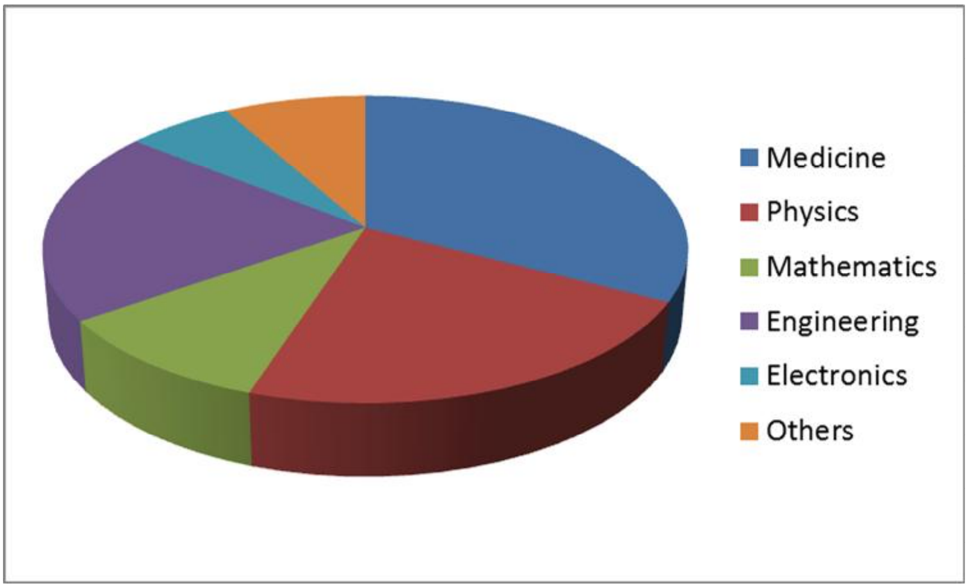
MI Lab Annual Report 2013

Summary

The Centres for Research-based Innovation represent a scheme in which several industrial partners, university and hospital work together in an open research environment. Our experience so far is that we in MI Lab are able to build an arena for open innovation and long-term industrial research with high scientific quality and commitment from the partners. In 2013 this resulted in publication of 42 refereed articles in international journals and two inventions that were considered for patenting.

For the 5 years period 2008 – 2013 there has been a total number of 214 full scientific papers with MI Lab involvement, and a total number of 13 inventions considered for patenting.

MI Lab has a strong focus on researcher training and for the entire 8-years period there will be a total number of 30 completed PhDs financed by MI Lab.
For the entire 8-years period there was total number of 19 post doc fellows with financing from MI Lab (some of these were clinical doctors with only part time post doc positions).
The figure shows the multi-disciplinarity of this group of 49 PhDs and post docs:



Recruitment of clever and motivated researchers is MI Lab strongest asset, and inside this research environment there is a continuous generation of new ideas that have potential for fulfilling the MI Lab vision of innovation that may facilitate cost efficient health care and improved patient outcome. It is nice to see the competence and enthusiasm of this group of PhD and post doc students. They obtain experience in medical R&D in the crossroad between university, industry and hospital, and will be a future pool for recruitment of high-quality personnel for Norwegian industrial R&D, health care and academia.

MI Lab has a broad range of research and innovation activities in ultrasound, MR and image-guided surgery. In 2013 we have (see Scientific activities and results subchapter below) chosen to high-light scientific results from the areas of:

- how new ultrasound technology with significantly increased frame rate can open new possibilities in ultrasound of cardiac function
- how new ultrasound technology for visualization and quantification of flow in the brain can benefit minimally invasive brain surgery
- ultrasound guided placement of catheters to drain excess cerebrospinal fluid from the brain ventricular system
- MR Imaging for early diagnosis of dementia
- Improvement of functional MRI to localize brain activity and networks
- new MR Imaging method for monitoring of target binding in targeted drug delivery
- how the pocket-sized hand-held ultrasound scanner Vscan can change medical practice at the hospital emergency admittance and in the GP office

MI Lab Vision

To facilitate cost efficient health care and improved patient outcome through innovation in medical imaging, and to exploit the innovations to create industrial enterprise in Norway.

MI Lab Research Plan

The MI Lab research plan is based on the understanding that the most important challenge for the future healthcare is how to exploit the great achievements in medical research in order to improve patient treatment and outcome while containing costs. Medical imaging is central to meeting this challenge, and new technology for improved cost efficacy should be a main focus for imaging research and industrial innovation. Innovation in medical imaging can contribute to improved cost-efficiency on several levels, and MI Lab has chosen to focus on three important areas:

- high quality medical imaging products and applications for non-expert users at the initial point of care
- less complications and more rapid patient rehabilitation with image-guided minimally invasive surgery
- more rapid and more precise choice of efficient treatment through decision-making based on advanced medical imaging.

Based on the advice from the MI Lab Scientific Advisory Board, it was chosen to have one “area of focus where it can be the synergistic agent for the creation of new program(s)". That is medical ultrasound integrating research on hardware, software and clinical feasibility studies.

Inside this framework, MI Lab has the following project structure:
Research Task 1: Ultrasound technology
- Ultrasound image improvement

Research Task 2: Advanced imaging applications for non-expert user
- Cardiac Ultrasound
- Pocket-sized Ultrasound

Research Task 3: Image guided minimally invasive surgery
- Neurosurgery
- Cardiac & Vascular surgery

Research Task 4: Imaging based information to support medical decision making
- Advanced MR methods in clinical diagnosis
- MR in regenerative medicine & nanoparticles for imaging

MI Lab Strategy

The strategy is to establish a creative melting pot for medical imaging research through:
- bringing together on a daily basis researchers from university, hospital and industry
- establishing a large multi-disciplinary research environment including medicine, ICT, physics, mathematics, cybernetics, electronics, physiology, molecular biology, neuroscience, psychology etc.
- in the same projects combine curiosity driven research and relevance for industry and health care

And that successful innovation for next generation technology will emanate from this integration between research on new technology and research on new clinical practice.

MI Lab has focused on the following success criteria (taken from the RCN "official" list of success criteria for Centres for Research-based Innovation):
- The centre engages in long-term industrial research of a high international calibre, and demonstrates its high quality through its production of doctorates, scientific publications, papers for presentation at recognised international conferences and other forms of scientific merit.
- Researchers from the host institution and partners participate actively in the centre's research. The centre has achieved mutual mobility of personnel between the centre and the user partners.
- The centre attends to researcher training effectively, and helps to train highly skilled personnel in the centre's special fields.
- The centre's research has engendered or is expected to engender possibilities for innovation and enhanced competitiveness among user partners and expectations about social ramifications over and above the partners' direct participation in the centre's activities.

MI Lab Organisation

The MI Lab board consisted in 2013 of:

Eva Nilsen, GE Vingmed Ultrasound, leader
Erik Swensen, MediStim
Atle Kleven, Sonowand
Audun Græsli, Aurotech Ultrasound
Sturla Eik-Nes, St. Olavs University Hospital
Stig Slørdahl, NTNU
Asta Håberg, NTNU

The MI Lab partners at the end of 2013 are:

- NTNU (Trondheim)
- St. Olavs University Hospital HF (Trondheim)
- GE Vingmed Ultrasound AS (Horten, Oslo and Trondheim)
- MediStim ASA (Oslo)
- Sonowand AS (Trondheim)
- Aurotech Ultrasound AS (Tydal and Trondheim)
- Arctic Silicon Devices AS (Trondheim)
- NordicNeuroLab AS (Bergen)
- CorTechs Labs Inc (San Diego, California, USA)
- SINTEF (Trondheim)
- Helse Midt-Norge RHF (Stjørdal)

The Centres for Research-based Innovation represent a scheme in which several industrial partners and the university work together in an open research environment. Our experience so far is that we in MI Lab are able to build an arena for open innovation and long-term industrial research with high scientific quality and commitment from the partners. In 2013 this resulted in publication of 42 refereed articles in international journals and two inventions that were considered for patenting.

Scientific activities and results in 2013

MI Lab has a broad activity in science and innovation, and below are described examples of some of the most important results in 2013.

MI Lab has had several important inventions in ultrasound technology for improved imaging of heart and blood flow. By combining several new methods in soft-ware beamforming (how the ultrasound signal is transmitted and received) it has been possible to significantly increase the acquisition frame rate of ultrasound images of the heart. A recently published study (Brekke B, Nilsen LC, Lund J, Torp H, Bjastad T, Amundsen BH, Stoylen A, Aase SA. Ultra-high frame rate tissue Doppler imaging. Ultrasound Med Biol. 2014 Jan;40(1):222-31) on healthy volunteers showed some of the clinical potenetial of this new technology. It was found that it was possible to reach an acquisition speed for Tissue Doppler Imaging (TDI) of 1.200 image updates per second (compared to 50-100 per second for present state-of-the-art methods). The

new method is called «Ultra-high frame rate TDI", and some citations from the scientific paper:
«Ultra-high-frame-rate TDI provided peak annular velocities and time to peak S' intervals in good agreement with those measured with conventional TDI. » This documents that the results are correct when compared to present state-of-the-art methods.
"Moreover, UFR-TDI provided additional information in early and late systole: In all subjects, the method was able to separate the timing of electrical activation, start of mechanical contraction, mitral valve closure and start of ejection. The earliest mechanical activation was seen before mitral valve closure. The method was also able to measure the propagation speed of the mechanical wave created by aortic valve closure". This documents the completely novel potential of the method, being able to obtain information about the timing of the electric propagation in the heart wall and the electrical the mechanical interaction on the millisecond level both in the normal heart and in heart disease. MI lab has now on-going research on patient groups where we expect this information to be of importance for more precise diagnosis and choice of treatment.
The scientific paper also demonstrates the importance of multi-disciplinary research and industry collaboration for this type of innovation success. The first author Brekke is technologists, and the co-authors Nilsen, Lund and Amundsen are medical doctors (all are MI Lab funded PhD students and post docs), Støylen is professor in cardiology, Torp is professor in ultrasound technology and Bjåstad and Åse are employees in the GE Vingmed Ultrasound R&D department localized in the St. Olavs Hospital buildings in Trondheim.

MI Lab has an extensive activity in minimally invasive image-guided neurosurgery combining advanced MR imaging prior to the operation and available in the operation room and co-registered with ultrasound imaging update during the operation. From this activity there has been some good examples of "spin-off" innovation, and this demonstrates how the multi-disciplinary research environment in MI lab fosters creative ideas that end up with new innovation that was not part of the original research plan.

- One example is a significant improvement of ultrasound based angiography of the brain. Previously it has not been possible to assess neither the direction of the flow nor the volume of the flow, however, with the new MI Lab innovation it is now possible to correctly assess the direction and also obtain some estimate of the flow volume. The first scientific paper on the method was published in 2013 with the MI Lab funded PhD student Daniel Høyer Iversen as first author (Iversen DH, Lindseth F, Unsgaard G, Torp H, Lovstakken L. Model-based correction of velocity measurements in navigated 3-D ultrasound imaging during neurosurgical interventions. IEEE Trans Med Imaging. 2013 Sep;32(9):1622-31). The method may become clinically very useful for operations of aneurysms on the cerebral arteries and of arteriovenous malformations, and cited from the paper: *"The method .. showed promising results in vivo, improving the depiction of flow in the distal branches of intracranial aneurysms and the feeding arteries of an arteriovenous malformation."*
- Another example is the innovation of ultrasound guided placement of catheters to drain excess cerebrospinal fluid from the brain ventriclular system (fluid filled cavities in the brain). The method was in 2013 published as a peer

reviewed short report in the journal World Neurosurgery (Jakola AS, Reinertsen I, Unsgård G et al. Three-Dimensional Ultrasound-Guided Placement of Ventricular Catheters. World Neurosurg. 2013 Aug 23), and cited from the paper: *«Many studies demonstrate that the accuracy of freehand catheter placement for cerebrospinal fluid (CSF) drainage is suboptimal. We have tested a newly developed setup with 3D ultrasound navigated ventricular catheter placement through a regular burr hole in 4 patients. The use of 3D ultrasound is a promising technique for accurate, fast and user-friendly navigated placement of catheters for CSF diversion."* The two first authors, Jakola and Reinertsen, are medical doctor and technologist respectively, and both are MI Lab funded post docs.

In 2013 there was also interesting results in the research that applies advanced MR Imaging to improve our understanding of brain functions linked to early symptoms for dementia. The goal is to develop imaging based methods to diagnose dementia as early as possible (in the subclinical phase). It is generally accepted that present therapeutic possibilities have to be started very early to have any significant effect on the functional outcome. A scientific study published in 2013 (J Cogn Neurosci. 2013 Jun;25(6):903-19) with MI Lab financed PhD student Alexander Olsen as first author focused on using functional MRI to localize brain networks related to attention, one of the early symptoms of dementia. Cited from the scientific paper: *"We…identified areas of activations uniquely related to stable- and adaptive attention processes in widespread cortical, cerebellar, and subcortical areas. Our results provide further evidence for a "core network" for attention control that is accompanied by unique areas of activation involved in domain specific processes operating on different temporal scales.»*

MI Lab has also had an important activity in technology research on improvements of new advanced MR methods, especially for diffusion MRI of white matter connectivity and functional MRI to localize brain activity and networks. Through a collaboration with the Erwin L. Hahn Institute of Magnetic Resonance Imaging at University Duisburg-Essen in Germany the MI Lab researcher Pål Erik Goa could access a 7 Tesla clinical MR system, and two recent publications have suggested improvements to the new method for functional MRI based on the steady-state free precession sequence (Goa PE, Poser BA, Barth M. Modeling and suppression of respiration induced B0-fluctuations in non-balanced steady-state free precession sequences at 7 Tesla. MAGMA. 2013 Aug;26(4):377-87 and Goa PE, Koopmans PJ, Poser BA, Barth M, Norris DG. BOLD fMRI signal characteristics of S1- and S2-SSFP at 7 Tesla. Front Neurosci. 2014 13;8:49).

MI Lab also has research activities in nanomedicine, and one of the main focuses is to develop imaging methods for in-vivo monitoring of how nanoparticles can be used for "targeted drug delivery", a method that allows much higher concentration of the drug in the diseased tissue as serious side effects in other tissues are avoided. This is especially relevant for cytotoxic drugs used for cancer treatment. In a recently published study (Hak S, Mulder WJ, Larsson HB, Haraldseth O et al. Periodicity in tumor vasculature targeting kinetics of ligand-functionalized nanoparticles studied by dynamic contrast enhanced magnetic resonance imaging and intravital microscopy. Angiogenesis. 2014 Jan;17(1):93-107) presented a completely new MR imaging method that is promising for in-vivo assessment of how much of the nanoparticles that binds to the diseased tissue. This can both be applied before treatment (with nanoparticles not loaded with the drug) to assess how many targets there are in the disease tissue, and during treatment (with nanoparticles loaded with drug) to assess how many nanoparticles that has bound to the tissue. The study was performed in an animal model of cancer, and demonstrates the importance of being able to perform preclinical research as part of the innovation process for new imaging methods.

The pocket-sized and hand-held ultrasound instrument Vscan has been an important success for MI Lab. In 2012 two published MI Lab studies showed the new potential of this innovation for general practitioners (GPs) and for diagnosis of patients at emergency admittance to a hospital; citation from the two scientific papers:

- *"In this study, we have shown that it is possible for GPs, after a limited period of focused training, to use a pUS [pocket-sized Ultrsound] scanner to assess a surrogate marker for global LV function in 87% of the patients with or at risk of developing reduced LV function. The pUS examination could easily be performed in 5 minutes during a routine consultation in the GPs office."*(Mjolstad et al. Eur J Intern Med. 2012;23(2):185-91).
- *"By adding a pocket-sized ultrasound examination of <10 min to usual care, we corrected the diagnosis in almost 1 of 5 patients admitted to a medical department, resulting in a completely different treatment strategy without delay in many of the patients. Routinely adding a cardiac and abdominal ultrasound screening has the potential to rearrange inpatients workflow and diagnosis."*(Mjolstad et al Fam Pract. 2012 Oct;29(5):534-40).

These scientific results are strong indications that pocket-sized and hand-held ultrasound is a disruptive technology that may significantly change how the medical doctors work in the hospital and at the GP offices.
This potential was further strengthened by an MI Lab publication from 2013 (Mjølstad et al. Feasibility and reliability of point-of-care pocket-size echocardiography performed by medical residents. Eur Heart J Cardiovasc Imaging. 2013;14(12):1195-1202.) This was a scientific study on how training in pocket-sized and hand-held ultrasound can be integrated in the teaching of medical students in a medical school, and the conclusion was:

- *"Medical students with minimal training were able to use PSID [Pocket Size Imaging Device] as a supplement to standard physical examination and successfully acquire acceptable relevant organ images for presentation and correctly interpret these with great accuracy. Incorporating training of point-of-care ultrasound in medical student education may be one step further towards providing patients with a faster and more accurate diagnosis."*

International and national cooperation

A main MI Lab strategy for strengthening international collaboration is to attach foreign professors and researchers in 20% positions as international guest professors and guest researchers, and in 2013 there were four such positions:

- Guest professor Arend Heerschap, Department of Radiology, Radeboud University, Nijmegen, Netherlands
- Guest professor Anders M. Dale, Multimodal Imaging Laboratory, University of California San Diego, USA

- Guest professor Jan D’hooge, Department of Cardiovascular Imaging and Dynamics, Catholic University Leuven, Belgium
- Guest professor Henrik Larsson, Unit for Functional Image Diagnostics at Glostrup University Hospital, Copenhagen, Denmark

MI Lab has also established collaboration with the ultrasound research environment in Oslo (both cardiology and technology), and in 2013MI Lab had these two guest professors:

- Guest professor Svend Aakhus, consultant in cardiology, Oslo University Hospital (Rikshospitalet).
- Guest professor Sverre Holm, Department of Informatics, University of Oslo.

These guest professors and guest researchers are chosen because they have a competence and research experience that is of benefit for MI Lab, and, at the same time, look upon MI Lab as an important possibility for improving their own research activities through active participation in the research environment in Trondheim.

The researchers involved in the MI Lab research activities have extensive international networks, and to exemplify: 11 of the 42 scientific papers on the MI Lab 2013 publication list (26 %) had co-authors from the following foreign academic institutions and companies:

- Institute Biomedical Technology, University of Ghent, Ghent, Belgium
- Department of Cardiovascular Diseases, Katholieke University of Leuven, Belgium
- Department of Vascular Medicine, Academic Medical Center, Amsterdam, The Netherlands
- Centre for Cognitive Neuroimaging, Radboud University Nijmegen, The Netherlands
- Institute for Molecules and Materials, Radboud University Nijmegen, The Netherlands
- Debye Institute for Nanomaterials Science, Utrecht University, The Netherlands
- German Heart Institute, Berlin, Germany
- Erwin L. Hahn Institute of Magnetic Resonance Imaging, University Duisburg-Essen, Germany
- Dept. of Neurosciences and Radiology, University of San Diego, La Jolla, CA, USA
- John A. Burns School of Medicine, University of Hawaii, Honolulu, HI, USA
- Dept. of Psychology, University of Arizona
- Graduate School of Biological Sciences, Icahn School of Medicine at Mount Sinai, New York, United States
- Derald H. Ruttenberg Cancer Center, Icahn School of Medicine at Mount Sinai, New York, United States
- Translational and Molecular Imaging Institute, Icahn School of Medicine at Mount Sinai, New York, United States
- Langone Medical Center, New York University, New York, United States
- Institute of the Human Brain of Russian Academy of Sciences, St. Petersburg, Russian Federation
- Andrzej Frycz Modrzewski Krakow University (AFMKU), Krakow, Poland

- Orobix s.r.l., Bergamo, Italy

MI Lab has also played an important role as initiator and participant in several activities to improve researcher education, to establish European and Norwegian national research infrastructures, and to initiate industrial innovation clusters.

- MI Lab leader Olav Haraldseth initiated and is current leader of the Norwegian Research School in Medical Imaging (MedIm) which is financed from the Research Council of Norway with a total budget of 24 millions NOK (app. 3 millions Euro) for 2008 – 2015. MedIm is described more in detail in the Researcher training subchapter below.
- MI Lab is partner in the Research Council of Norway appointed national infrastructure NORBRAIN (the Norwegian Brain Initiative). NORBRAIN is headed by professor Edvard Moser at the Kavli Center for Systems neuroscience at NTNU and is a large-scale national research infrastructure in neuroscience that aims to achieve a vertical integration: from cellular biology, through systems neuroscience research in animal models, and to research on patients and human volunteers with advanced MR technology. MI Lab is one of three partners together with the Kavli Institute for Systems Neuroscience in Trondheim and Centre of Molecular Biology and Neuroscience (CMBN) in Oslo. In 2011 The Research Council of Norway funded phase I of NORBRAIN with 80 millions NOK (app. 10 millions Euro).
- MI Lab leader Olav Haraldseth is national co-ordinator for medical imaging in the two ESFRI infrastructures Euro-BioImaging and EATRIS (European Infrastructure for Translational Medicine). Olav Haraldseth is also leader for an application to become a multi-modal European level infrastructure node in molecular imaging to the Euro-BioImaging first call for such transnational nodes in 2013.
- MI Lab is also involved in the new NorMIT (The Norwegian centre for minimally invasive image guided therapy and medical technologies) national infrastructure that was appointed by the Research Council of Norway in 2013, and which has a total budget of 396 millions NOK (app. 49 millions Euro) for a ten years period. NorMIT is a collaboration between NTNU/St. Olavs University Hospital in Trondheim and The Intervention Centre at Oslo University Hospital.
- MI Lab is founding partner in the innovation cluster Nansen Neuroscience Network (NNN) which is partly funded by Innovation Norway. In 2013 NNN has 39 members; 23 from industry, 12 academic research groups, 2 hospitals, and 3 Technology transfer organizations.

Recruitment in 2013

MI Lab thinks that recruitment of the best students is the main success factor to obtain the scientific goals.

During 2013 MI Lab financed 26 on-going PhD students/ post doc fellows (22,8 man-years since some of the medical doctors combine PhD/post doc with clinical positions in St. Olavs University Hospital).

The balance between between PhD and post doc, between Norwegian and foreign recruitment and the multi-disciplinarity are according to plan:

PhD / post doc	21 / 5
Norwegian / foreign	21 / 5
Medicine / technology & other	8 / 18

However, there is a less than satisfactory balance between the sexes:

Male / female 20/ 6 (23 % female)

The female recruitment is somewhat better when looking at the total groups of PhD students and post docs involved in MI Lab related projects (see appendix 1 below):

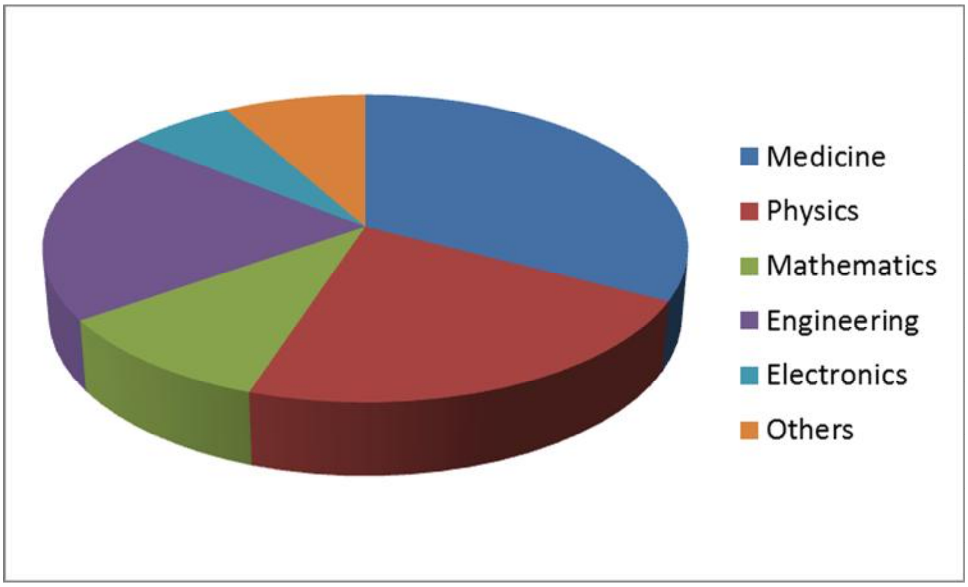
Male / female 46/ 31 (40 % female)

Researcher training – total 8-years period

MI Lab has a strong focus on researcher training and for the entire 8-years period there will be a total number of 30 completed PhDs financed by MI Lab.

During the entire 8-years period there was total number of 19 post doc fellows with financing from MI Lab (some of these were clinical doctors with only part time post doc positions).

The figure shows the multi-disciplinarity of this group of 49 PhDs and post docs:



To further improve the quality of the PhD training MI Lab leader Olav Haraldseth initiated and is the current leader of the Norwegian Research School in Medical Imaging (MedIm: www.ntnu.no/medicalimaging). The Research Council of Norway (RCN) had an open call for post graduate researcher training programmes [forskerskoler] in 2008, and the Norwegian Research School in Medical Imaging was one of the five appointed (the only in the area of medicine and health and the only at NTNU). It is a collaboration with the universities in Oslo, Bergen and Tromsø and has a total budget of 24 million NOK over 8 years. The researcher school is for all Norwegian PhD students in the area of medical imaging (including MR, ultrasound, PET, image guided surgery, optical imaging and bionanotechnology), and the main aim is to improve the quality of medical imaging research in Norway. This will be achieved through: improving the national collaboration, improving multi-disciplinarity in the research, improving the quality of the PhD training, and help recruiting the best students (also foreign recruitment). MI Lab also thinks that the researcher school is an important tool to improve female recruitment to this research area.

At NTNU (with Faculty of Medicine as host faculty) there is a PhD programme in medical technology headed by Professor Hans Torp, who is one of the key professors in MI Lab.

Communication and dissemination activities

A main concept for MI lab is that all original and important scientific results shall be published as quickly as possible though presentation at international scientific meetings and as full scientific papers in international journals with referee. The 2013 publication list (see appendix 3 below) contains 42 refereed articles in international journals.

The total number of full scientific papers with MI Lab involvement is 214 for the 5 years period 2008 – 2013.

MI Lab also has a focus on spreading knowledge about new technology and new methods to the relevant personnel in the Norwegian health care system. The MR, ultrasound and image-guided surgery research environment in Trondheim includes also three National Centres of Competence appointed by the Norwegian Ministry of Health.
They are National Centres of Competence in:

- Ultrasound- and image guided therapy
- Functional MRI
- Foetal ultrasound

One of the main tasks of these centres is to spread new knowledge of clinical relevance to the Norwegian health care system through hands-on training, courses and seminars, and they collaborate closely with MI Lab in this context.

APPENDIX 1 – MI Lab PERSONNEL 2013

The list includes all participants in research related to the MI Lab research subprojects.

Key Researchers

NAME	INSTITUTION	SEX	MAIN AREA
• Hans Torp	NTNU	M	Ultrasound technology
• Lasse Løvstakken	NTNU	M	Ultrasound technology
• Trond Ytterdal	NTNU	M	US probe electronics
• Asbjørn Støylen	NTNU & St. Olav	M	Cardiac ultrasound
• Asta Håberg	NTNU & St. Olav	F	Clinical MRI
• Olav Haraldseth	NTNU & St. Olav	M	Clinical MRI
• Tone F. Bathen	NTNU	F	Clinical MRI
• Ann-Mari Brubakk	NTNU	F	Clinical MRI
• Dag Ole Nordhaug	NTNU & St. Olav	M	Cardiac surgery
• Geirmund Unsgård	NTNU & St. Olav	M	Neurosurgery
• Ole Solheim	NTNU & St. Olav	M	Neurosurgery
• Sturla Eik-Nes	NTNU & St. Olav	M	Foetal ultrasound
• Kjell Arne Kvistad	NTNU & St. Olav	M	MR radiology
• Pål Erik Goa	St.Olavs Hospital	M	MR technology
• Anders Kristoffersen	St.Olavs Hospital	M	MR technology
• Marius Widerøe	NTNU	M	MR technology
• Toril A. Hernes	SINTEF & NTNU	F	Image guided surgery
• Tormod Selbekk	SINTEF	M	Neurosurgery
• Frank Lindseth	SINTEF	M	Neurosurgery
• Kjell Kristoffersen	GE Vingmed&NTNU	M	Ultrasound technology
• Eva Nilssen	GE Vingmed	F	Ultrasound technology
• Tore Bjåstad	GE Vingmed	M	Ultrasound technology
• Svein Arne Aase	GE Vingmed	M	Ultrasound technology
• Fredrik Orderud	GE Vingmed	M	Ultrasound technology
• Stein Inge Rabben	GE Vingmed	M	Ultrasound technology
• Erik Steen	GE Vingmed	M	Ultrasound technology
• Erik Swensen	MediStim	M	Ultrasound technology
• Jonas Crosby	MediStim	M	Ultrasound technology
• Tonni F. Johansen	SINTEF & NTNU	M	Ultrasound technology
• Atle Bjørnerud	Nordic NeuroLab	M	MR technology
• Audun Græsli	Aurotech	M	Ultrasound technology
• Torbjørn Hergum	Aurotech	M	Ultrasound technology
• Marco Voormolen	Aurotech	M	Ultrasound technology

Visiting Researchers (= guest professors/researchers in 20% position)

NAME	AFILIATION	SEX	MAIN AREA
Jan D'hooge	Catholic University, Leuven, Belgium	M	Ultrasound technology
Anders M. Dale	University of California, San Diego, USA	M	MR technology
Arend Heerschap	Radeboud University, Nijmegen, Netherlands	M	MR technology
Henrik Larsson	Glostrup Univ. Hospital, Copenhagen, Denmark	M	Clinical MRI
Svend Aakhus	Oslo University Hospital, Norway	M	Cardiac ultrasound
Sverre Holm	University of Oslo, Norway	M	Ultrasound technology

Postdoctoral researchers with financial support from the centre budget

NAME	NATIONALITY	SEX	SUBPROJECT
Brage H. Amundsen	Norway	M	2.1
Håvard Dalen	Norway	M	2.1
Bjørn Olav Haugen	Norway	M	2.2
Ingerid Reinertsen	Norway	F	3.1
Live Eikenes	Norway	F	4.1

Postdoctoral researchers involved in projects in the centre with financial support from other sources

NAME	FUNDING	NATIONALITY	SEX	
Gabriel Kiss	GE Vingmed	Romania	M	2.1
Reidar Brekken		Norway	M	3.2
Niels van Strien	RCN	Netherlands	M	4.1
Siver A. Mostue	NCS	Norway	M	4.1
Maria D. Cao	HMN	Norway	F	4.1
Guro Giskeødegård	HMN	Norway	F	4.1
Kirsten M. Selnæs	HMN	Norway	F	4.1
Debbie Hill	HMN	UK	F	4.1
Ioanna Sandvig	HMN	Greece	F	4.3
Else Marie Huuse	NTNU	Norway	F	4.3
Andreas Aaslund	RCN	Sweden	M	4.3

PhD students with financial support from the centre budget

NAME	NATIONALITY	SEX	SUBPROJECT
Tonje Fredriksen	Norway	F	1.1
Bastien Denarie	France	M	1.1
Birger Brekke	Norway	M	1.1
Solveig Fadnes	Norway	F	1.1
Engin Dikici	Turkey	M	1.1
Jørgen Avdal	Norway	M	1.1

• Hans H. Hansen	Norway	M	1.1
• Pang Weng	China	M	1.1
• Jørgen Moe	Norway	M	1.1
• Jon Petter Aasen	Norway	M	2.1
• Joakim Schistad Lund	Norway	M	2.1
• Lars Chr. Lervik Nilsen	Norway	M	2.1
• Ole Chr. Mjølstad	Norway	M	2.2
• Garrett N. Anderson	Norway	M	2.2
• Asgeir Jakola	Norway	M	3.1
• Daniel Høyer Iversen	Norway	M	3.1
• Ingvild K. Ekroll	Norway	F	3.2
• Øystein Pettersen	Norway	M	3.3
• Alexander Olsen	Norway	M	4.1
• Tuva Roldsdatter Hope	Norway	F	4.1
• Sjoerd Hak	Netherlands	M	4.3

PhD students involved in projects in the centre with financial support from other sources

NAME	FUNDING	NATIONALITY	SEX	SUBP
• Siri-Ann Nyrnes	HMN	Norway	F	1.1
• Thomas Skaug	HMN	Norway	M	1.1
• Våpenstad Cecilie	HMN	Norway	F	1.1
• Naiad Hossein Khan	HMN	Bangladesh	M	1.1
• Yucel Karabiyik	NTNU	Turkey	M	1.1
• Ole Martin brende	NTNU	Norway	M	1.1
• Lene Anette Rustad	NTNU	Norway	F	2.1
• Sigurd Storve	HMN	Norway	M	2.1
• Sinara Vijayan	EU funding	India	F	3.1
• Pall Jens Reynisson	NTNU	Iceland	M	3.1
• Lars Eirik Bø	HMN	Norway	M	3.1
• Geir Arne Tangen	RCN	Norway	M	3.2
• Frode Manstad-Hulaas	St.Olavs Hospital	Norway	M	3.2
• Emilie Vallee	RCN	France	F	4.1
• Hallvard R. Evensmo	NTNU	Norway	M	4.1
• Ida Antonsen	NTNU	Norway	F	4.1
• Tor Ivar Hansen	NTNU	Norway	M	4.1
• Jan Brunner	HMN	Norway	M	4.1
• Muhammed R. Vettukattil	NTNU	India	M	4.1
• Morteza Esmaeili	NTNU	Iran	M	4.1
• Saurabh Gorad	HMN	India	M	4.1
• Tonje Haukås	K.G. Jebsen Fund	Norway	F	4.1
• Marie Austdal	HMN	Norway	F	4.1
• Jose Teruel	HMN	Spain	M	4.1
• Aline F. Hansen	NCS	Norway	F	4.1
• Hanna Maja Tunset	RCN	Norway	F	4.1
• Leslie Euceda Wood	RCN	Honduras	F	4.1
• Brage Krüger Stokke	St. Olavs Hospital	Norway	M	4.1
• Nicolas Elvemo	NTNU	Norway	M	4.1
• Marit Indergaard	HMN	Norway	F	4.1
• Bjørg Johanne Warø		Norway	F	4.1

- Anne Elisabeth Sølsnes RCN Norway F 4.1
- Carl Pintzka NTNU (forskerlinje) Norway M 4.1
- Jarle Alexander Møller NTNU (forskerlinje) Norway M 4.1
- Kristine Skårdal RCN Norway F 4.3
- Tora Sund Morken HMN Norway F 4.3
- Hester Berger HMN Netherlands F 4.3
- Jana Cebulla NTNU Germany F 4.3
- Ingrid Augestad HMN Norway F 4.3
- Axel Nyman NTNU (forskerlinje) Norway M 4.3

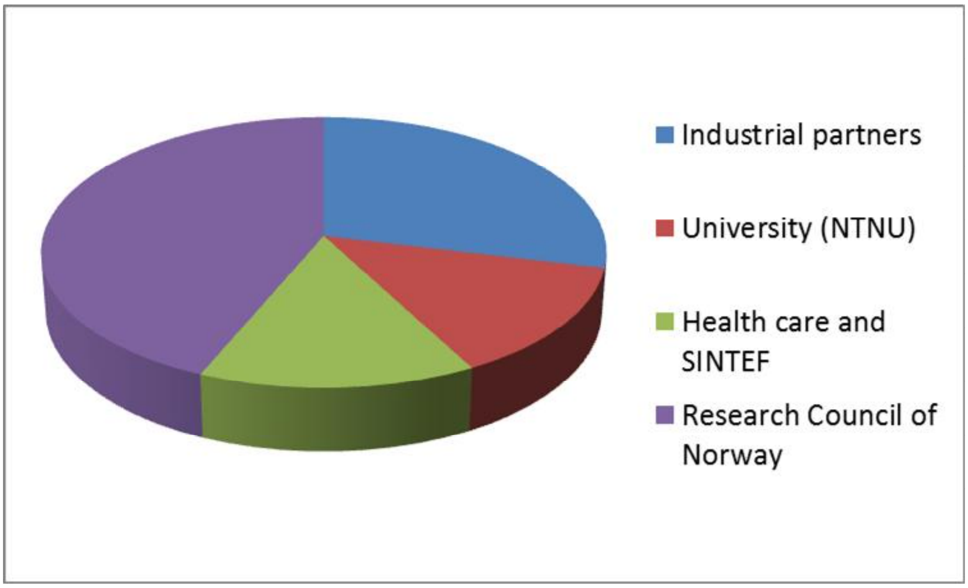
RCN = The Research Council of Norway
HMN = Helse Midt-Norge (the Regional Health Authority of Middle Norway)
NCS = The Norwegian Cancer Society

APPENDIX 2 - Annual accounts 2013

The total costs in 2013 of 29,0 million NOK (app. 3,6 million Euro) were split between cash contributions of 18,5 MNOK and own effort contributions from the partners (including the host NTNU) of 10,5 MNOK.

The financing split on type of source was:

Industrial partners	29 %
NTNU	13 %
Health care and SINTEF	14 %
Research Council of Norway	44 %



APPENDIX 3 – MI Lab Publications and PhD dissertations 2013

PhD dissertations 2013

The listed PhD dissertations cover scientific results from the MI Lab research activities. Some of the PhD students are fully financed from MI Lab, some are partly financed from MI Lab, and some are the result of a close collaboration with the MI Lab researchers.

Medical doctors

1. **Ole Christian Mjølstad.** Pocket-size ultrasound, a new diagnostic tool in clinical practice.
2. **Asgeir Jakola.** Risk and benefits of brain tumor surgery – a balancing act.
3. **Frode Manstad Hulaas.** Image guided endovascular procedures.
4. **Muhammed Riyas Vettukattil.** Identification and characterization of biomarkers using MR metabolomics: metabolic portraits of cancers and aerobic fitness.
5. **Tora Sund Morken.** Brain development and metabolism after hypoxia-ischemia and varying oxygen levels in neonatal rat studied with 13C-MRS and MRI.

Technologists

6. **Ingvild Kinn Ekroll.** Ultrasound imaging of blood flow based on high frame rate acquisition and adaptive signal processing.
7. **Engin Dikici.** Ultrasound cardiac modelling, segmentation and tracking.
8. **Sjoerd Hak.** Optimization of oil-in-water nanoemulsions for tumor targeting and molecular dynamic contrast enhanced MRI.
9. **Tormod Selbekk.** Ultrasound imaging in neurosurgery.
10. **Hallvard Røe Evensmoen.** A functional segregation along the hippocampal anterior-posterior axis.
11. **Kristine Haraldstad Skårdal.** The role of self-gated MRI in murine models of heart failure.

Publication list 2013

Only full scientific papers and review papers in international journals with referee are listed, and all are registered in the PubMed database at The National Institute of Health, NIH, USA (with the exemption of items 7-10 which are refereed conference proceedings in the area of ultrasound electronics, and item 23 which is a peer reviewed short report).

1.1 Ultrasound image improvement

1. Iversen DH, Lindseth F, Unsgaard G, Torp H, Lovstakken L. Model-based correction of velocity measurements in navigated 3-D ultrasound imaging during neurosurgical interventions. IEEE Trans Med Imaging. 2013 Sep;32(9):1622-31. doi: 10.1109/TMI.2013.2261536. PMID: 23661314

2. Denarie B, Tangen TA, Ekroll IK, Rolim N, Torp H, Bjåstad T, Lovstakken L. Coherent plane wave compounding for very high frame rate ultrasonography of rapidly moving targets. IEEE Trans Med Imaging. 2013 Jul;32(7):1265-76. doi: 10.1109/TMI.2013.2255310. PMID: 23549887
3. Ekroll IK, Swillens A, Segers P, Dahl T, Torp H, Lovstakken L. Simultaneous quantification of flow and tissue velocities based on multi-angle plane wave imaging. IEEE Trans Ultrason Ferroelectr Freq Control. 2013 Apr;60(4):727-38. doi: 10.1109/TUFFC.2013.2621. PMID: 23549533
4. Prieur F, Dénarié B, Austeng A, Torp H. Multi-line transmission in medical imaging using the second-harmonic signal. IEEE Trans Ultrason Ferroelectr Freq Control. 2013 Dec;60(12):2682-92. PMID: 24297034
5. Van Canneyt K, Swillens A, Lovstakken L, Antiga L, Verdonck P, Segers P. The accuracy of ultrasound volume flow measurements in the complex flow setting of a forearm vascular access. J Vasc Access. 2013 Oct 1;14(3):281-90. doi: 10.5301/jva.5000118. PMID: 23172170
6. Gao H, Hergum T, Torp H, D'hooge J. Comparison of the performance of different tools for fast simulation of ultrasound data. Ultrasonics. 2012 Jul;52(5):573-7. PMID:22348943
7. Wang P, Halvorsrød T, Ytterdal T. A 12b-control ultra-low-power low-noise SC-VGA for medical ultrasound probes. The Journal of Engineering 2013. doi: 10.1049/JOE.2013.0088
8. Wang P, Halvorsrød T, Ytterdal T. A Low Noise Single-End to Differential Switched-Capacitor VGA for PZT Xducer Ulstrasound Imaging. Proceedings of European Conference on Circuit Theory and Design, 2013. doi: 10.1109/ECCTD.2013.6662289: 4 pages
9. Wang P, Halvorsrød T, Ytterdal T. A Low Noise Single-Ended to Differential Linear Charge Sampling SC-VGA for Second Harmonic Cardiac Ultrasound Imaging. Proceedings of European Conference on Circuit Theory and Design, 2013. doi: 10.1109/ECCTD.2013.6662288: 4 pages
10. Wang P, Ytterdal T, Halvorsrød T. A low-power, low-noise, and low-cost VGA for second harmonic imaging ultrasound probes. 2013 IEEE Biomedical Circuits and Systems Conference(BioCAS 2013). doi: 10.1109/BioCAS.2013.6679702: 314-317
11. Rau JM, Måsøy SE, Hansen R, Angelsen B, Tangen TA. Methods for reverberation suppression utilizing dual frequency band imaging. J Acoust Soc Am. 2013 Sep;134(3):2313-25. doi: 10.1121/1.4817900. PID: 23967962
12. Afadzi M, Strand SP, Nilssen EA, Måsøy SE, Johansen TF, Hansen R, Angelsen BA, de L Davies C. Mechanisms of the ultrasound-mediated intracellular delivery of liposomes and dextrans. IEEE Trans Ultrason Ferroelectr Freq Control. 2013 Jan;60(1):21-33. doi: 10.1109/TUFFC.2013.2534. PMID: 23287910

2.1 Cardiac ultrasound

13. Thorstensen A, Dalen H, Hala P, Kiss G, D'hooge J, Torp H, Støylen A, Amundsen B. Three-dimensional echocardiography in the evaluation of global and regional function in patients with recent myocardial infarction: a comparison with magnetic resonance imaging. Echocardiography. 2013 Jul;30(6):682-92. doi: 10.1111/echo.12115. PMID: 23347171
14. Brekke B, Nilsen LC, Lund J, Torp H, Bjastad T, Amundsen BH, Stoylen A, Aase SA. Ultra-high Frame Rate Tissue Doppler Imaging. Ultrasound Med Biol. 2013 Jan;40(1):222-31. PMID: 24210859
15. Rustad LA, Nytrøen K, Andreassen A, Geiran O, Endresen K, Gullestad L, Aakhus S, Amundsen BH. Heart transplant systolic and diastolic function is impaired by prolonged pretransplant graft ischaemic time and high donor age: an

echocardiographic study. Eur J Cardiothorac Surg. 2013 Aug;44(2):e97-104. doi: 10.1093/ejcts/ezt233. PMID: 23657552

16. Doltra A, Amundsen BH, Gebker R, Fleck E, Kelle S. Emerging concepts for myocardial late gadolinium enhancement MRI. Curr Cardiol Rev. 2013 Aug;9(3):185-90. PMID: 23909638

2.2 Pocket-sized ultrasound

17. Dalen H, Haugen BO, Graven T. Feasibility and clinical implementation of hand-held echocardiography. Expert Rev Cardiovasc Ther. 2013 Jan;11(1):49-54. doi: 10.1586/erc.12.165. Review. PMID: 23259444
18. Mjølstad OC, Andersen GN, Dalen H, Graven T, Skjetne K, Kleinau JO, Haugen BO. Feasibility and reliability of point-of-care pocket-size echocardiography performed by medical residents. Eur Heart J Cardiovasc Imaging. 2013 Dec;14(12):1195-202. doi: 10.1093/ehjci/jet062. PMID: 23644936

3.1 Neurosurgery

19. Selbekk T, Jakola AS, Solheim O, Johansen TF, Lindseth F, Reinertsen I, Unsgård G. Ultrasound imaging in neurosurgery: approaches to minimize surgically induced image artefacts for improved resection control. Acta Neurochir (Wien). 2013 Jun;155(6):973-80. doi: 10.1007/s00701-013-1647-7. PMID: 23459867
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21. Weber C, Jakola AS, Gulati S, Nygaard OP, Solheim O. Evidence-based clinical management and utilization of new technology in European neurosurgery. Acta Neurochir (Wien). 2013 Apr;155(4):747-54. doi: 10.1007/s00701-013-1640-1. PMID: 23440373
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23. Jakola AS, Reinertsen I, Selbekk T, Solheim O, Lindseth F, Gulati S, Unsgård G. Three-Dimensional Ultrasound-Guided Placement of Ventricular Catheters. World Neurosurg. 2013 Aug 23. doi:pii: S1878-8750(13)01008-5. 10.1016/j.wneu.2013.08.021. PMID: 23973451

3.2 Cardiac & Vascular surgery

24. Rimehaug AE, Lyng O, Nordhaug DO, Løvstakken L, Aadahl P, Kirkeby-Garstad I. Cardiac power integral: a new method for monitoring cardiovascular performance. Physiol Rep. 2013 Nov;1(6):e00159. doi: 10.1002/phy2.159. PMID: 24400160

4.1 Advanced MR methods in clinical diagnosis

25. Eikenes L, Martinussen MP, Lund LK, Løhaugen GC, Indredavik MS, Jacobsen GW, Skranes J, Brubakk AM, Håberg AK. Being born small for gestational age reduces white matter integrity in adulthood: a prospective cohort study. Pediatr Res. 2012 Dec;72(6):649-54. PMID:23007032
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performance of an fMRI-adapted clinical continuous performance test. J Cogn Neurosci. 2013 Jun;25(6):903-19. doi: 10.1162/jocn_a_00358. PMID: 23363414
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