microbubble treatment for improved delivery of nanomedicine to tumors and the brain	C Davies
Ekaterina Zotcheva	F	Norwegian	HIST	2016-21	Physical activity, cardiorespiratory fitness, and brain health: Evidence from epidemiological studies and a 5-year exercise intervention in older adults	L Erntsen
Silje K Øen	F	Norwegian	The Liaison Committee for Education, Research and Innovation in Central Norway	2016-22	PET/MRI – Towards clinical use in the brain	L Eikenes
Margrete Haram	F	Norwegian	NFR	2016-22	Ultrasound and microbubble-enhanced therapy of Gastrointestinal tumors using conventional cytotoxic drugs in preclinical and clinical settings	E Hofsli
Anna Hjort Hansen	F	Norwegian	Interreg, Helse Nord-Trøndelag	2016-23	Limited echocardiography and focused hand-held ultrasound by non-experts with decision-support for diagnosis and follow-up of heart failure patients	H Dalen
Stine Myhre Hverven	F	Norwegian	Strategic UiO fund, MEDIMA	2016-23	Image quality enhancement in medical ultrasound: detecting point scatterers	A Austeng
Tollef Struksnes Jahren	M	Norwegian	NFR, cooperation GE Vingmed	2016-24	Deep learning for detecting valvular events and suppressing reverberations in cardiac ultrasound	A Solberg
Morten Wigen	M	Norwegian	NFR FRIPRO	2017-18	4D ultrasound vector flow imaging for intraventricular flow assessment	L Løvstakken
Stein-Martin Fagerland	M	Norwegian	NTNU	2017-19	Nanoparticles, ultrasound and microbubble mediated drug delivery in cancer models	C Davies
Jahn Frederik Grue	M	Norwegian	Strategic funding NTNU/forskerlinja	2018-19	Automatic measurements of mitral annular motion indices	BO Haugen
Jonas Stenberg	M	Norwegian	The Liaison Committee for Education, Research and Innovation in Central Norway	2018-21	Outcome after mild traumatic brain injury – The role of neuroimaging findings and preinjury risk factors	A Vik
Jasmine Pani	F	Italian	The Liaison Committee for Education, Research and Innovation in Central Norway	2018-22	Exercise and cardiorespiratory fitness in the aging brain: evidence from the Generation 100 brain MR substudy	A Håberg

PhD students with other financial support associated with the centre who are still in the process of finishing studies

NAME	M/F	NATIONALITY	FUNDING	YEARS IN CENTRE
Harald Garvik	M	Norwegian	Strategic funding NTNU	2015-19
Vincent Perrot	M	French	University of Lyon	2016-19
Lars Saxhaug	M	Norwegian	The Liaison Committee for Education, Research and Innovation in Central Norway	2016-22
Trine Husby	F	Norwegian	Digital Life	2016-20
Elisabeth Grønn Ramsdal	F	Norwegian	Strategic UIO fund, MEDIMA	2016-17
Sri Nivas Chandrasekaran	M	Indian	Horizon 2020, Force	2016-19
Anders Tjellaug Braathen	M	Norwegian	HMN	2017-20
Torvald Espeland	M	Norwegian	Strategic funding NTNU	2017-19
Melina Muhlenpfordt	F	German	NFR	2018-22
Annichen Søyland Daae	F	Norwegian	HMN	2018-21
Thomas Grønli	M	Norwegian	HMN	2018-22
Jun Fang	M	China	NSFC mobility programme with China	2018-18
Ellen Sagaas Røed	F	Norwegian	Industrial PhD, NFR	2018-21
Henrik Fon	M	Norwegian	Strategic funding NTNU	2018-22
Ivar Salte	M	Norwegian	HSØ	2018-21
Torfin Eriksen Volnes	M	Norwegian	The Liaison Committee for Education, Research and Innovation in Central Norway	2018-24
Sindre Hellum Olaisen	M	Norwegian	Strategic funding NTNU	2019-22
Margrete Haram	F	Norwegian	HMN	2019-25
Kristian Sørensen	M	Norwegian	HMN	2019-25
Jueyu Hu	F	China	The Liaison Committee for Education, Research and Innovation in Central Norway	2020-23
Håkon Pettersen	M	Norwegian	CAG (HMN-NTNU)	2020-26
Caroline Einen	F	Norwegian	NFR	2020-23
Sebastian Price	M	Norwegian	NFR	2020-23
Ole Jacob Lorenzen	M	Norwegian	FFI	2020-23
Mohammad Danial Mohajery	M	Iran	RSO	2020-23
Ståle Hauge	M	Norwegian	The Liaison Committee for Education, Research and Innovation in Central Norway	2020-24

Peter W Strandhaugen	M	Norwegian	180 grader Nord (Bergen forskningsstiftelse)	2020-2024
Sander Bøe Thygesen	M	Norwegian	NFR	2021-24
Gabor Gereb	M	Hungarian	KM/UiO	2021-24
John Nyberg	M	Norwegian	SFI-Procardio/NTNU	2021-24
Artem Chernyshov	M	Russian	SFI-Procardio	2021-24
Daniela Melichova	F	Norwegian	SSHF	2021-25
Jinjang Yu	M	Norwegian	NTNU	2021-25
Håvard Kjellmo Arnestad	M	Norwegian	UiO	2021-25
Vegard Holmstrøm	M	Norwegian	The Liaison Committee for Education, Research and Innovation in Central Norway	2021-26
Henrik Agerup Kildahl	M	Norwegian	SFI-Procardio	2022-25
Azad Abulkalam	M	Bangladesh	The Liaison Committee for Education, Research and Innovation in Central Norway	2023-26
Håkon Dahlbom	M	Norwegian	The Liaison Committee for Education, Research and Innovation in Central Norway	2023-26
Ingrid Tveten	F	Norwegian	SINTEF	2023-27
Håkon Wesche	M	Norwegian	NFR	
Viktoria Nordlund	F	Norwegian	The Liaison Committee for Education, Research and Innovation in Central Norway	

MSc and Forskerlinje candidates with thesis related to the centre research agenda and an advisor from the centre staff

NAME	M/F	NATIONALITY	YEARS IN THE CENTRE	THESIS TITLE	MAIN THESIS ADVISOR
Duy Le An	M	Vietnamese	2015-16	Investigation of Element Variations in Ultrasound Transducer Arrays by Electrical Impedance Measurements	L Hoff
Thong Tuan Huynh	M	Vietnamese	2015-16	Optimization of Ultrasound Pulses for Second Harmonic Imaging	L Hoff
Thi Thao Khuong Pham	F	Vietnamese	2015-16	A study on Acoustic Characterization on Medical Ultrasound Transducers using pulse echo methods	L Hoff
Thi Khanh Hoa Tran	F	Vietnamese	2015-16	Characterization of Acoustic Material Prperties Using Broadband Trough Transmission Technique	L Hoff
Petr Ryzhonkov	M	Russian	2015-16	Ultrasound particle separation: experimental setup design	L Hoff
Aleksandra Egorova	F	Russian	2015-16	Ultrasound particle separation for water purification - Theory and Simulations	L Hoff
Thomas Grønli	M	Norwegian	2016-17	Modeling and data assimilation for improved ultrasound measurement of blood velocity fields	L Løvstakken
Beate Vågsholm	F	Norwegian	2016-17	Adaptive Clutter Filtering for Improved Measurement of Cardiac Blood Velocities	R de sousa Dias (L Løvstakken co-supervisor)
Sondre Strand Ravn	M	Norwegian	2016-17	Optimizing Transmit Sequence for Ultrafast Ultrasound Imaging	L Løvstakken
Benjamin Strandli Fermann	M	Norwegian	2016-17	Implementation and Assessment of Supersonic Shear Imaging Techniques	I Balasingham (L Løvstakken co-supervisor)
Solveig Bech	F	Norwegian	2016-17	Motion Tracking by Transverse Oscillations in 3D Cardiac Ultrasound Imaging	H Torp
Bikash Kumar Chaudary		Nepalese	2016-17	Dual frequency ultrasound transducer array	L Hoff
Per Kristian Bolstad	M	Norwegian	2016-17	Miniature Highly Sensitive Ultrasound Doppler Transducers	L Hoff
Alex Khiem Dinh Tran	M		2017-18	Modelling and monotoring blood flow in premature infants with open ductus arteriousus using ultrasound Doppler technique	H Torp
Anna Karoline Wisløff	F	Norwegian	2017-18	Modeling of Peripheral Resistance in the Micro-vasulature for Diabetic Patients with Ultrasound Doppler Technique	H Torp
Fabian Dietrichson	M	Norwegian	2017-18	Deep learning applications in medical imaging: Deep Convoluational Generative adversarial networks	L Løvstakken
Mikhail Vasilyev	M	Russian	2017-18	Implementation and optimization of ultrasound image classification and segmentation on a portable device based on deep learning	L Løvstakken
Magnus Sælesminde	M	Norwegian	2017-18	Intraventricular Vector Flow Mapping - An In Silicio and In Vivo Evaluation	C Davies (L Løvstakken co-supervisor)
Kristine Andreassen	F	Norwegian	2017-18	Adressing the barriers for delivery of liposomal nanoparticles to tumors	C Davies
Ingunn Hanson	F	Norwegian	2017-18	Solid Stress and nanoparticle microdistribution in xenografs: Effects of ultrasound and microbubble cavitation	C Davies
Ruth Gong Li	F	Norwegian	2017-18	Engineering a vascular model based on microfluidics for studying microbubbles in an acoustic field	C Davies
May Lise Salomonsen	F	Norwegian	2017-18	Study of the chicken choriolloantoic membrane (CMS) as a vivo-model for ultrasound-mediated delivery of drugs using nanoparticle-stabilized and standard ultrasound microbibbles	C Davies
Ellen Nymark	F	Norwegian	2017-18	Acoustic cluster therapy and the chicken chorioalloantoic membrane model	C Davies
Amirfereydoon Mansoori	F	Iranian	2017-18	Piezoelectric Material Characterization for Ultrasonic Transducers	L Hoff
Martin Henrik Hassel	M	Norwegian	2017-18	Perioperative Monitoring of Cardiac Function Based on Transesophageal Echocardiographic Data	G Kiss/ EA Berg
Gerard Clarke	M	Slovenian	2017-18	Trondheim Mild TBI Study: an investigation into blood biomarkers & the etiology of post-concussion Syndrome	A Håberg

Henrik Fon	M	Norwegian	2017-18	SAR ADC block in 22 nm FDSOI	T Ytterdal
Marjeris Romero	M		2017-18	Compiled analog and digital building blocks in 22nm FDSOI	T Ytterdal
Sindre Langen Bjørvik	M	Norwegian	2017-18	Using Delay Line Ultrasonic Transducer to Measure Temperature and Compensate	TF Johansen
Shankkar Balasubramanian	M		2018-19	Behavioral Modelling and Design of Noise Shaping SAR ADC in 22nm FDSOI	T Ytterdal
Simon Berg	M	Norwegian	2018-19	A Chopper Offset-Stabilized Operational Amplifier in 22nm FD-SOI	T Ytterdal
Astri Mikalsen	F	Norwegian	2018-19	Sensitivity of Transducer for Medical Ultrasound - Models and measurements	L Hoff
Md Ebne Al Ashad	M	Bangladesh	2018-19	Manufacturing and Characterization of acoustic matching layers for ultrasound transducers	L Hoff
Anders Hagen Jarmund	M	Norwegian	2018-19	Cerebral Hemodynamics in Normal Neonates During Tilt	R Dias (H Torp co-supervisor)
Thanh Quyen Nguyen	M		2018-19	A lumped parameters model for cerebral blood flow in neonates and infants with patent ductus arteriosus	R Dias (H Torp co-supervisor)
Adrian Fiorito	M	Norwegian	2018-19	Age Estimation from B-mode Echocardiography with 3D Convolutional Neural Networks	L Løvstakken
Marianne Lia	F	Norwegian	2018-19	The impact of tumor associate macrophages in delivery of nanoparticles to tumor cells	C Davies
Karoline Bråten	F	Norwegian	2018-19	Nanoparticle-stabilized microbubbles and focused ultrasound for targeted drug delivery to tumours: Characterization in the chicken chorioallantoic membrane model	C Davies
Stig-Martin Liavåg	M	Norwegian	2018-19	Modeling nanoparticle transport in tumors with a pore network model	C Davies
Torjus Haukom	M	Norwegian	2018-19	Basal Strain Estimation in Transesophageal Echocardiography using Unsupervised Deep Learning	G Kiss
Trym Nordal	M	Norwegian	2018-19	Automatic Detection of Mitral Annular Plane Systolic Excursion from Transesophageal Echocardiography Using Deep Learning	L Løvstakken
Anders Johannessen	M	Norwegian	2018-19	Affine Alignment of Ultrasound Volumes Using Deep Learning	G Kiss
David Pasdeloup	M	French	2018-19	Deep Learning in the Echocardiography Workflow: Challenges and Opportunities	L Løvstakken
Andreas Tesaker	M	Norwegian	2018-19	Directive under-water transducer design for Doppler velocity log	H Dong
Manar Alsenwar	F	Norwegian	2019	A New Method For Aliasing Correction in Vector Doppler Ultrasound: Evaluation of a Duplex Setup	J Avdal
Emil Braserud	M	Norwegian	2019	GPU Implementation of Aliasing-Resistant Blood Flow Estimation Using Doppler Ultrasound	L Løvstakken
Lars Erik Myrstuen	M	Norwegian	2019	Finite Element Modeling of Heat Generation in 1-3 Piezocomposite Transducers for Underwater Ultrasonic Applications	L Hoff
Cole Nielsen	M		2020	Ultra Low Power Frequency Synthesizer	T Ytterdal
Dewan Abu Md Arefin	M		2020	An Integrated Sub-nW CMOS Temperature Sensor for Realtime Thermal Monitoring of an Ultrasonic Probe	T Ytterdal
Pål Gunnar Hogganvik	M	Norwegian	2020	An all-digital sub-sampling integer-N PLL with wide tuning range in a 22nm UTBB FDSOI process	T Ytterdal
Sanjida Orin Tawhid	F		2020	Asynchronous 16-bit ALU Design For Ultrasound Application	T Ytterdal
Karoline Kjeldsaas	F	Norwegian	2020	Detection of Air Emboli in the Brain of Neonates by Ultrasound Doppler	H Torp
Yohann Sandvik	M	Norwegian	2020	Machine Learning for Classification of Myocardial Infarction and Heart Failure Using Longitudinal Myocardial Strain	I Balasingham (L Løvstakken co supervisor)
Benjamin Nedregård	M	Norwegian	2020	Heart phase recognition and insufficiency detection using machine learning on intra-operative transit time blood flow measurements	L Løvstakken
Hector Mercado Valls	M	Spanish	2020	Ultrasound image processing using deep generative models	L Løvstakken

Sigurd Wifstad	M	Norwegian	2020	Reconstruction of Ultrasound Blood Velocity Fields using Deep Learning	L Løvstaken
Krister Vikedal	M	Norwegian	2020	Examining immune responses and nanoparticle uptake in tumors caused by Acoustic Cluster Therapy	C Davies
Mathilde Mårdalen	F	Norwegian	2020	Examining immune responses and nanoparticle uptake in tumors caused by Acoustic Cluster Therapy	C Davies
Anna Kurbatskaya	F	Norwegian	2020	Effects of Ultrasound-Stimulated Microbubble Treatment on Blood Perfusion and Vascular Permeability in Tumors	C Davies
Ida Sandsbraaten	F	Norwegian	2020	Tissue Deformation Estimation with Deep Learning on Ultrasound Data	G Kiss
Kristoffer Røise	M	Norwegian	2020	Deep Learning Based Ultrasound Volume Registration for Interventional Applications	G Kiss
Anette Sollien Nicolaisen	F	Norwegian	2020-21	Characterization of Layers with Metal-Coated Polymer Spheres for use in Ultrasound Transducers	L Hoff
Josh Hoi Yi Siu	M	Hong Kong	2020-21	Fabrication and Characterization of a Low Frequency Array for a Hybrid PZT-CMUT Transducer	L Hoff
Mikael Isak Nilsen	M	Norwegian	2020-21	Analysis of an Ultrasound Transducer using a Laser Doppler Vibrometer	L Hoff
Fredrik Feyling	M		2020-21	Design Considerations for a Low-Power Control-Bounded A/D Converter	T Ytterdal
Christian Steinsland	M	Norwegian	2020-21	Design and Implementation of a Digital Standard Cell Library for 28nm Technology	T Ytterdal
Muhammad Shafiq	M		2020-21	Design of Energy Efficient LNAs for Medical Ultrasound Imaging Applications	T Ytterdal
Sanjida Orin Tawhid	F		2020-21	ASIC Implementation of a 16-Bit Asynchronous ALU for Ultrasound Application	T Ytterdal
My Tam Lam	F		2020-21	Automatic detection of air emboli in in the cerebral circulation in newborns by ultrasound doppler technique	H Torp
Tora Grenness Haga	F	Norwegian	2020-21	The Ultrasound Cardiac Supercycle for high temporal and spatial resolution	L Løvstakken
Sigvard Johansen Seljelv	M	Norwegian	2020-21	Deep Learning for Deformation Analysis in Echocardiography	L Løvstakken
Amanda Kathrine Jansen	F	Norwegian	2020-21	Automatic annotation of structures in echocardiography using deep learning	L Løvstakken
Ivan Krasovec	M	American	2020-21	Investigating systems of white matter integrity and cognitive performance using partial least squares analysis	A Håberg
Emma Bøe Olsen	F	Norwegian	2020-21	Acoustic Cluster Therapy (ACT) induced immune response in the brain and characterization of ACT cluster activation	C Davies
Mathilde Riisnæs	F	Norwegian	2020-21	Effects of Acoustic Cluster Therapy (ACT) on tumor vasculature in a mouse model of pancreatic ductal adenocarcinoma	C Davies
Gopana Sripalan	F	Norwegian	2020-21	Acoustic Cluster Therapy (ACT) and induced immune response	C Davies
Kim Ulvik	M	Norwegian	2020-21	The effect of ultrasound on transport of nanoparticles in an extracellular matrix phantom	C Davies
Hanne Maren Helgedagsrud	F	Norwegian	2020-21	Estimation of nonlinear bulk elasticity parameters for cancer tumor	R Hansen
Sigbjørn Sæbø	M	Norwegian	2020-21	Artificial intelligence for improved ultrasound diagnostics	JM Letnes, H Dalen
Anders Austlid Tasken	M	Norwegian	2020-21	Automated Segmental Cardiac Monitoring by Advanced Computerized Artificial Intelligence on Intra-Operative ThreeDimensional Ultrasound Recordings	G Kiss
Sven Goffin	M	Belgian	2020-21	Improved Strain Computation for Transesophageal Echocardiography Acquisitions	G Kiss
Håvard Kjellmo Arnestad	M	Norwegian	2020-21	A Fast Simulation Method for Ultrasonic Wave Propagation in Coupled Non-parallel Plates	E Viggen
Anders Emil Vrålstad	M	Norwegian	2020-21	Patient Adaptive Beamforming in Echocardiography	S-E Måsøy

Evelyn Lauvstad Brenne	F	Norwegian	2020-22	Cardiac surgery with cardiopulmonary bypass and the associations with stroke, bleeding, and embolic events in infectious endocarditis	H Dalen
Erlend Løland Gundersen	M	Norwegian	2021-22	Patient Adaptive Beamforming in Echocardiography	Svein-Erik Måsøy
Nina Edvardsdal	F	Norwegian	2021-22	Comparisons of Image Quality and Aperture Blockage Caused by the Ribs for Male and Female Patients in Echocardiography	Svein-Erik Måsøy
Andreas Fagerland Haavik	M	Norwegian	2021-22	Development of an FPGA echo sounder system	H Balk (Sverre Holm medveileder)
Charlotte Årseth	F	Norwegian	2021-22	Effect of ultrasound and microbubbles on vasculature and extracellular matrix components in murine breast cancer tumors	C Davies
Sara Beate Stjern Årbogen	F	Norwegian	2021-22	Acoustic Cluster Therapy and induced immune response	C Davies
Camilla Bang	F	Norwegian	2021-22	Using atomic force microscopy and second harmonic generation to investigate the effects of ultrasound and microbubbles on the extracellular matrix in 4T1 breast tumors	C Davies
Heidi Hammer Eriksen	F	Norwegian	2021-22	Risk factors for cerebral infarction in a general population aged 50-66 years	A Håberg
Vilde Wøien	F	Norwegian	2021-22	Supervised Deep Learning for Perioperative Cardiovascular Monitoring	J Vatn, G Kiss
Kåre Fosli Obrestad	M	Norwegian	2021-22	Aortic Valve Localisation in 3D Transesophageal Echocardiography Volumes using Deep Learning	G Kiss
Bendik Nilsen Brunvoll	M	Norwegian	2021-22	Implementing Volume Rendering Optimizations for Real-Time Performance Directly on Microsoft's HoloLens 2	G Kiss
Espen Lønes	M	Norwegian	2021-23	Deep-learning based covariance matrix inversion in adaptive ultrasound beamforming	P Näsholm
Sigbjørn Sæbø	M	Norwegian	2021-23	Relative left atrial and ventricular chamber size in a healthy population – The HUNT Study	JM Letnes, H Dalen
Even Olav Jakobsen	M	Norwegian	2022-24	Comprehensive evaluation of novel quality indicators for echocardiography and their importance for left ventricular strain.	H Dalen
Md Mehedi Billah	M	Bangladesh	2023	Feasibility of acoustically engineered backing material for ultrasound transducer	L Hoff
Tore Bergebakken	M	Norwegian	2023	HoloNeoDoppler: Augmented Reality Training Application for Monitoring Cerebral Blood Flow in Infants	G Kiss
Michal Zelencik	M	Norwegian	2023	Vision transformers as a support for prostate cancer detection	G Kiss
Kristian Tveiten	M	Norwegian	2023	Evolving in-game opponents with NEAT and evaluating its effect on brain activity with fMRI	OJ Mengshoel (A Håberg co-supervisor)
Martin S Hallan	M	Norwegian	2023	Evolving in-game opponents with NEAT and evaluating its effect on brain activity with fMRI	OJ Mengshoel (A Håberg co-supervisor)
Mathias Kristensen	M	Norwegian	2023	Acoustic Cluster Therapy: Immune response, tumor uptake, and bubble characterization	C Davies
Håkon Fossland Wesche	M	Norwegian	2023	Identifying Barriers in Extracellular Matrix for Ultrasound-Mediated Delivery of Nanoparticles in 4T1, KPC and CT26 Tumor Models	C Davies
Ella Johanna Devold	F	Norwegian	2023	Characterization of the mechanical properties of pancreatic, breast and colon tumor models	C Davies
Andrea Berge Kastellet	F	Norwegian	2023	Effect of Ultrasound and Microbubble Treatment on Tumor Vasculature and Liposomal Uptake in Murine Cancer Models	S Snipstad
Bahareh Malekianarani	F	Norwegian	2023-2024	Evaluation and simulation of LiNbO3 (Lithium Niobate) piezocomposite ultrasound transducer with center frequency of 3MHz.	L Hoff
Ada Woelfert	F	Norwegian	2022-2024	Not finalized	B Grenne
Ingrid Yttervoll	F	Norwegian	2022-2024	Not finalized	B Grenne

Scientific publications

– Journal articles, Articles in books and Books/reports

AUTHOR/AUTHORS	TITLE	JOURNAL/PUBLISHER
2016		
Smiseth OA, Torp H, Opdahl A, Haugaa K, Urheim S	Myocardial strain imaging: How useful is it in clinical decision making?	European Heart Journal
Atarzadeh H, Lim SK, Ytterdal T	Design and Analysis of a Stochastic Flash Analog-to-Digital Converter in 3D IC technology for integration with ultrasound transducer array	Microelectronics Journal
Bergum D, Skjeflo GW, Nordseth T, Mjølstad OC, Haugen BO, Skogvoll E, Loennechen JP	ECG patterns in early pulseless electrical activity-Associations with aetiology and survival of in-hospital cardiac arrest.	Resuscitation
Eidet J, Dahle G, Bugge JF, Bendz B, Rein KA, Aaberge L, Offstad J, Fosse E, Aakhus S, Halvorsen PS	Long-term outcomes after transcatheter aortic valve implantation: The impact of intraoperative tissue Doppler echocardiography	Interactive Cardiovascular and Thoracic Surgery
Ekroll IK, Avdal J, Swillens AE, Torp H, Løvstakken L	An Extended Least Squares Method for Aliasing-Resistant Vector Velocity Estimation	IEEE Transactions on Ultrasonics, Ferroelectrics and Frequency Control
Kaald R, Eggen T, Ytterdal T	A 1 MHz BW 34.2 fJ/step continuous time delta sigma modulator with an integrated mixer for cardiac ultrasound	IEEE Transactions on Biomedical Circuits and Systems
Ladstein J, Evensmoen HR, Håberg A, Kristoffersen A, Goa PE	Effect of task-correlated physiological fluctuations and motion in 2D and 3D echo-planar imaging in a higher cognitive level fMRI paradigm	Frontiers in Neuroscience
Rimehaug AE, Skogvoll E, Aadahl P, Lyng O, Nordhaug DO, Løvstakken L, Kirkeby-Garstad I	Minimally invasive beat-by-beat monitoring of cardiac power in normal hearts and during acute ventricular dysfunction	Physiological Reports
Sharma S, Ytterdal T	Low-power low-area beamformer design using switched-current ARAM using external capacitors	Microelectronics Journal
Wang P, Ytterdal T	A 54-uW Inverter-Based Low-Noise Single-Ended to Differential VGA for Second Harmonic Ultrasound Probes in 65-nm CMOS	IEEE Transactions on Circuits and Systems - II - Express Briefs
Håberg A, Hammer T, Kvistad KA, Rydland J, Müller TB, Eikenes L, Gårseth M, Stovner LJ	Incidental Intracranial Findings and Their Clinical Impact; The HUNT MRI Study in a General Population of 1006 Participants between 50-66 Years	PLOS ONE
Kathpalia A, Karabiyik Y, Eik-Nes S, Tegnander E, Ekroll IK, Kiss G, Torp HG	Adaptive Spectral Envelope Estimation for Doppler Ultrasound	IEEE Transactions on Ultrasonics, Ferroelectrics and Frequency Control
Van Cauwenberge J, Løvstakken L, Fadnes S, Rodriguez-Molares A, Vierendeels J, Segers P, Swillens A	Assessing the Performance of Ultrafast Vector Flow Imaging in the Neonatal Heart via Multiphysics Modeling and in Vitro Experiments	IEEE Transactions on Ultrasonics, Ferroelectrics and Frequency Control
Storve S, Grue JF, Samstad S, Dalen H, Haugen BO, Torp H	Realtime Automatic Assessment of Cardiac Function in Echocardiography	IEEE Transactions on Ultrasonics, Ferroelectrics and Frequency Control
Wang P, Ytterdal T	Low noise, -50 dB second harmonic distortion single-ended to differential switched-capacitive variable gain amplifier for ultrasound imaging	IET Circuits, Devices & Systems
Ye X, Harpe P, Ytterdal T	An area-and-power-efficient 8.4-bit ENOB 30 MS/s SAR ADC in 65 nm CMOS	Analog Integrated Circuits and Signal Processing
Karlberg AM, Sæther O, Eikenes L, Goa PE	Quantitative comparison of PET performance-Siemens Biograph mCT and mMR	EJNMMI Physics
Wamel A, van, Healey A, Sontum PC, Kvåle S, Bush N, Bamber J, Davies CDL	Acoustic Cluster Therapy (ACT) - pre-clinical proof of principle for local drug delivery and enhanced uptake.	Journal of Controlled Release
Dong H	Measurement of Ocean Bottom Reflection Loss with a Horizontal Line Array	Acta Acustica united with Acustica
Gundersen GH, Norekvål T, Haug HH, Skjetne K, Kleinau JO, Graven T, Dalen H	Adding point of care ultrasound to assess volume status in heart failure patients in a nurse-led outpatient clinic. A randomised study	Heart
Moen KJ, Vik A, Olsen A, Skandsen T, Håberg A, Evensen KAI, Eikenes L	Traumatic axonal injury: Relationships between lesions in the early phase and diffusion tensor imaging parameters in the chronic phase of traumatic brain injury	Journal of Neuroscience Research

AUTHOR/AUTHORS	TITLE	JOURNAL/PUBLISHER
Pandey V, Näsholm SP, Holm S	Spatial dispersion of elastic waves in a bar characterized by tempered nonlocal elasticity	Fractional Caluculus and Applied Analysis
Prieur FJG, Pillon A, Mestas J-l, Cartron V, Cebe P, Chansard N, Lafond M, Lafon C	Enhancement of fluorescent probes penetration into tumors in vivo using unseeded inertial cavitation	Ultrasound in Medicine and Biology
Selbekk T, Solheim O, Unsgård G	Ultrasound-guided neurosurgery: Experiences from 20 years of cross-disciplinary research in Trondheim, Norway	Neurosurgical
Solheim O, Johansen TF, Cappelen J, Unsgård G, Selbekk T	Transsellar Ultrasound in Pituitary Surgery With a Designated Probe: Early Experiences.	Operative Neurosurgery
Sølsnes AE, Sripada K, Yendik A, Bjuland KJ, Østgård HF, Aanes S, Grunewaldt KH, Løhaugen G, Eikenes L, Håberg A, Rimol LM, Skranes JS	Limited microstructural and connectivity deficits despite subcortical volume reductions in school-aged children born preterm with very low birth weight	NeuroImage
Vigge EM, Johansen TF	Simulation and modeling of ultrasonic pitch-catch through-tubing logging	Geophysics
Viggen EM, Johansen TF	Analysis of outer-casing echoes in simulations of ultrasonic pulse-echo through-tubing logging	Geophysics
Zang W, Holm S	Estimation of shear modulus in media with power law characteristics	Ultrasonics
Wamel A van, Sontum PC, Healey A, Kvåle S, Bush N, Bamber J, Davies CDL	Acoustic Cluster Therapy (ACT) enhances the therapeutic efficacy of paclitaxel and Abraxane® for treatment of human prostate adenocarcinoma in mice.	Journal of Controlled Release
Rimol LM, Indreavik M, Sæbø M	Cortial trajectories during adolescence in preterm born teenagers with very low birthweight	Cortex
Østgård HF, Sølsnes AE, Bjuland KJ, Rimol LM, Martinussen M, Brubakk AM, Håberg AK, Skranes J, Løhaugen GCC	Executive function relates to surface area of frontal and temporal cortex in very-low-birth-weight late teenagers	Early Human Developement
Garvik H, Wulff C, Ytterdal T	Noise transfer functions and loop filters especially suited for noise-shaping SAR ADCs	Proceedings - IEEE International Symposium on Cicuits and Systems
Fadnes S, Nyrnes SA, Wigen MS, Tegnander E, Løvstakken L	Detailed flow visualization in fetal and neonatal hearts using 2-D speckle tracking	Proceedings - IEEE Ultrasonics Symposium
Grønli T, Smistad E, Nyrnes SA, Gomez A, Løvstakken L	Reconstruction of In Vivo Flow Velocity Fields Based On a Rapid Ultrasound Image Segmentation and B-spline Regularization Framework	Proceedings - IEEE Ultrasonics Symposium
Høgenes J, Wigen MS, Nyrnes SA, Segers P, Swillens A, Løvstakken L	Model-based estimation of intra-cardiac blood flow velocities using an unscented Kalman filter	Proceedings - IEEE Ultrasonics Symposium
Le AD, Manh T, Hoff L	A study on electrical impedance variations between transducer elements in one-dimensional piezoelectric arrays	Proceedings - IEEE Ultrasonics Symposium
Manh T, Hoff L, Eggen T, Johansen TF, Lanteri F, Gelly J-F	Dual frequency hybrid ultrasonic transducers - Design and simulations	Proceedings - IEEE Ultrasonics Symposium
Palmer CL, Rindal OMH, Holm S, Austeng A	Realtime plane-wave software beamforming with an iPhone	Proceedings - IEEE Ultrasonics Symposium
Rindal OMH, Austeng A, Torp HG, Holm S, Rodriguez-Molares A	The dynamic range of adaptive beamformers	Proceedings - IEEE Ultrasonics Symposium
Tran TKH, Manh T, Johansen TF, Hoff L	Temperature effects on ultrasonic phase velocity and attenuation in Eccosorb and PMMA	Proceedings - IEEE Ultrasonics Symposium
Wigen MS, Løvstakken L	In vivo three-dimensional intra-cardiac vector flow imaging using a 2D matrix array transducer	Proceedings - IEEE Ultrasonics Symposium
Avdal J, Ekroll IK, Løvstakken L, Torp H	Combined 2-D vector and tracking Doppler imaging for improved blood velocity quantification	Proceedings - IEEE Ultrasonics Symposium
Karabiyik Y, Avdal J, Ekroll IK, Torp H, Løvstakken L	Data adaptive 2-D tracking Doppler	Proceedings - IEEE Ultrasonics Symposium
Prieur FJG, Catheline S	Simulation of shear wave elastography imaging using the toolbox "k-Wave"	Proceedings of Meetings on Acoustics (POMA)
Rodriguez-Molares A, Fatemi SAM, Torp H, Løvstakken L	Adaptive beamforming based on Snell's law of reflection	Proceedings - IEEE Ultrasonics Symposium
2017		
Atarzadeh H, Xu Y, Ytterdal T	A Low-Power High-Dynamic-Range Receiver System for In-Probe 3-D Ultrasonic Imaging	IEEE Transactions on Biomedical Circuits and Systems
Atarzadeh H, Ytterdal T	An in-probe low-noise low-power variable-gain receive amplifier for medical ultrasound imaging using CMUT transducers	Analog Integrated Circuits and Signal Processing

AUTHOR/AUTHORS	TITLE	JOURNAL/PUBLISHER
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Moe HK, Follestad T, Andelic N, Håberg AK, Flusund AMH, Kvistad KA, Saksvoll EH, Olsen Ø, Abel-Gruner 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
Wu G, Dong H, Ke G, Song J	An adapted eigenvalue-based filter for ocean ambient noise processing	Geophysics
Wu G, Dong H, Ke G, Song J	Shear-Wave Tomography Using Ocean Ambient Noise with Interference	Remote Sensing
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
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
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Bolstad PK, Kuziora S, Nguyen H-V, Manh T, Aasmundtveit K, Hoff L	Impact of High Pressures on Au-Sn Solid Liquid Interdiffusion (SLID) Bonds	2020 IEEE 8th Electronics System-Integration Technology Conference (ESTC)
Cochran Z, Ytterdal T, Madan A, Rizkalla M	Emerging Josephson Junction/Graphene Device Technologies towards THz Signal Generation	Proceedings of the 2020 IEEE International Symposium on Circuits and Systems
Liu X, Ytterdal T, Shur MS	TeraFET amplifier detector	Proceedings of the 2020 International Topical Meeting on Microwave Photonics
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	Proceedings of the 63rd IEEE International Midwest Symposium on Circuits and Systems
Shad EHT, Moeinfard T, Molinas M, Ytterdal T	A Power Efficient, High Gain and High Input Impedance Capacitively-coupled Neural Amplifier	IEEE Nordix Circuits and Systems Conferences (NORCaS)
Somayeh HZ, Ytterdal T, Aunet S	Multi-threshold voltage and dynamic body biasing techniques for energy efficient ultra low voltage subthreshold adders	IEEE Nordix Circuits and Systems Conferences (NORCaS)
Somayeh HZ, Ytterdal T, Aunet S	Comparative Study of Single, Regular and Flip well Subthreshold SRAMs in 22 nm FDSOI Technology	IEEE Nordix Circuits and Systems Conferences (NORCaS)
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
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)
Bolstad PK, Manh T, Midtseter N, Frijlink ME, Hoff L	Ultrasound Transducers for High Pressure Environments Up to 1000 Bar	Proceedings - IEEE Ultrasonics Symposium
Fadnes S, Sørensen K, Nyrnes SA, Wigen MS, Løvstakken L	Intraventricular Pressure Gradients - Vector Flow Imaging versus Color M-Mode	Proceedings - IEEE Ultrasonics Symposium
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Blachet A, Austeng A, Aparicio J, Hunter AJ, Hansen RE	Multibeam Echosounder With Orthogonal Waveforms: Feasibility and Potential Benefits	IEEE Journal of Oceanic Engineering

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Daae AS, Wigen MS, Fadnes S, Løvstakken L, Støylen A	Intraventricular Vector Flow Imaging with Blood Speckle Tracking in Adults: Feasibility, Normal Physiology and Mechanisms in Healthy Volunteers	Ultrasound in Medicine & Biology
Gopinath A, Cochran Z, Ytterdal T, Rizkalla M	SRAM design leveraging material properties of exploratory transistors	Materials Today: Proceedings
Grenne B, Dalen H, Nordhaug DO, Aas TS, Holte E, Damås JK, Mjølstad OC	Corynebacterium freneyi as a cause of early prosthetic valve endocarditis	BMJ Case Reports
Hauge SW, Dalen H, Estensen M-E, Persson R, Abebe S, Mekonnen D, Nega B, Solholm A, Farstad M, Bogale N, Graven T, Nielssen N-E, Brekke HK ,Vikenes K, Haaverstad R	Short-term outcome after open-heart surgery for severe chronic rheumatic heart disease in a low-income country, with comparison with an historical control group: An observational study	Open heart
Letnes JM, Eriksen-Volnes T, Nes B, Wisløff U, Salvesen Ø, Dalen H	Variability of echocardiographic measures of left ventricular diastolic function. The HUNT study	Echocardiography
Liu X, Ytterdal T, Shur MS	Frequency to digital conversion using Si TeraFETs	Optical Engineering: The Journal of SPIE
Mawad W, Løvstakken L, Fadnes S, Grønli T, Segers P, Mertens L, Nyrnes SA	Right Ventricular Flow Dynamics in Dilated Right Ventricles: Energy Loss Estimation Based on Blood Speckle Tracking Echocardiography-A Pilot Study in Children	Ultrasound in Medicine and Biology
Nguyen TT, Espinoza AW, Hyler S, Remme EW, D'hooge J, Hoff L	Myocardial strain measured by epicardial transducers —Comparison between velocity estimators	Ultrasound in Medicine and Biology
Godin OA, Deal TJ, Dong H	Physics-based characterization of soft marine sediments using vector sensors	The Journal of the Acoustical Society of America
Holm S, Holm T, Martinsen ØG	Simple circuit equivalents for the constant phase element	Plos One
Salte IM, Østvik A, Smistad E, Melichova D, Nguyen TM, Karlsen S, Brunvand H, Haugaa KH, Edvardsen T, Løvstakken L, Grenne B	Artificial Intelligence for Automatic Measurement of Left Ventricular Strain in Echocardiography	JACC Cardiovascular Imaging
Saxhaug LM, Graven T, Olsen Ø, Kleinau JO, Skjetne K, Ellekjær H, Dalen H	Feasibility and clinical impact of point-of-care carotid artery examinations by experts using hand-held ultrasound devices in patients with ischemic stroke or transitory ischemic attack	Journal of Stroke & Cerebrovascular Diseases
Støylen A, Daae AS	Physiological significance of pre- and post-ejection left ventricular tissue velocities and relations to mitral and aortic valve closures	Clinical Physiology and Functional Imaging
Viggen EM, Løvstakken L, Måsøy S-E, Merciu IA	Better Automatic Interpretation of Cement Evaluation Logs through Feature Engineering	SPE Journal
Østvik A, Salte IM, Smistad E, Nguyen TM, Melichova D, Brunvand H, Haugaa K, Edvardsen T, Grenne B, Løvstakken L	Myocardial Function Imaging in Echocardiography Using Deep Learning	IEEE Transactions on Medical Imaging
Pettersen EM, Avdal J, Fiorentini S, Salvesen Ø, Hisdal J, Torp H, Seternes A	Validation of a novel ultrasound Doppler monitoring device (earlybird) for measurements of volume flow rate in arteriovenous fistulas for hemodialysis	The Journal of Vascular Access
Zotcheva E, Håberg AK, Wisløff U, Salvesen Ø, Selbæk G, Stensvold D, Erntsen L	Effects of 5 Years Aerobic Exercise on Cognition in Older Adults: The Generation 100 Study: A Randomized Controlled Trial	Sports Medicine
Aker K, Thomas N, Adde L, Koshy B, MartinezBiarge M, Nakken I, Padankatti CS, Støen R	Prediction of outcome from MRI and general movements assessment after hypoxic-ischaemic encephalopathy in low-income and middle-income countries: data from a randomised controlled trial	"Archives of Disease in Childhood: Fetal and Neonatal Edition"
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Berntsen EM, Haukedal MD, Håberg AK	Normative data for pituitary size and volume in the general population between 50 and 66 years	Pituitary
Clarke GJB, Skandsen T, Zetterberg H, Einarsen CE, Feyling C, Follestad T, Vik A, Blennow K, Håberg AK	One-Year Prospective Study of Plasma Biomarkers From CNS in Patients With Mild Traumatic Brain Injury	Frontiers in Neurobiology
Stenberg J, Eikenes L, Moen KG, Vik A, Håberg AK, Skandsen T	Acute Diffusion Tensor and Kurtosis Imaging and Outcome Following Mild Traumatic Brain Injury	Journal of Neurotrauma
Olsman M, Mühlenpfordt M, Olsen EB, Torp SH, Kotopoulis S, Rijcken CJF, Hu Q, Thewissen M, Snipstad S, de Lange Davies C	Acoustic Cluster Therapy (ACT®) increases blood-brain barrier permeability and enhances accumulation of core-crosslinked polymeric micelles	Journal of Controlled Release
Olsman M, Sereti V, Muhlenpfordt M, Johnsen KB, Andresen TL, Urquart AJ, de Lange Davies C	Focused ultrasound and mocrobubble treatment increases delivery of transferrin reseptor-targeting liposomes to the brain	Ultrasound in Medicine & Biology

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Thavendiranathan P, Negishi T, Somerset E, Negishi K, Penicka M, Lemieu J, Aakhus S, Miyazaki S, Shirazi M, Galderisi M, Marwick TH, Investigators, SUCCOUR	Strain-Guided Management of Potentially Cardiotoxic Cancer Therapy	Journal of the American College of Cardiology
Snipstad S, Vikedal K, Maardalen M, Kurbatskaya A, Sulheim E, de Lange Davies C	Ultrasound and microbubbles to beat barriers in tumors: improving delivery of nanomedicine	Advanced Drug Delivery Reviews
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Thon SH, Hansen RE, Austeng A	Detection of Point Scatterers in Medical Ultrasound	IEEE Transactions on Ultrasonics, Ferroelectrics, and Frequency Control
Arnestad HK, Viggen EM	A fast semi-analytical method for propagating leaky Lamb wavefields	Proceedings of the 44th Scandinavian Symposium on Physical Acoustics
Estuariwinarno MY, Viggen EM	Determining Inner Geometry Properties From Eccentered Pulse-Echo Measurements in a Pipe	Proceedings of the 44th Scandinavian Symposium on Physical Acoustics
Gudala NA, Lee J, Ytterdal T, Rizkalla M	Implementation of High Speed and Low Power Carry Select Adder with BEC	Proceedings 2021 Midwest Symposium on Circuits and Systems
Liu X, Ytterdal T, Shur MS	Design and Optimization of TeraFET Spectrometer	Proceedings 2021 IEEE International Conference on Microwaves, Antennas, Communications and Electronic Systems (COMCAS)
Liu X, Ytterdal T, Shur MS	Traveling Wave TeraFET Spectrometer	Proceedings 46th International Conference on Infrared, Millimeter, and Terahertz Waves
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Mekhael G, Morgan N, Patnala M, Ytterdal T, Rizkalla M	GNRFET-Based DC-DC Converters for Low Power Data Management in ULSI System, a Feasibility Study	Proceedings 2021 IEEE International Symposium on Circuits and Systems
Mirea O, Wulff C, Ytterdal T	Current-reuse Low-Power Single-Ended to Differential LNA for Medical Ultrasound Imaging	International Conference on SMACD and 16th Conference on PRIME
Rahmani M, Patnala M, Ytterdal T, Rizkalla M	Characterization of GNRFET Devices for Applications towards 5G Communication	2021 IEEE International Conference on Design & Test of Integrated Micro & Nano-Systems (DTS)
Viggen EM, Arnestad HK	Understanding sound radiation from surface vibrations moving at subsonic speeds	Proceedings of the 44th Scandinavian Symposium on Physical Acoustics
Viggen EM, Løvstakken L, Merciu IA, Måsøy S-E	Better Automatic Interpretation of Cement Evaluation Logs through Feature Engineering	IADC/SPE Managed Pressure Drilling & Underbalanced Operations Conference & Exhibition, Virtual, September 2021
Patnala M, Ytterdal T, Rizkalla M	Low Power High Speed ADCs using GNRFET Device Technology	Proceedings of the IEEE National Aerospace and Electronics Conference
Thygesen SB, Sirevaag TL, Näsholm SP	Novel ultrasonic data processing to detect ultralight cement behind casing-a field study from Utsira High in the North Sea	IEEE International Ultrasonics Symposium
Smistad E, Salte IM, Dalen H, Lovstakken L	Real-time temporal coherent left ventricle segmentation using convolutional LSTMs	Proceedings - IEEE Ultrasonics Symposium
Smistad E, Steinsland EN, Løvstakken L	Real-time 3D left ventricle segmentation and ejection fraction using deep learning	Proceedings - IEEE Ultrasonics Symposium
Smistad E, Østvik A, Løvstakken L	Annotation Web - An open-source web-based annotation tool for ultrasound images	Proceedings - IEEE Ultrasonics Symposium
Zadeh SH, Ytterdal T, Aunet S	Subthreshold Power PC and Nand Race-Free Flip-Flops in Frequency Divider Applications	2021 IEEE Nordic Circuits and Systems Conference
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Shad EHT, Moeinfard T, Molinas M, Ytterdal T	A Low-power High-gain Inverter Stacking Amplifier with Rail-to-Rail Output	2021 IEEE International Conference on Design & Test of Integrated Micro & Nano-Systems (DTS)

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Bolstad PK, Manh T, Frijlink M, Hoff L	Acoustic Characterization of Inhomogenous Layers using Finite Element Method	Proceedings - IEEE Ultrasonics Symposium
Smistad E	FAST: A framework for high-performance medical image computing and visualization	Association for Computing Machinery (ACM)
Viggen EM	Proceedings of the 44th Scandinavian Symposium on Physical Acoustics	Norsk Fysisk Selskap

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Wifstad SV, Løvstakken L, Berg EAR, Avdal J, Torp H, Grenne B, Fiorentini S	Quantifying Valve Regurgitation using 3-D Doppler Ultrasound Images and Deep Learning	IEEE Transactions on Ultrasonics, Ferroelectrics and Frequency Control
Wamel A van, Mühlenpfordt M, Hansen R, Healey A, Villanueva FS, Kotopoulis S, Davies C de Lange, Chen X	Ultrafast microscopy imaging of Acoustic Cluster Therapy (ACT®) bubbles: Activation and Oscillation	Ultrasound in Medicine & Biology
Mawad W, Fadnes S, Løvstakken L, Henry M, Mertens L, Nyrnes SA	Pulmonary Hypertension in Children is associated with Abnormal Flow patterns in the Main Pulmonary Artery as demonstrated by Blood Speckle Tracking	CJC Pediatric and Congenital Heart Disease
Husby T, Johansen H, Bogsrud TV, Hustad KV, Evensen BV, Boellaard R, Giskeødegård GF, Fagerli UM, Eikenes L	Prognostic value of combined MTV and ADC derived from baseline FDG PET/MRI in aggressive non-Hodgkins lymphoma	BMC Cancer
Husby T, Johansen H, Bogsrud T, Hustad KV, Evensen BV, Boellard R, Giskeødegård GF, Fagerli UM, Eikenes L	A comparison of FDG PET/MR and PET/CT for staging, response assessment, and prognostic imaging biomarkers in lymphoma	Annals of Hematology
Shur MS, Liu X, Ytterdal T	Improved Thin Film Transistor Model Predicts TFT Operation in the THz Range	ECS Transactions
Saxhaug LM, Graven T, Olsen Ø, Kleinau JO, Skjetne K, Ellekjær H, Dalen H	Reliability and agreement of point-of-care carotid artery examinations by experts using hand-held ultrasound devices in patients with ischaemic stroke or transitory ischaemic attack	Open heart
Øen SK; Johannessen K, Pedersen LK, Berntsen EM, Totland JA, Johansen H, Bogsrud TV, Solheim TS, Karlberg A, Eikenes L	Diagnostic Value of 18F-FACBC PET/MRI in Brain Metastases	Clinical nuclear medicine
Midtbø SH, Aanes M, Talberg AS, Måsøy SE	ASM and finite beam description of the excited leaky Lamb wave fields in a fluid-immersed plate	Ultrasonics
Røed EKS, Bring M, Tichy F, Henriksen A, Asjord E-M, Hoff L	Optimization of Matching Layers to Extend the Usable Frequency Band for Underwater Single-Crystal Piezocomposite Transducers	IEEE Transactions on Ultrasonics, Ferroelectrics and Frequency Control
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Pasdeloup DFP, Olaisen SH, Østvik A, Sæbø S, Pettersen HN, Holte E, Grenne B, Stølen SB, Smistad E, Aase SA, Dalen H, Løvstakken L	Real-Time Echocardiography Guidance for Optimized Apical Standard Views	Ultrasound in Medicine and Biology
Leinan PR, Grønli t, Skjetne P, Wigen ms, Urheim S, Lovstakken L, Dahl SK	Comparison of ultrasound vector flow imaging and CFD simulations with PIV measurements of flow in a left ventricular outflow trackt phantom - Implications for clinical use and in silico studies	Computers in Biology and Medicine
Grande M, Bjørnsen LP, Næss-Pleym LE, Laugsand LE, Grenne B	Observational study on chest pain during the Covid-19 pandemic: changes and characteristics of visits to a Norwegian emergency department during the lockdown	BMC Emergency Medicine
Liu X, Ytterdal T, Shur MS	Multi-Segment TFT Compact Model for THz Applications	Nanomaterials
Jacobsen L, Grenne B, Olsen RB, Jortveit J	Feasibility of prehospital identification of non-ST-elevation myocardial infarction by ECG, troponin and echocardiography	Emergency Medicine Journal
Eikenes L, Visser E, Vangberg T, Håberg AK	Both brain size and biological sex contribute to variation in white matter microstructure in middle-aged healthy adults	Human Brain maping
Stenberg J, Skandsen T, Moen KG, Vik A, Eikenes L, Håberg AK	Diffusion Tensor and Kurtosis Imaging Findings the First Year Following Mild Traumatic Brain Injury	Journal of Neurotrauma
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Mansoori A, Hoff L, Salmani H, Halvorsen E	An Efficient Electrode Optimization Method for Multi-Frequency PMUTs	IEEE Transactions on Ultrasonics, Ferroelectrics and Frequency Control
Ness HO, Ljones K, Gjelsvik RH, Tjønna AE, Malmo V, Nilsen H-O, Hollekim-Strand SM, Dalen H, Høydal M	Acute effects of high intensity training on cardiac function: a pilot study comparing subjects with type 2 diabetes to healthy controls	Scientific Reports
Viggen EM, Singstad BJ, Time E, Mishra A, Berg E	Assisted Cement Log Interpretation Using Machine Learning	SPE Drilling & Completion
Aamodt EB, Lydersen S, Alnæs D, Schellhorn T, Saltvedt I, Beyer MK, Håberg A	Longitudinal Brain Changes After Stroke and the Association With Cognitive Decline	Frontiers in Neurology
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Dalen H, Letnes JM	Rethinking Left Atrial Enlargement: Identifying Individuals at Risk by Appropriate Scaling	JACC Cardiovascular Imaging
Dalen H, Graven T, Slagsvold KH, Krogstad LEB, Saxhaug LM, Tannvik TD, Holte E, Nordhaug DO, Karlsen Ø, Thorstensen A, Wahba A, Winnerkvist A	Complete embolization of a mechanical aortic valve during trail running - a case report with a lucky ending	European Heart Journal - Case Reports
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Hjorth-Hansen AK, Magelssen MI, Andersen GN, Graven T, Kleinau JO, Landstad B, Løvstakken L, Skjetne K, Mjølstad OC, Dalen H	User experience and image quality influence on performance of automated real-time quantification of left ventricular function by hand-held ultrasound devices: A diagnostic accuracy study with data from general practitioners, nurses, and cardiologists	Open heart
Chandrasekaran SN, Näsholm SP, Holm S	Wave equations for porous media described by the Biot model	Journal of the Acoustical Society of America
Poon C, Mühlenpfordt M, Olsman M, Kotopoulis S, de Lange Davies C, Hynynen K	Real-Time Intravital Multiphoton Microscopy to Visualize Focused Ultrasound and Microbubble Treatments to Increase Blood-Brain Barrier Permeability	Bioengineering
Bolstad PK, Frijlink M, Manh T, Hoff L	Estimating Effective Material Parameters of Inhomogeneous Layers Using Finite Element Method	IEEE Transactions on Ultrasonics, Ferroelectrics and Frequency Control
Brørs G, Dalen H, Allore H, Deaton C, Fridlund B, Osborne RH, Palm P, Wentzel-Larsen T, Norekvål TM, investigators CONCARD	Health Literacy and Risk Factors for Coronary Artery Disease (From the CONCARD PCI Study)	The American Journal of Cardiology
Fraser A, Markovitz AR, Haug EB, Horn J, Romundstad PR, Dalen H, Rich-Edwards J, Åsvold BO	Ten-Year Cardiovascular disease risk trajectories by obsteteric history: A longitudinal study in the Norwegian HUNT sample	Journal of the American Heart Association
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Massey RJ, Myrdal OH, Diep PP, Burman MM, Brinch L, Gullestad LL, Ruud E, Aakhus S, Beitnes JO	Reduced exercise capacity is associated with left ventricular systolic dysfunction in long-term survivors of allogeneic hematopoietic stem-cell transplantation	Journal of Clinical Ultrasound
Halle M, Prescott E, van Craenenbroeck EM, Beckers P, Videm V, Karlsen T, Feiereisen P, Winzer EB, Mangner N, Snoer M, Christle JW, Dalen H, Støylen A, Esefeld K, Heitkamp M, Spanier B, Linke A, Ellingsen Ø, Delagardelle C	Moderate continuous or high intensity interval exercise in heart failure with reduced ejection fraction: Differences between ischemic and non-ischemic etiology	American Heart Journal Plus: Cardiology Research and Practice
Gustad LT, Myklebust TÅ, Bjerkeset O, Williams LJ, Laugsand LE, Dalen H, Berk M, Romundstad S	Anxiety and depression symptoms, albuminuria and risk of acute myocardial infarction in the Norwegian HUNT cohort study	BMC Cardiocasvular Disorders
Tauschek L, Røsbjørgen REN, Dalen H, Larsen T, Karlsen T	No Effect of Calanus Oil on Maximal Oxygen Uptake in Healthy Participants: A Randomized Controlled Study	International Journal of Sport Nutrition and Exercise Metabolism
Pani J, Marzi C, Stensvold D, Wisløff U, Håberga AK, Diciotti S	Longitudinal study of the effect of a 5-year exercise intervention on structural brain complexity in older adults. A Generation 100 substudy	NeuroImage
Leth-Olsen M, Døhlen G, Torp H, Nyrnes SA	Detection of Cerebral High-Intensity Transient Signals by NeoDoppler during Cardiac Catheterization and Cardiac Surgery in Infants	Ultrasound in Medicine & Biology
Langlo KAR, Lundgren KM, Zanaboni P, Mo R, Ellingsen Ø, Hallan SI, Aksetøy ILA, Dalen H	Cardiorenal syndrome and the association with fitness: Data from a telerehabilitation randomized clinical trial	ESC Heart Failure
Tari AR, Berg HH, Videm V, Bråthen G, White LR, Røsbjørgen RN, Scheffler K, Dalen H, Holte E, Haberg AK, Selbaek G, Lydersen S, Duezel E, Bergh S, Logan-Halvorsrud KR, Sando SB, Wisløff U	Safety and efficacy of plasma transfusion from exercise-trained donors in patients with early Alzheimer's disease: protocol for the ExPlas study	BMJ Open

AUTHOR/AUTHORS	TITLE	JOURNAL/PUBLISHER
Ødegård SS, Torp H, Follestad T, Leth-Olsen M, Støen R, Nyrnes SA	Low frequency cerebral arterial and venous flow oscillations in healthy neonates measured by NeoDoppler	Frontiers in Pediatrics
Yadhav A, Rizkalla M, Ytterdal T, Lee JH, Balasubramanian LS, Gopinath A	Evaluation of FinFET in Ultra Low Power ALU	Proceedings of the 4th IEEE International Conference on Design & Test of Integrated Micro & Nano-Systems
Viggen EM, Arnestad H	Inhomogeneous P- and S-wavefields radiated into isotropic elastic solids	Proceedings of the 45th Scandinavian Symposium on Physical Acoustics
Rindal OMH, Bjåstad T G, Austeng A, Måsøy S-E	Coherence from Refocus Compared to Retrospective Transmit Beamforming	Proceedings - IEEE Ultrasonics Symposium
Liu X, Shur MS, Ytterdal T	Optimization of Si CMOS TeraFETs for 300 GHz band operation	Proceedings of the 47th International Conference on Infrared, Millimeter, and Terahertz Waves
Hu J, Smistad E, Olaisen SH, Dalen H, Lovstakken L	Exploiting temporal information in echocardiography for improved image segmentation	Proceedings - IEEE Ultrasonics Symposium
Arnestad HK, Austeng A, Näsholm SP, Rindal OMH	The Effect of Retrospective Transmit Focusing on Minimum Variance Beamforming	Proceedings - IEEE Ultrasonics Symposium
Chernyshov A, Østvik A, Smistad E, Løvstakken L	Segmentation of 2D Cardiac Ultrasound with Deep Learning: Simpler Models for a Simple Task	Proceedings - IEEE Ultrasonics Symposium
Arnestad HK, Geréb G, Lønmo TIB, Kirkebø JE, Austeng A, Näsholm SP	Sonar array beampattern bounds and an interval arithmetic toolbox	Proceedings of Meetings on Acoustics
Feyling F, Malmberg H, Wulff C, Loeliger HA, Ytterdal T	High-level Comparison of Control-Bounded A/D Converters and Continuous- Time Sigma-Delta Modulators	2022 IEEE Nordic Circuits and Systems Conference (NorCAS)
Kirkebø JE, Austeng A	Amplitude tolerance analysis of curved sonar arrays	OCEANS 2021: San Diego – Porto
Bolstad PK, Frijlink M, Hoff L	Metallurgical AuSn Bonding of Piezoelectric Layers	Proceedings - IEEE Ultrasonics Symposium
Smistad E, Østvik A, Grue JF, Dalen H, Løvstakken L	Tracking-based mitral annular plane systolic excursion (MAPSE) measurement using deep learning in B-mode ultrasound	Proceedings - IEEE Ultrasonics Symposium
Smistad E, Dalen H, Grenne B, Løvstakken L	Segmentation of parasternal long axis views using deep learning	Proceedings - IEEE Ultrasonics Symposium
Shur MS, Liu X, Ytterdal T	Plasmonic Si CMOS TeraFETs for detection, mixing, and processing sub-THz radiation	Proceedings of SPIE, the International Society for Optical Engineering
Viggen EM	Proceedings of the 45th Scandinavian Symposium on Physical Acoustics	Norsk Fysisk Selskap

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Viggen EM, Arnestad H	Modelling acoustic radiation from vibrating surfaces around coincidence: Radiation into fluids	Journal of Sound and Vibration
Taskén AA, Berg EAR, renne B, Holte E, Dalen H, Stølen S, Lindseth F, Aakhus S, Kiss G	Automated estimation of mitral annular plane systolic excursion by artificial intelligence from 3D ultrasound recordings	Artificial Intelligence In Medicine
Sæbø S, Pettersen HN, Smistad E, Pasdeloup DFP, Stølen SB, Grenne BL, Løvstakken L, Holte E, Dalen H	Real-time guiding by deep learning during echocardiography to reduce left ventricular foreshortening and measurement variability	European Heart Journal - Imaging Methods and Practice
Magelssen MI, Hjort-Hansen AK, Andersen GN, Graven T, Kleinau JO, Skjetne K, Løvstakken L, Dalen H, Mjølstad OC	Clinical Influence of Handheld Ultrasound, Supported by Automatic Quantification and Telemedicine, in Suspected Heart Failure	Ultrasound in Medicine & Biology
Støylen A, Mølmen HE, Dalen H	Regional motion of the AV-plane is related to the cardiac anatomy and deformation of the AV-plane. Data from the HUNT study	Clinical Physiology and Functional Imaging
Siu JHY, Hoff L, Frijlink M	High Temperature Performance of 3 MHz 36° Y-Cut Lithium Niobate Ultrasonic Transducer for Non-Destructive Testing at 550 °C	2023 IEEE International Ultrasonics Symposium
Shur M, Liu X, Ytterdal T	Switching Characteristics of GaN Power Transistors	ECS Transactions
Shur M, Liu X, Ytterdal	Editors' Choice - Thin Film Transistor Response in the THz range	ECS Journal of Solid State Sceince and Technology
Salte IM, Østvik A, Olaisen SH, Karlsen S, Dahlslett T, Smistad E, Eriksen-Volnes TK, Brunvand H, Haugaa KIHH, Edvardsen T, Dalen H, Løvstakken L, Grenne BL	Deep Learning for Improved Precision and Reproducibility of Left Ventricular Strain in Echocardiography: A Test-Retest Study	Journal of the American Society of Echocardiography
Rindal OMH, Bjastad TG, Espeland T, Berg EAR, Måsøy SE	A Very Large Cardiac Channel Data Database (VLCD) used to Evaluate Global Image Coherence (GIC) as an In-Vivo Image Quality Metric	IEEE Transactions on Ultrasonics, Ferroelectrics, and Frequency Control

AUTHOR/AUTHORS	TITLE	JOURNAL/PUBLISHER
Mansoori A, Hoff L, Salmani H, Halvorsen E	Electrode Design Based on Strain Mode Shapes for Configurable PMUTs	IEEE Open Journal of Ultrasonics, Ferroelectrics, and Frequency Control
Letnes JM, Nes BM, Langlo KAR, Aamodt IL, Lundgren KM, Skovereng K, Sandbakk ØB, Wisløff U, Dalen H	Indexing cardiac volumes for peak oxygen uptake to improve differentiation of physiological and pathological remodeling: from elite athletes to heart failure patients	European Heart Journal - Cardiovascular Imaging
Hu J, Olaisen SH, Smistad E, Dalen H, Løvstakken L	Automated 2-D and 3-D Left Atrial Volume Measurements Using Deep Learning	Ultrasound in Medicine and Biology
Holm S, Chandrasekaran SN, Nasholm SP	Adding a low frequency limit to fractional wave propagation models	Frontiers in Physics
Feyling F, Malmberg H, Wulff C, Loeliger H-A, Ytterdal T	Design and Analysis of the Leapfrog Control-Bounded A/D Converter	IEEE Transactions on Very Large Scale Integration
Espeland T, Wigen MS, Dalen H, Berg EAR, Hammer TA, Salles S, Løvstakken L, Amundsen BH, Aakhus S	Mechanical wave velocities in left ventricular walls in healthy subjects and patients with aortic stenosis	JACC Cardiovascular Imaging
Bolstad PK, Frijlink M, Hoff L	Evaluation of bonding techniques for ultrasound transducers	Microelectronics Reliability
Berg EAR, Taskén AA, Nordal T, Grenne B, Espeland T, Kirkeby-Garstad I, Dalen H, Holte E, Stølen S, Aakhus S, Kiss G	Fully automatic estimation of global left ventricular systolic function using deep learning in transoesophageal echocardiography	European Heart Journal - Imaging Methods and Practice
Måsøy SE, Dénarié B, Sørnes A, Holte E, Grenne B, Espeland T, Berg EAR, Rindal OMH, Rigby W, Bjåstad T	Aberration correction in 2D echocardiography	Quantitative Imaging in Medicine and Surgery
Henry M, Fadnes S, Lovstakken L, Mawad W, Mertens L, Nyrnes SA	Flow Dynamics in Children With Bicuspid Aortic Valve: A Blood Speckle Tracking Study	Ultrasound in Medicine & Biology
Indimath S, Fiorentini S, Bøklepp BR, Avdal J, Johansen TF, Måsøy SE	Effect of bubble size on ultrasound backscatter from bubble clouds in the context of gas kick detection in boreholes	Nature Scientific Reports
Fiorentini S, Berg EAR, Torp H, Aakhus S, Avdal J	Quantification of flow rates and flow volumes in valve regurgitation using 3-D high frame-rate ultrasound	IEEE Open Journal of Ultrasonics, Ferroelectrics, and Frequency Control
Sørensen K, Fadnes S, Mertens L, Henry M, Segers P, Løvstakken L, Nyrnes SA	Assessment of Early Diastolic Intraventricular Pressure Difference in Children by Blood Speckle Tracking Echocardiography	Journal of the American Society of Echocardiography
Daae AS, Wigen MS, Halvorsrød MI, Løvstakken L, Støylen A, Fadnes S	Retrospective Ultrasound Doppler Quantification Using a Single Acquisition in Healthy Adults	Ultrasound in Medicine & Biology
Yu J, Flade H-M, Tasken AA, Berg EAR, Grenne BL, Rimehaug AE	Left ventricular function monitored in intensive care using artificial intelligence and transesophageal echocardiography	Critical care
Pinto MS, Winzeck S, Kornaropoulos EN, Richter S, Paolella R, Correia MM, Glocker B, Williams G, Vik A, Posti JP, Haberg A, Stenberg J, Guns PJ, den Dekker AJ, Menon DK, Sijbers J, Van Dyck P, Newcombe VFJ	Use of support vector machines approach via ComBat harmonized diffusion tensor imaging for the diagnosis and prognosis of mild traumatic brain injury: a CENTER-TBI study	Journal of Neurotrauma
Stenberg J, Skandsen T, Moen KG, Vik A, Eikenes L, Håberg AK	Diffusion Tensor and Kurtosis Imaging Findings the First Year following Mild Traumatic Brain Injury.	Journal of Neurotrauma
Ingvaldsen SH, Hansen TI, Håberg AK, Moholdt V, Evensen KAI, Dammann O, Austeng D, Morken TS	Visual function correlates with neurodevelopment in a population cohort of school-aged children born extremely preterm	Acta Paediatrica
Karlberg A, Pedersen LK, Vindstad BE, Skjulsvik AJ, Johansen H, Solheim O, Skogen K, Kvistad KA, Bogsrud TV, Myrmel KS, Giskeødegård GF, Ingebrigtsen T, Berntsen EM, Eikenes L	Diagnostic accuracy of anti-3-[18F]-FACBC PET/MRI in gliomas	European Journal of Nuclear Medicine and Molecular Imaging
Mühlenpfordt M, Olsen EB, Kotopoulis S, Torp SH, Snipstad S, Davies CdeL, Olsman M	Real time imaging of Acoustic Cluster Therapy - induced vascular effects in the murine brain	Ultrasound in Medicine and Biology
Einen C, Price SEN, Ulvik K, Gjennestad Maa, Hansen R, Kjelstrup S, Davies deLange C	Nanoparticle Dynamics in Composite Hydrogels Exposed to Low-Frequency Focused Ultrasound	Gels
Fernandez JL, Årbogen S , Sadeghinia MJ, Haram M, Snipstad S, Torp SH, Einen C, Mühlenpfordt M, Maardalen M, Vikedal K, Davies Cde L	A Comparative Analysis of Orthotopic and Subcutaneous Pancreatic Tumour Models: Tumour Microenvironment and Drug Delivery	Cancers
Haram M, Hansen R, Bouget D, Myhre OF, de Lange Davies C, Hofsli E	Treatment of Liver Metastases With Focused Ultrasound and Microbubbles in Patients With Colorectal Cancer Receiving Chemotherapy	Ultrasound in Medicine and Biology
Haram M, Snipstad S, Berg S, Mjønes P, Rønne E, Lage J, Mühlenpfordt M, de Lange Davies C	Ultrasound and microbubbles increase the uptake of platinum in murine orthotopic pancreatic tumors	Ultrasound in Medicine and Biology
Olaisen S, Smistad E, Espeland T, Hu J, Pasdeloup D, Østvik A, Aakhus S, Rösner A, Malm S, Stylidis M, Holte E, Grenne , Løvstakken L, Dalen H	Automatic measurements of left ventricular volumes and ejection fraction by artificial intelligence: Clinical validation in real-time and large databases	European Heart Journal - Cardiovascular Imaging
Halvorsrød MI, Kiss G, Dahlslett T, Støylen A, Grenne B	Automated tissue Doppler imaging for identification of occluded coronary artery in patients with suspected non-ST-elevation myocardial infarction	The International Journal of Cardiovascular Imaging

AUTHOR/AUTHORS	TITLE	JOURNAL/PUBLISHER
Halvorsrød MI, Thorstensen A, Kiss G, Støylen A	Segmental myocardial viability by echocardiography at rest	Scandinavian Cardiovascular Journal
Eriksen-Volnes T, Grude JF, Olaisen SH, Letnes JM, Nes B, Løvstakken L, Wisløff U, Dalen H	Normalized Echocardiographic Values From Guideline-Directed Dedicated Views for Cardiac Dimensions and Left Ventricular Function	JACC: Cardiovascular Imaging
Holm S, Chandrasekaran SN, Nasholm SP	Finding wave equations for sediment acoustic theories	The Journal of the Acoustical Society of America
Vik SD, Torp H, Jarmund AH, Kiss G, Follestad T, Støen R, Nyrnes SA	Continuous monitoring of cerebral blood flow during general anaesthesia in infants	BJA Open
Strand KM, Torp H, Husby AE, Salvesen KÅB, Nyrnes SA	Continuous fetal cerebral blood flow monitoring during labor: A feasibility study	Early Human Development
Smevik H, Habli S, Saksvik SB, Kliem E, Evensmoen HR, Conde V, Petroni A, Asarnow RF, Dennis EL, Eikenes L, Kallestad H, Sand T, Thompson PM, Saksvik-Lehouillier A, Håberg AK, Olsen A	Poorer sleep health is associated with altered brain activation during cognitive control processing in healthy adults	Cerebral CORTEX
Reitlo LS, Mihailovic JM, Stensvold D, Wisløff U, Hyder F, Håberg AK	Hippocampal neurochemicals are associated with exercise group and intensity, psychological health, and general cognition in older adults	GeroScience
Hindenes LB, Ingebrigtsen T, Isaksen JG, Håberg AK, Johnsen L-H, Herder M, Mathiesen EB, Vangberg TR	Anatomical variations in the circle of Willis are associated with increased odds of intracranial aneurysms: The Tromsø study	Journal of the neurological sciences
Jarmund AH, Pedersen SA, Torp H, Dudink J, Nyrnes SA	A Scoping Review of Cerebral Doppler Arterial Waveforms in Infants	Ultrasound in Medicine & Biology
Rimol LM, Rise HH, Evensen KAI, Yendiki A, Løhaugen GC, Indredavik MS, Brubakk AM, Bjuland KJ, Eikenes L, Weider S, Håberg A, Skranes J	Atypical brain structure mediates reduced IQ in young adults born preterm with very low birth weight	NeuroImage
Garone RV, Lønmo TIB, Schimel ACG Schimel, Diesing M, Thorsnes T, Løvstakken L	Seabed classification of multibeam echosounder data into bedrock/non-bedrock using Deep Learning	Frontiers in Eart Science
Fiorentini S, Måsøy S-E, Avdal J	Analysis of Aberration Effects on Flow Imaging and Quantification in Echocardiography	IEEE Open Journal of Ultrasonics, Ferroelectrics, and Frequency Control
Clarke G, Skandsen T, Zetterberg H, Follestad T, Einarsen C, Vik A, Mollnes TE, Pischke SE, Blennow K, Håberg AK	Longitudinal Associations Between Persistent Post-Concussion Symptoms and Blood Biomarkers of Inflammation and CNS-Injury Following Mild Traumatic Brain Injury	Journal of Neurotrauma
Mohajery M, Salles S, Espeland T, Fadnes S, Løvstakken L	Automated 3D velocity estimation of natural mechanical wave propagation in the myocardium	IEEE Open Journal of Ultrasonics, Ferroelectrics, and Frequency Control
Kildahl HA, Brenne EML, Dalen H, Wahba A	Systemic embolization in infective endocarditis	Indian journal of thoracic and cardiovascular surgery
Shur M, Liu X, Ytterdal T	Phase-sensitive Silicon CMOS TeraFETs	48th International Conference on Infrared, Milimeter, and Terahertz Waves
Kasongo M, Ytterdal T, Lee J, Rizkalla M, Kumar M	Evaluation of Leakage Currents in Memristor Crossbar Arrays	Proc. 2023 IEEE National Aerospace and Electronics Conference
Johansen TF, Buschmann PE, Røsberg KM, Diez A, Viggen EM	Ultrasonic Well Integrity Logging Using Phased Array Technology	International Conference on Offshore Mechanics and Arctic Engineering
Hu J, Smistad E, Grenne BL, Holte E, Dalen H, Løvstakken L	Left-Ventricular Volume Estimation in Contrast-Enhanced Echocardiography Using Deep Learning	2023 IEEE International Ultrasonics Symposium
Gopinath A, Ytterdal T, Yadav A, Lee J, Rizkalla M, Kumar M	SRAM Vmin Scaling Via Negative Wordline	Proceeding of the 66th IEEE International Midwest Symposium on Circuits and Systems
Diez A, Johansen TF, Viggen EM	From 3D to 1D: Effective numerical modelling of pulse-echo measurements in pipes	Proceedings of the 46th Scandinavian Symposium on Physical Acoustics
Balasubramanian LS, Rizkalla M, Lee J, Ytterdal T, Kumar M	Towards No Penalty Control Hazard Handling	Proceeding of the 66th IEEE International Midwest Symposium on Circuits and Systems
Balasubramanian LS, Cochran Z, Rizkalla M, Lee J, Ytterdal T	Ultra Low-Power Low-Noise GNRFET Wideband Amplifier for Cryogenic Applications	Proc. 2023 IEEE National Aerospace and Electronics Conference
Balasubramanian S, Wulff C, Ytterdal T	A 160-GHz Power Amplifier with 32-dB Gain and 9.8% Peak PAE in 28-nm FD-SOI	2023 IEEE International Symposium on Circuits and Systems (ISCAS)
Kvalevåg MD, Vrålstad AE, Rindal OMH, Bjåstad TG, Denarie B, Kristoffersen K, Måsøy S-E, Løvstakken L	vbeam: a Fast and Differentiable Beamformer for Optimizing Ultrasound Imaging	2023 IEEE International Ultrasonics Symposium
Wangensteen M, Johansen TF, Fatemi A, Viggen EM	Ultrasonic Guided Waves and Machine Learning for Corrosion Monitoring in Steel Pipes	AMPP Annual 2023 Conference Proceedings
Fiorentini S, Mohajery M, Løvstakken L, Salles S	Detection of natural mechanical waves in the heart using Directional Clutter Filter Wave Imaging (DCFWI)	2023 IEEE International Ultrasonics Symposium

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Fiorentini S, Sauvage J, Mostefaoui S, Lovstakken L, Salles S	Detection of Natural Pulse Waves (PWs) for Anisotropy characterization: an in vitro Study	2023 IEEE International Ultrasonics Symposium
Indimath S, Bøklepp BR, Måsøy SE	Early gas-kick detection while drilling boreholes using ultrasonic LWD transducers	2023 IEEE International Ultrasonics Symposium
Bryon V, Wifstad SV, Grønli T, Hu J, Løvstakken L	Automated Patient-Specific Left Ventricular Simulations for Cardiac Function Evaluation Using Image-Based Computational Fluid Dynamics and Color Flow Imaging	2023 IEEE International Ultrasonics Symposium
Khan M	Equivalent Circuit Model for a Dual Hybrid Ultrasound Transducer	Proceedings of the 46th Scandinavian Symposium on Physical Acoustics
Le DH, Manh T, Hoff L	A novel wide-band design of dual-frequency transducer based on PZT-PVDF for super harmonic imaging	2023 IEEE International Ultrasonics Symposium
Chandrasekaran SN, Holm S, Näsholm SP	Wave equations of the two common sediment acoustic theories	Proceedings of Meetings on Acoustics
Gopinath A, Ytterdal T, Lee J, Rizkalla M, Kumar M	SRAM Process and Debug Sensor	NAECON 2023 - IEEE National Aerospace and Electronics Conference
Viggen EM	Proceedings of the 46th Scandinavian Symposium on Physical Acoustics	Norsk Fysisk Selskap

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Ingvaldsen SH, Jørgensen AP, Grøtting A, Sand T, Eikenes L, Håberg AK, Indredavik MS, Lydersen S, Austeng D, Morken TS, Evensen KAI	Visual outcomes and their association with grey and white matter microstructure in adults born preterm with very low birth weight	Scientific reports
Le DH, Manh T, Hoff L	Lamination of Capacitive Micromachined Ultrasonic Transducer on a Piezoelectric Array: Process and Evaluation	24th European Microelectronics and Packaging Conference & Exhibition
Faldaas BO, Nielsen EW, Storm BS, Lappegård KT, Nilsen BA, Kiss G, Skogvoll E, Torp H, Ingul CB	Real-time feedback on chest compression efficacy by hands-free carotid Doppler in a porcine model	Resuscitation Plus
Zhu AH, Nir T, Javid S, Villalon-Reina JE, Rodrigue AL, Strike LT, Zubicaray GI, McMahon KL, Wright MJ, Medland SE, Blangero J, Glahn DC, Kochunov P, Håberg AK, Thompson PM, Jahanshad N, Alzheimer's Disease Neuroimaging Initiative	Lifespan reference curves for harmonizing multi-site regional brain white matter metrics from diffusion MRI	bioRxiv
Kong XY, Lauritzen KH, Dahl TB, Holm S, Olsen MB, Skjelland M, Nielsen C, Michelsen AE, Ueland T, Aukrust P, Halvorsen B, Sandanger Ø	CD38 deficient mice are not protected from atherosclerosis	Biochemical and Biophysical Research Communications
Fermann BS, Nyberg J, Remme EW, Grue JF, Grue H, Håland R, Lovstakken L, Dalen H, Grenne B, Aase SA, Snare SR, Østvik A	Cardiac Valve Event Timing in Echocardiography using Deep Learning and Triplane Recordings	IEEE Journal of Biomedical and Health Informatics
Taskén AA, Yu J, Berg EAR, Grenne B, Holte E, Dalen H, Stølen S, Lindseth F, Aakhus S, Kiss G	Automatic Detection and Tracking of Anatomical Landmarks in Transesophageal Echocardiography for Quantification of Left Ventricular Function	Ultrasound in Medicine & Biology
Chotirios NP, Holm S	Modeling and simulation of underwater acoustic propagation through a random distribution of ice blocks	JASA Express Letter
Olsen MB, Kong XY, Louwe MC, Lauritzen KH, Schanke Y, Kaasbøll OJ, Attramadal H, Øgaard J, Holm S, Aukrust P, Ryan L, Espevik T, Yurchenko M, Halvorsen B	SLAMF1-derived peptide exhibits cardio protection after permanent left anterior descending artery ligation in mice	Frontiers in Immunology
Leth-Olsen M, Døhlen G, Torp H, Nyrnes SA	Cerebral blood flow dynamics during cardiac surgery in infants	Pediatric Research
Flusund A-MH, Bø LE, Reinertsen I, Solheim O, Skandsen T, Håberg A, Andelic N, Vik A, Moen KG	Lesion Frequency Distribution Maps of Traumatic Axonal Injury on Early Magnetic Resonance Imaging After Moderate and Severe Traumatic Brain Injury and Associations to 12 Months Outcome	Journal of Neurotrauma
Strand BH, Håberg AK, Eyjólfsdóttir HS, Kok A, Skirbekk V, Huxhold O, Løset GK, Lennartsson C, Schirmer H, Herlofson K, Veenstra M	Spousal bereavement and its effects on later life physical and cognitive capability: the Tromsø study	GeroScience
Edwin TH, Asta K. Håberg, Ekaterina Zotcheva, Bernt Bratsberg, Astanand Jugessur, Bo Engdahl, Catherine Bowen, Geir Selbæk, Hans-Peter Kohler, Jennifer R. Harris, Sarah E. Tom, Steinar Krokstad, Teferi Mekonnen, Yaakov Stern, Vegard F. Skirbekk, Bjørn H. Strand	Trajectories of Occupational Cognitive Demands and Risk of Mild Cognitive Impairment and Dementia in Later Life. The HUNT4 70+ Study	Neurology
Mansoori A, Salmani H, Hanke U, Hoff L, Halvorsen E	Electroacoustic Modeling of Patterned Piezoelectric Micromachined Ultrasonic Transducers	IEEE Sensors Journal

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Clarke GJB, Follestad T, Skandsen T, Zetterberg H, Vik A, Blennow K, Olsen A, Håberg AK	Chronic immunosuppression across 12 months and high ability of acute and subacute CNS-injury biomarker concentrations to identify individuals with complicated mTBI on acute CT and MRI	Journal of Neuroinflammation
Wifstad SV, Kildahl HA, Grenne B, Holte E, Hauge SW, Sæbø S, Mekonnen D, Nega B, Haaverstad R, Estensen ME, Dalen H, Lovstakken L.	Mitral Valve Segmentation and Tracking from Transthoracic Echocardiography Using Deep Learning	Ultrasound in Medicine & Biology
Chernyshov A, Grue JF, Nyberg J, Grenne B, Dalen H, Aase SA, Østvik A, Lovstakken L	Automated Segmentation and Quantification of the Right Ventricle in 2-D Echocardiography	Ultrasound in Medicine & Biology
Shah AM, Myhre PL, Arthur V, Dorbala P, Rasheed H, Buckley LF, Claggett B, Liu G, Ma J, Nguyen NQ, Matsushita K, Ndumele C, Tin A, Hveem K, Jonasson C, Dalen H, Boerwinkle E, Hoogeveen RC, Ballantyne C, Coresh J, Omland T, Yu B.	Large scale plasma proteomics identifies novel proteins and protein networks associated with heart failure development.	Nature communications
Rye CS, Ofstad AP, Åsvold BO, Romundstad PR, Horn J, Dalen H	The influence of diagnostic subgroups, patient- and hospital characteristics for the validity of cardiovascular diagnoses-Data from a Norwegian hospital trust	Plos One
Knol MJ, Poot RA, Evans TE, Satizabal CL, Mishra A, Sargurupremraj M, Auwera S van der, Duperron M-G, Jian X, Hostettler IC, van Dam-Nolen D H.K, Lamballais S, Pawlak MA, Lewis CE, Carrion-Castillo A, van Erp T G.M, Reinbold CS, Shin J, Scholz M, Håberg AK…Adams H H.H	Genetic variants for head size share genes and pathways with cancer	Call Reports Medicine
Walhovd KB, Krogsrud SK, Amlien IK, Sørensen Ø, Wang Y, Bråthen ACS, Overbye K, Kransberg J, Mowinckel AM, Magnussen F, Herud M, Håberg AK, Fjell AM, Vidal-Pineiro D	Fetal influence on the human brain through the lifespan	eLife
Yari Y, Næve I, Bergtun PH, Hammerdal A, Måsøy SE, Voormolen MM, Løvstakken L	Deep Learning for Automated Egg Maturation Prediction of Atlantic Salmon Using Ultrasound Imaging	IEEE Access
Yari Y, Næve I, Hammerdal A, Bergtun PH, Måsøy SE, Voormolen MM, Løvstakken L	Automated Measurement of Ovary Development in Atlantic Salmon Using Deep Learning	Ultrasound in Medicine & Biology
Vrålstad AE, Kvalevåg MD, Rindal OMH, Måsøy SE	Universal REFoCUS Beamforming With Spatial Weighting	IEEE Open Journal of Ultrasonics, Ferroelectrics, and Frequency Control
Vrålstad AE, Rindal OMH, Bjåstad TG, Måsøy SE	Sound Speed and Virtual Source Correction in Synthetic Transmit Focusing	IEEE Open Journal of Ultrasonics, Ferroelectrics, and Frequency Control
Midtbø SH, Måsøy SE, Aanes M	The higher order leaky Lamb wave sensitivity of a notch in a fluid-immersed plate	Ultrasonics
Indimath S, Wifstad SV, Bryon V, Bøklepp BR, Lovstakken L, Avdal J, Fiorentini S, Måsøy SE	Subpixel segmentation of borehole fractures from low resolution Doppler ultrasound images using machine learning	Geoenergy Science and Engineering
Indimath S, Bøklepp BR, Måsøy SE	Performance of Doppler ultrasound for fluid influx/efflux velocity estimation from borehole fractures in water-based and oil-based muds	Geoenergy Science and Engineering
Gundersen EL, Smistad E, Jahren TS, Måsøy SE	Hardware-Independent Deep Signal Processing: A Feasibility Study in Echocardiography	IEEE Transactions on Ultrasonics, Ferroelectrics, and Frequency Control
Liu X, Ytterdal T, Shur M	Compact SPICE models for TeraFETs	International Journal of High Speed Electronics Systems

Over the years we have discovered some errors in our reporting of research articles. This list therefore contains more than the total of 533 scientific works reported. The correct number should be 561.

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