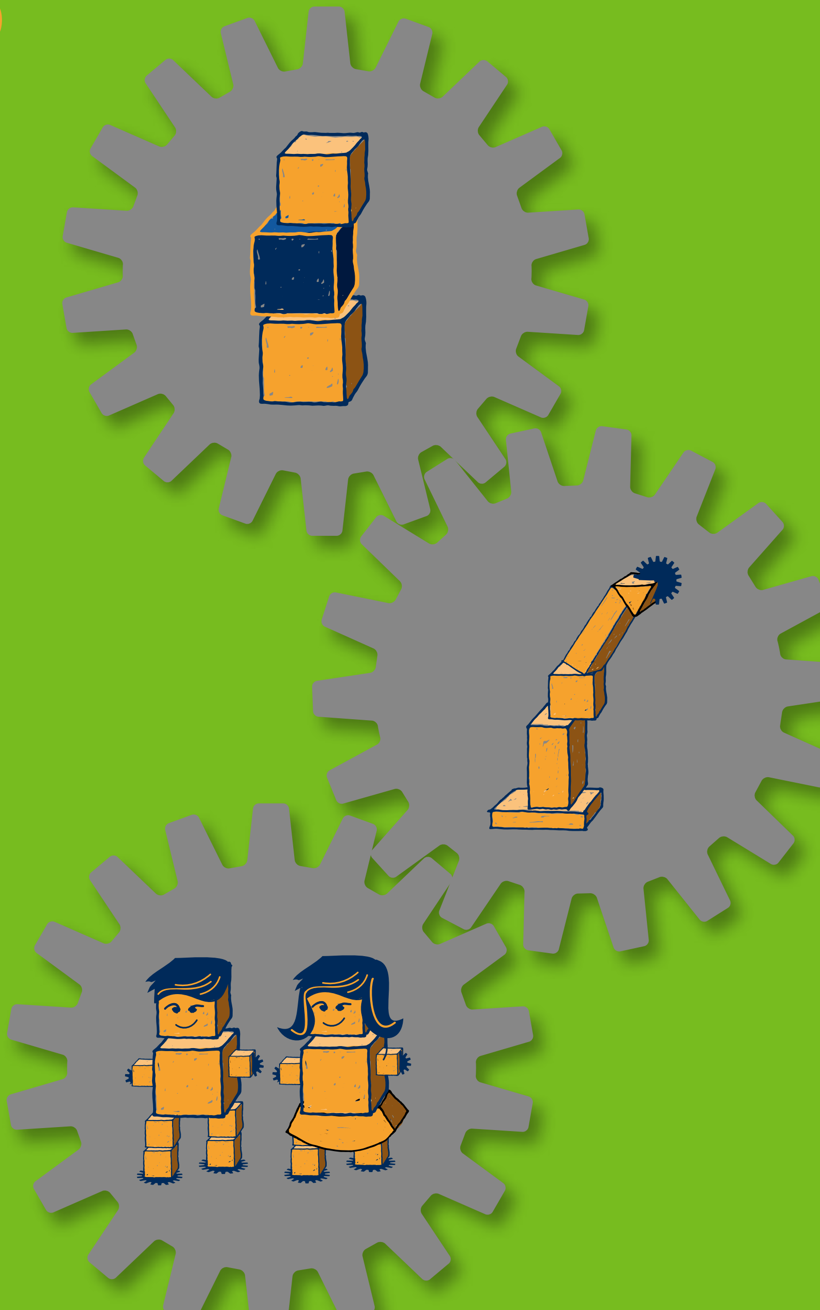
manufacturing

Annual report 2016



Centre for Research-based Innovation

The Research Council of Norway

Index

> *“Future contracts will not accept todays cost level”*
>
> Ole B. Hoen
> GKN Aerospace

Picture from Neuman Aluminium Raufoss Technology, Raufoss

Welcome to the SFI Manufacturing annual report 2016

Norwegian Manufacturing industry, in general, had a difficult year in 2016 due to the crisis in oil-related business segments. For many of the SFI members it was quite the opposite. Important contracts, several awards and production moving back to Norway are among the achievements in 2016. Welcome to read our annual report!

2016 was the first full year of SFI Manufacturing. During the year, the centre has established itself as a major force in Norwegian manufacturing, both politically and in the field of research. The centre management has represented the industry on many occasions both in Norway and internationally, such as the minister of education delegation to Berlin and giving input to the ministry of trade, industry and fisheries in the preparation for the Governments forthcoming white paper on industry policy.

The centre structure focuses on SFI Manufacturing workshops three times a year. In 2016, we have visited Åndalsnes, hosted by Plasto, Raufoss, hosted by Benteler and Kongsberg, hosted by GKN Aerospace. The workshops have proved highly interesting with 60 to 90 people participating each time.

The board has met frequently through the year, both physically but also often on-line. We aim to embrace the use of new technology in all fields in order to build a sustainable centre structure. The board consists of Ole Hoen, GKN Aerospace, Svein Terje Strandlie, SINTEF Raufoss Manufacturing, Rudie Spooren, SINTEF Materials and Chemistry, Torbjørn Skogsrød, NTNU Gjøvik, Anne Borg, NTNU Trondheim, Olav Holst-Dyrnes, Ekornes, Geir Liaklev, Kongsberg Automotive and Vegard Sande, Nammo.

The industrial partners are interacting in the centre on a daily basis. Through good use of communication tools, web site, social media and above all, through spin-offs, in the form of industrial research projects in smaller groups of partners, closer to the companies' core business but still closely connected to the SFI. This model is highly appreciated and will be developed even further in the years to come. Involvement and acknowledgement of the research challenges from the industry perspective is a key value in SFI Manufacturing.

As Chair of the board, I am very pleased to introduce you to the annual report of SFI Manufacturing 2016. I hope you enjoy the reading!

Lars Stenerud
CEO, Plasto AS
Chair of the board, SFI Manufacturing
Raufoss, 29th of March, 2017

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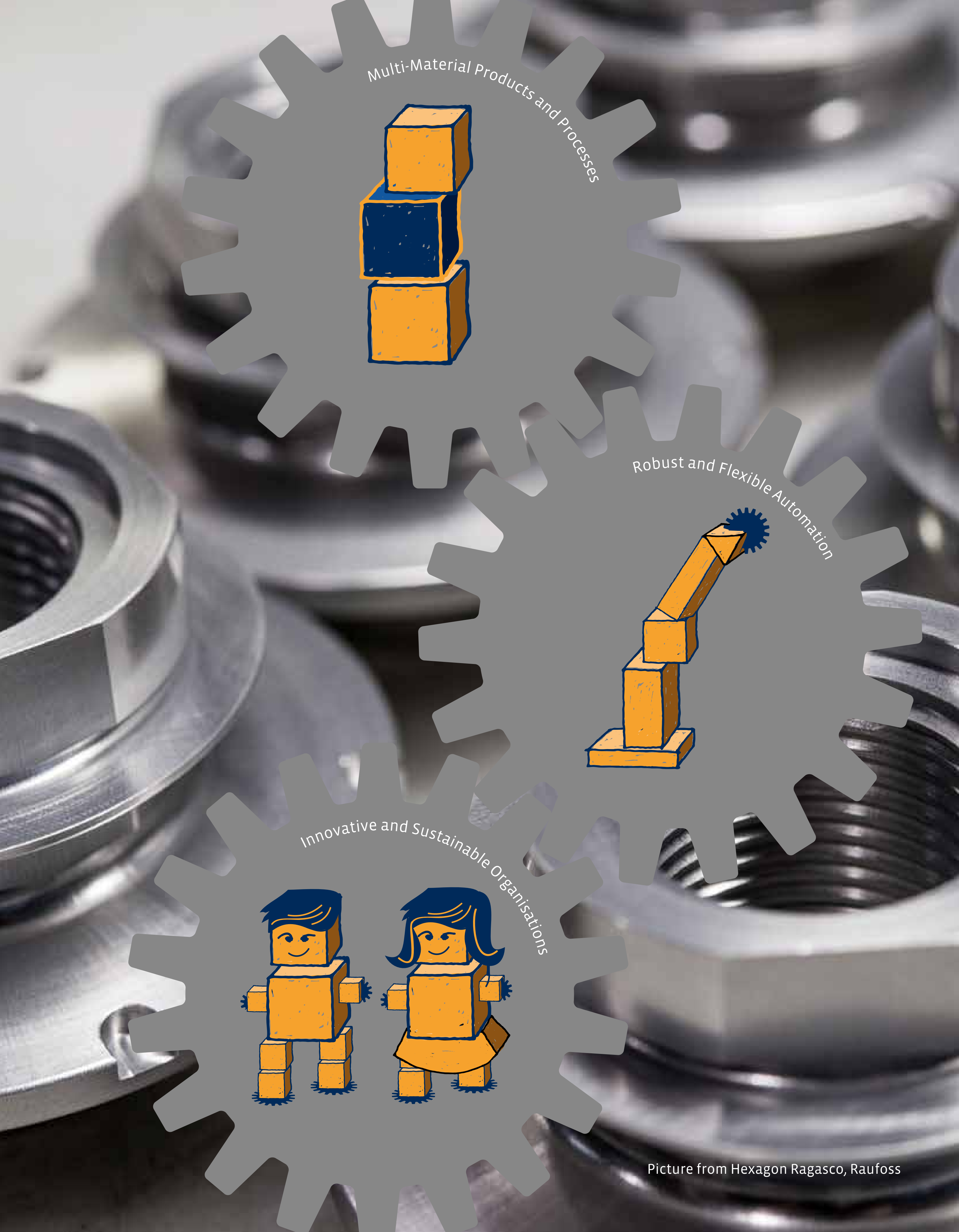
SFI: A program for industrially oriented research in active cooperation between innovative companies and prominent research groups

- High potential for innovation and value creation
- Active cooperation between innovative companies and prominent research groups
- High scientific quality of research
- Bridgehead for international cooperation
- Recruitment of talented researchers

Picture from Benteler Aluminium Systems Norway, Raufoss



Picture from Hexagon Ragasco, Raufoss

To show that sustainable and advanced manufacturing is possible in high cost countries, with the right products, technologies and humans involved.

The vision of SFI Manufacturing

SFI Manufacturing builds on existing national capabilities and aims to strengthen the Norwegian manufacturing companies' ability to innovate. The centre seeks to mirror the inherent cross-disciplinary innovation systems in the industry and combine research on Multi-Material Product solutions, Flexible Automated Manufacturing, and Organisational Processes.

The innovation process itself is a core research topic and SFI Manufacturing strives to be a basis for unleashing innovation potentials and research challenges embedded in the crossdisciplinary interfaces, and to develop new research methods.

The objectives of the SFI Manufacturing's research areas which support this vision are:

Multi-Material Products and Processes

To develop the ability to optimise material choice, multi-materials geometry and processes simultaneously.

Robust and Flexible Automation

To further develop and link novel technologies and methodologies within automation to support innovation processes and advanced work systems in the manufacturing industries.

Innovative and sustainable organisations

To develop advanced work systems enabling utilisation of new technology and flexible and automated processes to manufacture sustainable multi-material product solutions.

SFI Manufacturing take-off

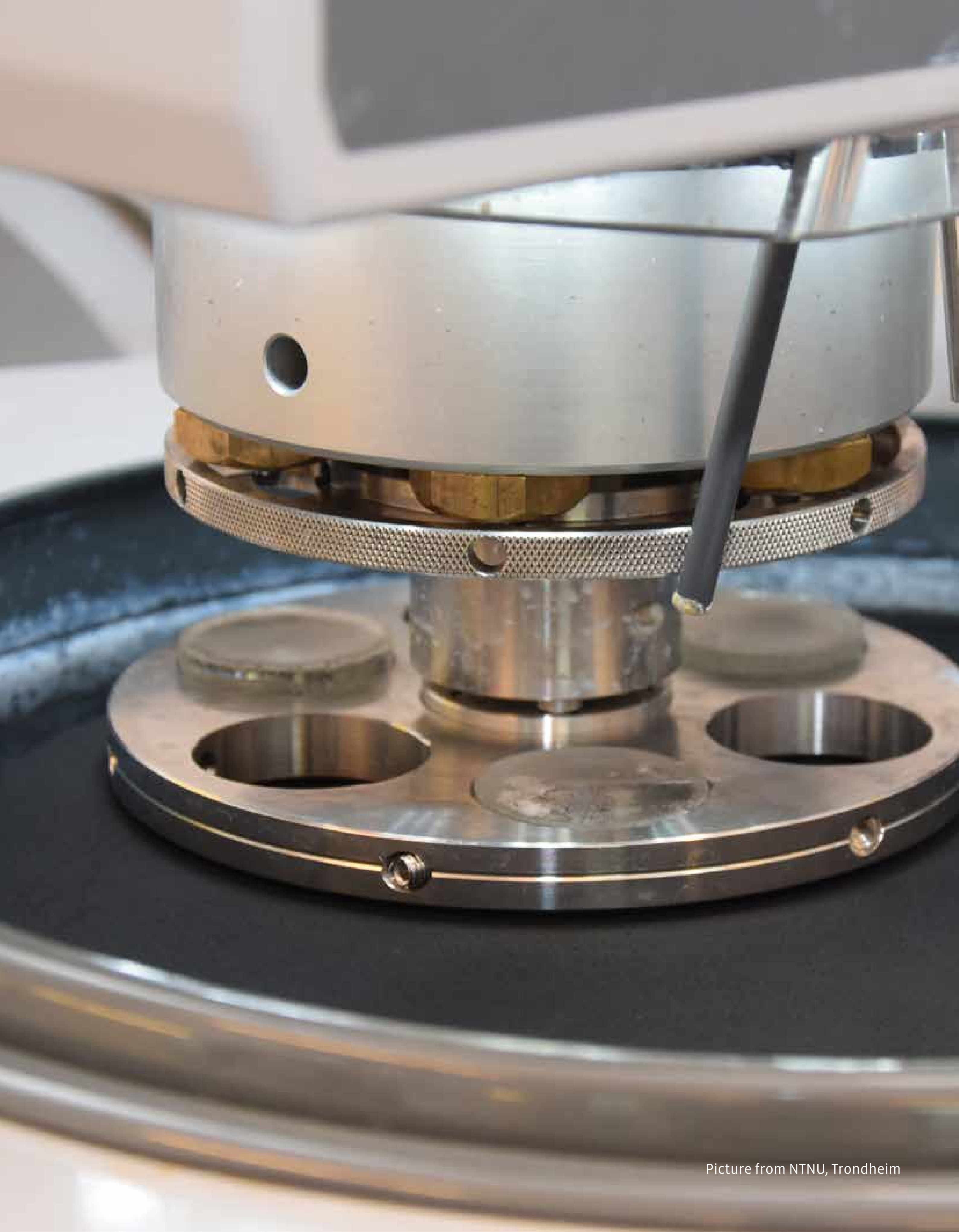
The first full year for SFI Manufacturing was a great one. The overall status at the centre is according to plan. The good start gives us the peace of mind to step up to the challenge of achieving our cross-disciplinary goals.

It has been a privilege to be a part of SFI Manufacturing through 2016 and experience the shaping and start of centre activities. The centre has grown with Hydro and Mjøs Metallvare as new industrial partners. In addition, we have succeeded with the implementation of several complementary spin-off activities, such as the Centre for Innovative Green Polymers and 8 new innovation projects partially funded by the Research Council of Norway (IPNs). SFI Manfufacturing as a birthplace for innovation projects is one of the main deliverables for the centre and we are on track towards the goal of spin-off activities in the range of 800 million NOKs over the centre period.

The focus in 2016 has been recruitment of PhD candidates within the centre. Our ambition was to start half of the 14 PhD scholarships within the first 1.5 years of the centre period in order to have two education cohorts where the candidates have the possibility to follow similar development. We are very pleased to announce that we're not only are according to plan concerning the number of employed PhD candidates, but we have succeeded with recruitment of excellent qualified candidates in all areas of research within SFI Manufacturing. The shaping and development of each of these PhD positions will be the core of the centre activity in the years to follow.

As centre director I am confident that we have had a successful take-off in 2016 and that the started activities will take our consortium to new heights in 2017.

Sverre Gulbrandsen-Dahl
Raufoss, 29th of March, 2017



Picture from NTNU, Trondheim

SFI Manufactuing as birth place for new projects

Covering the whole innovation stream from R&D to market requires more than research on technology readiness level 1-3. The strategy of SFI Manufacturing has a bigger perspective in order to assist its members in their overall development.

From the development phase of SFI Manufacturing the consortium has agreed upon the ambition to use the centre as an incubator for spin-off projects, such as user driven innovation projects (supported by the Research Council of Norway) and collaborative projects (supported by the European Commission).

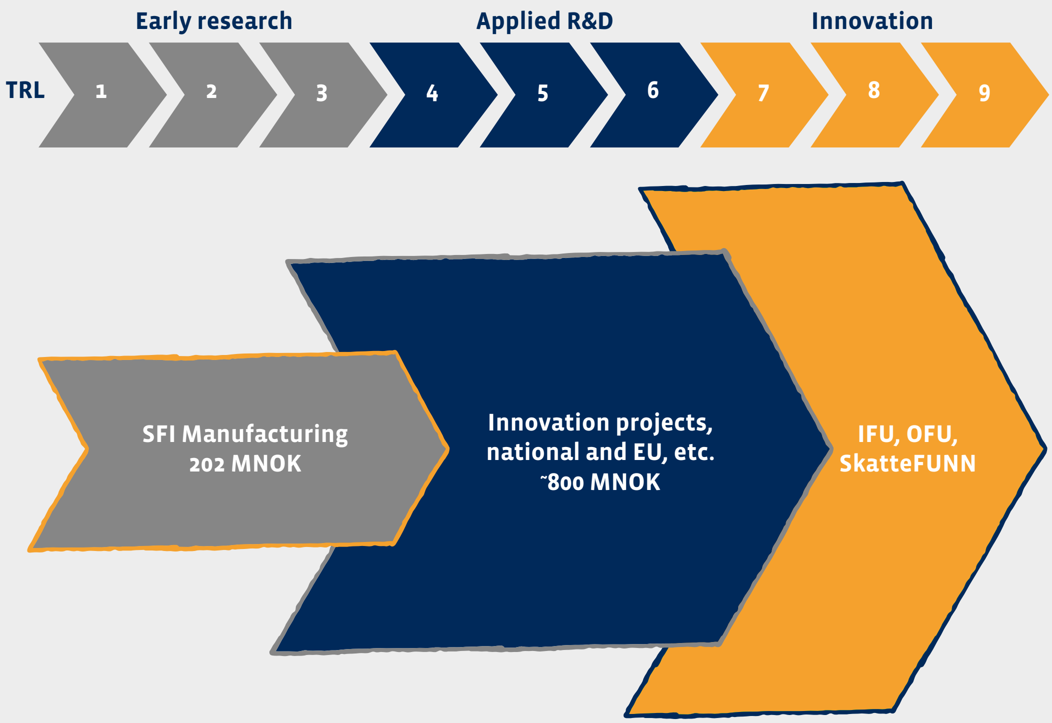
The figure illustrates how the SFI activities and the activities of potential spin-off projects are linked to the technology readiness level (TRL). The consortium has a common ambition to generate a total portfolio of spin-off projects for 800 million NOKs providing a total research activity on manufacturing of 1 billion NOKs over the 8 years period of SFI Manufacturing.

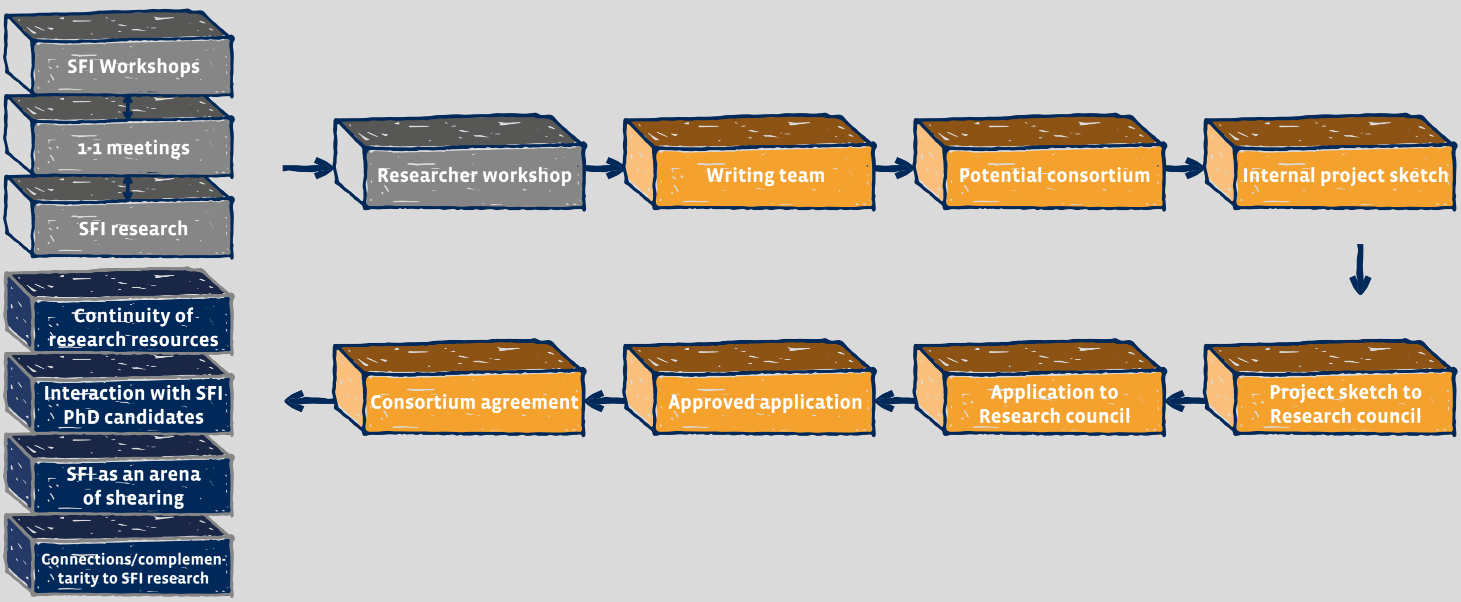
This ambition is based on the belief that the total portfolio of manufacturing research linked to SFI Manufacturing will provide:

- Attractiveness for international collaboration
- Research and innovation closer to the core business of each partner due to smaller consortiums of the innovation projects and stricter IPR regulations
- Strengthen the SFI as an attractive arena for sharing of generic early research

SFI Manufacturing has developed a working model for development and implementation of spin-off projects that will ensure complementarity and relevance for the SFI research and the SFI partners throughout the centre period. It is believed that this model can be further developed and serve as collaborative arena beyond the initial 8 year centre period. The model that is illustrated is divided into 3 phases. The first phase is the generation and collection of ideas/needs for new projects and organising of these through various centre activities. After the researcher work-shop, the coordinated initiatives are individually developed and this phase shall be in-kind contribution of the involved partners. Finally, when a new spin-of project is started, the SFI will provide various arenas for interaction and sharing.

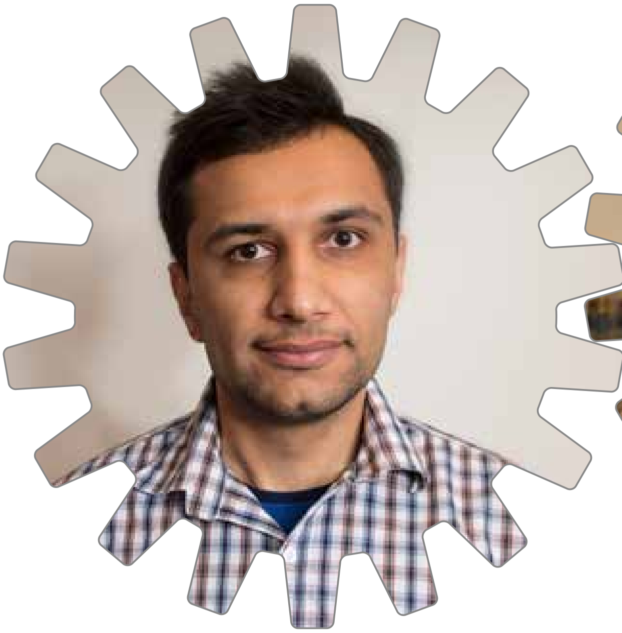
Based on the working-model of SFI Manufacturing, the centre has generated spin-off projects that started in 2016 and will start in 2017 with a total budget of 350 million NOK. In addition, the SFI Manufacturing budget has increased to 202 million NOK based on growth of the consortium and additional funding. Hence, after 1,5 years of operation we have succeeded to establish a total activity exceeding 50% of the ambition of the 8-year period.


Early research
Applied R&D
Innovation
TRL
1
2
3
4
5
6
7
8
9
SFI Manufacturing
202 MNOK
Innovation projects,
national and EU, etc.
~800 MNOK
IFU, OFU,
SkatteFUNN


SFI Workshops
1-1 meetings
SFI research
Continuity of research resources
Interaction with SFI PhD candidates
SFI as an arena of shearing
Connections/complementarity to SFI research
Researcher workshop
Writing team
Potential consortium
Internal project sketch
Project sketch to Research council
Application to Research council
Approved application
Consortium agreement

Meet the next generation scientists

PhD candidates and postdoctoral researchers are essential resources within SFI Manufacturing. Muhammed, Tina, Siri Marthe, Marit, Vetle, Mathias and Henrik started their PhD studies in 2015 or 2016. They will introduce themselves on the next pages, and will tell you a bit more about their background and the work they are doing in their projects.



Muhammad Zeeshan Khalid
Atomistic modelling of multi-material interfaces
My name is Muhammad, and I started my PhD in October 2016. During my PhD, I will focus on atomistic modelling of multi-material interfaces.

I did my Master in Applied Physics from University of engineering and technology, Taxila, Pakistan. My master thesis focused on the mathematical modelling of high temperature thermal energy storage system for solar thermal power plant applications.

The research project that my PhD is a part of, focuses on the development of multi-material products that combine desirable properties of the parent materials. I will collaborate closely with the PhD candidates Siri Marthe and Tina. Both are working on the joining process itself, while I will be using their data as input and starting parameters to perform simulations.

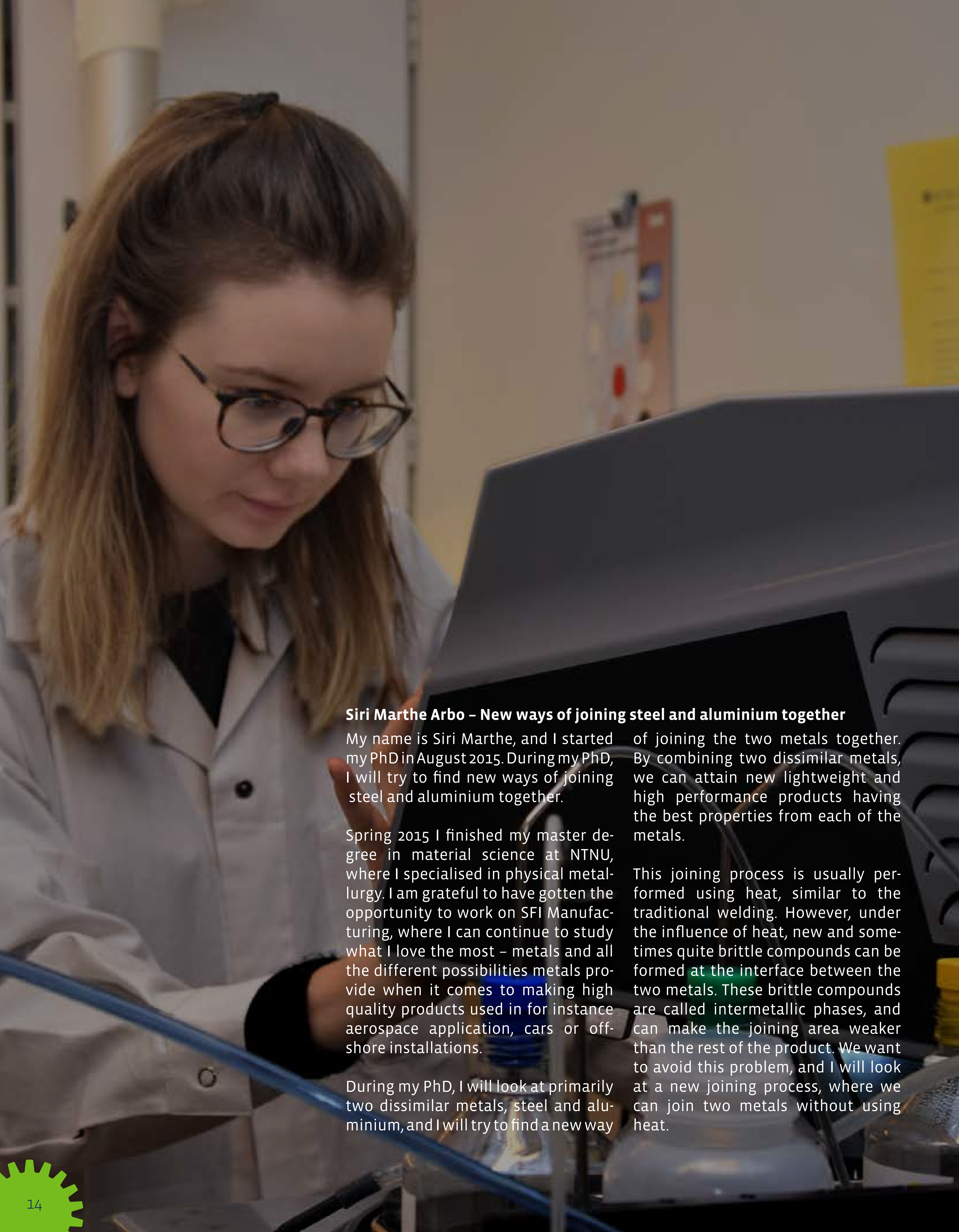
An improved understanding of the nanostructured materials is needed to further develop the use of efficient and lightweight technologies for the automotive, shipbuilding and transportation industry for example, not only to perform efficiently, but also to minimise the use of fuel. My project will provide the basic information about the nanostructure changing mechanisms during the welding of dissimilar materials, to help experimentalists to improve their welding methodologies. My initial plan is to study the interfaces of aluminium and steel, by developing an atomistic model using transmission electron microscopy (TEM) images.

Tina Bergh
The interface between joined aluminium and steel
I am Tina, and I started my PhD in the fall of 2016. During my PhD, I will characterise the interface in joined materials, first and foremost joined aluminium and steel.

My background is from the nanotechnology study programme at NTNU. During my Master's thesis work, I used transmission electron microscopy (TEM) to study silicon carbide from Saint-Gobain in Lillesand. With a transmission electron microscope, I can determine both the crystal structure and composition of the investigated material, down to atomic scale. These characteristics determine the material's mechanical properties and are thus important from an industrial perspective.

The research project that my PhD is a part of, focuses on the development of multi-material products that combines desirable properties of the parent materials. My role in this project is to use TEM to characterise the interface. For aluminium and steel, several different intermetallic compounds are found at the interface, and these influence the properties of the joint. My goal is to get a thorough understanding of the interface, and to link its characteristics at the microscopic scale back to the properties of the joint on the macroscopic scale.

So far, I have been studying a sample made by SINTEF Chemistry and Materials, where aluminium and steel were joined using a cold metal transfer technique. For the next three years, I will explore samples made from different aluminium and steel alloys and different joining techniques. I am excited to continue to improve on techniques within TEM and to get new and useful insights into these materials' characteristics.



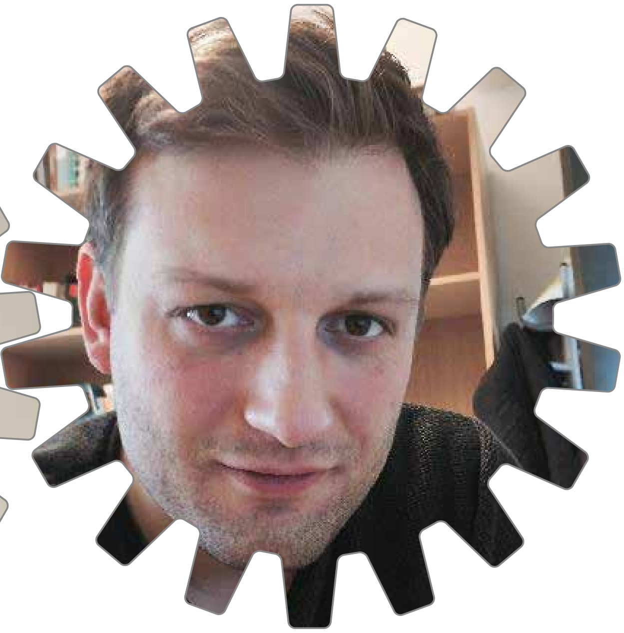
Siri Marthe Arbo – New ways of joining steel and aluminium together

My name is Siri Marthe, and I started my PhD in August 2015. During my PhD, I will try to find new ways of joining steel and aluminium together.

Spring 2015 I finished my master degree in material science at NTNU, where I specialised in physical metallurgy. I am grateful to have gotten the opportunity to work on SFI Manufacturing, where I can continue to study what I love the most – metals and all the different possibilities metals provide when it comes to making high quality products used in for instance aerospace application, cars or offshore installations.

During my PhD, I will look at primarily two dissimilar metals, steel and aluminium, and I will try to find a new way of joining the two metals together. By combining two dissimilar metals, we can attain new lightweight and high performance products having the best properties from each of the metals.

This joining process is usually performed using heat, similar to the traditional welding. However, under the influence of heat, new and sometimes quite brittle compounds can be formed at the interface between the two metals. These brittle compounds are called intermetallic phases, and can make the joining area weaker than the rest of the product. We want to avoid this problem, and I will look at a new joining process, where we can join two metals without using heat.



Marit Moe Bjørnbet
LCA as a management tool to facilitate the transition towards a green economy

I am Marit, and I started my PhD in August 2016. During my PhD, I will focus on life cycle assessments (LCA) as a management tool to facilitate the transition towards a green economy.

My background is a master's degree in nanotechnology, with a specialisation on materials, energy and industrial ecology. Before starting my PhD, I have been working in SINTEF Raufoss Manufacturing on several research projects concerning sustainability in the industry. My field of expertise is life cycle assessments and environmental management. I am truly passionate about the environment and working towards a more sustainable industry really motivates me.

Through the Paris agreement, the Norwegian government has committed to contribute to limiting the temperature increase to below 2 degrees, compared to preindustrial time. More specific, the Norwegian government has stated a national goal of at least 40% reduction in greenhouse gases emissions in 2030, compared to the level in 1990. These reduction targets will affect the Norwegian manufacturing industry in the years to come.

My idea is that life cycle assessments can be utilised to develop tools, preparing the Norwegian manufacturing industry for the green shift, integrating environmental management into core business activities. My aim is to provide recommendations for the Norwegian manufacturing industry on how they can use LCA as a management tool to facilitate the transition towards a green economy.

Vetle Engesbak
Step-changes in mature production systems

I am Vetle, and I started my PhD in April 2015. During my PhD, I will focus on how organisations with mature production systems may better organise to capture the value from step-change improvements.

My background is a master's degree in innovation and entrepreneurship. My master thesis focused on the importance of learning, cooperation and networks for regional innovation systems. Before starting my PhD, I worked as a project manager at Kjeller Innovasjon, where I commercialised research results. I am passionate about innovation, and being able to immerse myself in real challenges organisations face is what drives me in my quest for knowledge.

Industrial organisations need to continuously improve their production process in order to remain competitive. Improvements typically take the form of efficiency gains through cost reductions and increased production volumes. Local improvements in organisation of work, gained from rationalisation techniques such as lean, TQM and Six Sigma, are important, but more complex organisational learning from exploration activities are also needed to remain competitive.
During my PhD, I will assess how Scandinavian industry should organise to be able to gain the most from these explorative activities. I will look at questions such as: What characterises organisational learning in process industries? How should expert divisions (like R&D) collaborate with the line organisation to support implementation of new technology? And how do rationalisation efforts in the production process impact the organisations ability to innovate?

Mathias Hauan Arbo – Robots interacting with flexible materials and objects

I am Mathias, and I started my PhD in the fall of 2015. My PhD focuses on robotic assembly and sensor fusion.
I come from the department of engineering cybernetics and work mainly with sensor fusion and robotics. My master thesis was on sensor fusion of delayed displacement measurements. The Bayesian formulation of how to handle that delay was my main topic.

In my PhD I look at assembly with articulated robots under uncertainty. With enclosed robots we can know exactly where everything is placed and can make plans that will work in these environments. We as humans operate in an environment of uncertainty, objects are larger or smaller than we expected, but we compensate. And that is what we are trying to make the robots do in a systematic fashion.

The probabilistic approach to uncertainties sees things as likelihood. It is likely that the piece is there, and based on how likely it is, the robot can form a better understanding of the object. Of particular interest is the screw-in process, where a small uncertainty can cause large issues. Estimation of the angle of entry, the location of the hole, and the relative orientation of the screw combined with robust control strategies will allow users to do faster prototyping of robot tasks and simplify automation.

Henrik Brynthe Lund
Industrial networks, learning systems and cluster development

My name is Henrik, and I started my PhD in August 2016. The topic of my PhD is industrial networks, learning systems and cluster development.

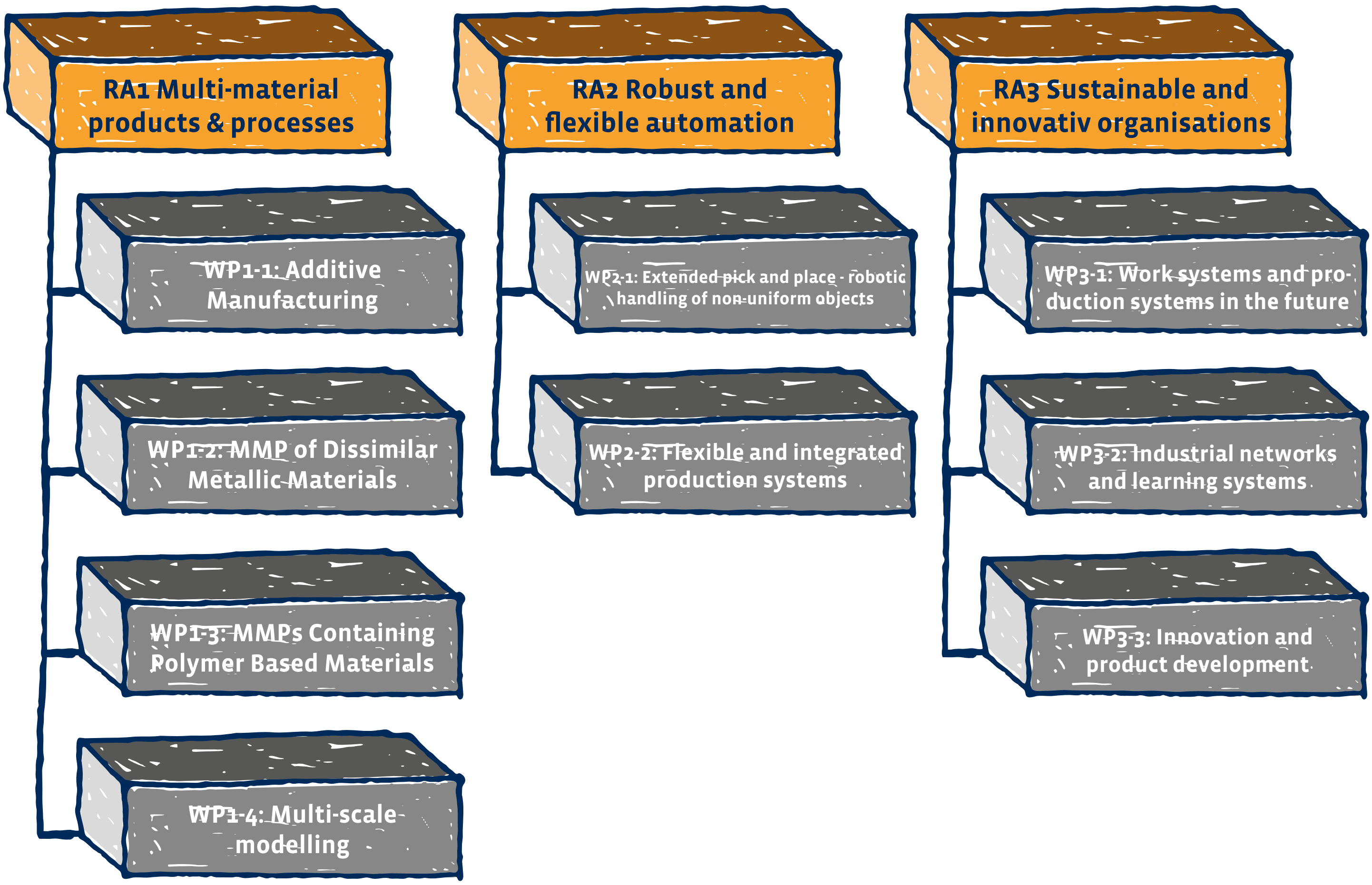
I finished my combined geography and teacher master's degree at the Department of Geography at NTNU in the spring of 2014. The topic of my master thesis was urban development and how economic and political processes' influenced a property development project in my home town Moss. The following two years, I worked a teacher at a primary and lower secondary school.

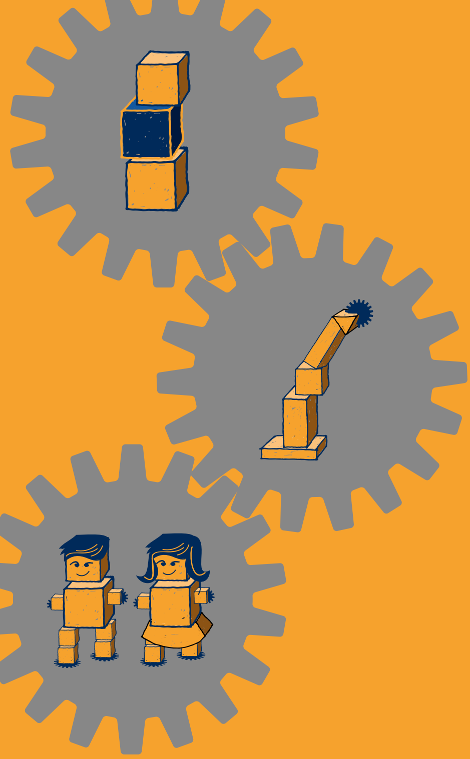
Industrial networks, learning systems and cluster development are the main subjects of my PhD. At the heart of innovation lies knowledge, which by many scholars has been deemed the most important factor in innovation. In the face of technological change within the manufacturing industry, e.g. adapting to Industry 4.0 and smart technology, firms are forced to improve their knowledge bases in all levels of manufacturing, from the floor up.

During my PhD, I will look at how the industrial clusters at Raufoss and Kongsberg plan to cope with the challenges posed by technological change, and how they work with actors on all levels, from local to global, to appropriate the knowledge needed in order to stay competitive and innovative. Initially I plan to study the future role of skilled, vocationally trained workers in the manufacturing industry, and how actors both inside and outside the clusters approach the issue of retraining skilled workers, in order to meet new knowledge demands posed by emerging technology.

Organisation
Centre structure

Organisation
Centre structure





Report from the research areas 2016

Multi-material products (MMP) is a major trend for high performance products in demanding markets such as automotive, aerospace and maritime industry, and opens new potentials for innovations in Norwegian manufacturing industry. The potential competitiveness lies in the companies' ability to utilise knowledge and technology efficiently by combing advanced materials, flexible and cost effective production and an innovative and sustainable organisation. Industrial partners and researchers at SFI Manufacturing strive towards a better understanding of competitive manufacturing in Norway by combining relevant technical- and social science studies, multi scale modelling approaches and state-of-the-art laboratories. Here we give a brief insight into some of the research areas that have had priority in 2016 to underpin this understanding.

Introduction

The manufacturing companies are continuously developing and improving products and production technology. In accordance with trends, the companies are expected to develop more complex multi-material products in an accelerated pace. Further, the companies are expected to fulfil sustainability targets. This requires the ability to optimise material choice and product design with focus on both product performance and end of life fate, and at the same time having a robust and economical production processes.

In this context, the manufacturing industry is faced with the diversity of automating more complex manufacturing processes, and at the same time lowering the cost and complexity of setting up, programming and controlling the manufacturing processes. Therefore, automation technologies and methods that enhance innovation and rapid introduction of new products and processes are prioritised in the SFI.

Increased digitalisation and integration of a company's manufacturing processes and indeed entire value chains, affects the everyday working situation in the industry. More advanced manufacturing processes and increased use of digital tools, will change the everyday life in the industry. The future shopfloor worker might have responsibility for more than one machine or station, he might be expected to have knowledge on digital tools, simulation and programming as well as general maintenance. Increased responsibility as well as more advanced and digitally integrated production technology will also demand new shop floor team structures and new production organisations. Finally, the companies need to be able to develop new products and new production technologies, that fulfils customers' demands and the societal demands towards a more sustainable development. The manufacturing companies' success might depend upon their ability to develop more complex solutions at an accelerated phase. Which depends upon internal organisation for innovation and learning, as well as the companies ability to cooperate and co-create with other companies, R&D institutes, NGO's etc.

Understanding multi-material products

In the first year of SFI Manufacturing we have focused on selected challenges related to design and manufacturing processes of multi-material products. The methodology we use is with industrial relevant demonstrator cases as a starting point for developing scientific understanding of the challenges using an experimental – numerical approach. We start at the atomistic scale with advanced characterisation of the material combined with atomistic modelling to understand properties of the interface between different materials, and then going all the way up to product performance testing and structural modelling using finite element software.

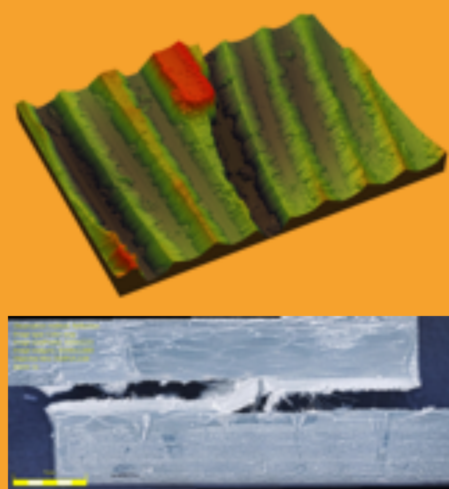
Joining and bonding different metals

Our first focus have been to study processes of joining different materials. Among various dissimilar material combinations, joining of aluminium to steel attracts extensive attention both scientifically and in the industry due to increasing interests in lightweight solutions. Within SFI Manufacturing, we have identified six different approaches of joining these two metals. One PhD student has started investigating the cold pressure welding process for joining aluminium to steel, and two PhD students (see separate section on page 13-14) focus on material structure and properties in the vicinity of the interface using advanced material characterisation methods and atomistic modelling respectively Other joining processes we have started to investigate are cold metal transfer (CMT) and a hybrid extrusion and bonding technology patented by the partner company HyBond.

Steps towards understanding of multi-material products using CMT as example: Joining process (upper), microstructure analysis (middle) and testing of interface property (lower).

Gluing

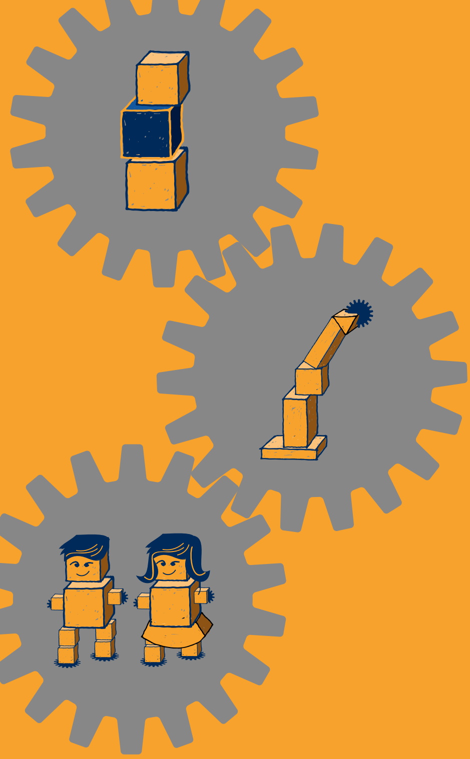
A very important method for joining a wide variety of materials, not only metals but also plastics, is adhesive bonding or gluing. We have begun to study the physical and chemical parameters of both the adhesive and the surfaces to be bonded in order to understand effects influencing the adhesion and strength of the glue line, and to understand when adhesive bonding is the suitable and the preferred bonding method. An example we have started to look into is the adhesive bonding of fibre reinforced polymer composites. In this case, the surface cannot be melted so welding is not an option, and through-thickness mechanical bonds (rivets, screws etc) perforate the fibre reinforcements, leading to structural damage. Therefore adhesive bonding, either gluing or secondary lamination, is key process in joining thermoset matrix composites. The strength of an adhesive bond is a function of surface topography and surface chemistry. Studies performed on a common composite, glass fibre reinforced epoxy laminate, revealed the effect of polishing on the surface roughness (topography) of the part, as measured by white light interferometry at SINTEF. Surface topography in combination with chemical analysis and mechanical tests of bond strength is used to fully understand the behaviour of adhesive bonds. Work in this field will be continued in the recently granted project "Joining of composite structures", managed by SFI-Manufacturing member Brødrene Aa



Surface topography of a glass fibre reinforced composite using white light interferometry (top) in combination with chemical surface analysis are used to understand the bond strength (bottom).

Additive Manufacturing

In addition to more conventional processes of producing multi-material products, we have in SFI Manufacturing a special focus on additive manufacturing (AM) as an important enabling production technology alone and/or in combination with traditional production methods.



We have learned that there is a demand for producing rather large additive components in the industry. Therefore, an investigation into methods that enable additive manufacturing of large and multi-material products has started, resulting in a prototype idea of building additive parts using the CMT-technique for welding aluminium to steel.

Cold Metal Transfer cycle to be put on a robotic arm

A doctoral position regarding robotic control and sensors in such an AM set-up has been defined. Linn Danielsen Evjemo under the supervision of Prof. Jan Tommy Gravdahl will start her doctoral work on this topic in 2017.

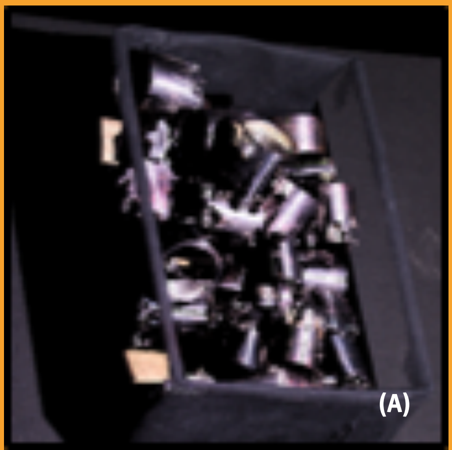
To get an updated view on the recent movements in the AM research community, the SFI has made a sum-up of international roadmaps and standards. This summary illustrates the main points of future technology development, and is usually a basis for government- and EU- research funding. In particular, the simulation of AM processes received great interest at the largest AM exhibition (Form-Next) in Frankfurt.

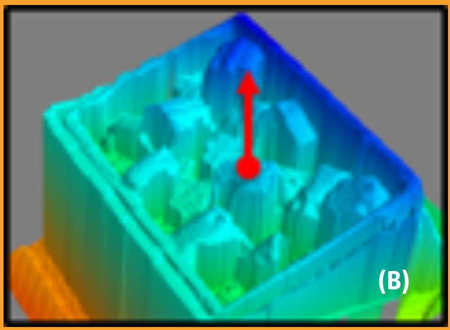
Automatic grasping using Deep Learning

Flexible and robust automation is a promising approach to competitive manufacturing in a high cost country. Therefore, one objective within SFI Manufacturing is to increase flexibility and reduce development time for automated solutions. To reach this objective automation grasping is a key challenge to solve. In traditional automation object localisation and grasping has been solved by a fixed setup with an exact position of the object. A more flexible approach is vision based grasping which can eliminate the need for a fixed setup. However, such an approach require that the objects are known to the vision system.

A long-term goal within the SFI is to create a generic system for vision based grasping of all types of objects in cluttered scenes. As a step towards this goal, we have developed a system for robot grasping using deep learning. Deep learning algorithms can learn features and tasks directly from images, by automatically extracting high-level, complex abstractions from the images. Instead of learning a traditional machine vision system each new object it should handle, a deep learning algorithm can be trained for handling a large spectre of objects and objects in cluttered scenes.

In this work, we present a vision-based robotic grasping system, which not only can recognise different objects, but also estimate their poses by using a deep learning model, finally grasp them and move to a predefined destination. The experimental results demonstrate that the vision-based robotic system can grasp objects successfully regardless of different poses, illuminations and scenes.





3D image of a bin with steel parts. A) Real point cloud, B) Grasp points; he red arrow shows the gripping point and angle.

However, deep learning algorithms need huge amount of data in order to generate a good model. To cope with this issue we have developed a simulation tool that produces simulated data to train our model. This will give an improved model, reduce the total number of grasps needed, and save time. In 2017 the simulated data will be combined with real data from a physical experiment, so that the algorithm can continue to learn how to make the best possible grasps.

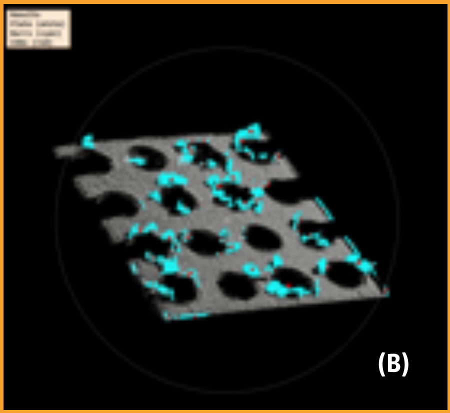
A vacuum gripper will be used in the physical experiment. By using a differential flow sensor it is possible to distinguish a successful from an unsuccessful grasp.

3D vision

Recent developments in the sensor-field enable us to generate so-called point clouds fast and with high accuracy, which makes it useful for industrial inspection and quality control. These point clouds can be used for 3D vision which, compared to 2D vision, is robust to variation in light conditions, simplify object localisation and makes inspection of more unconstrained scenes possible.

Point cloud of shiny metal tool part from Sandvik Teeness.

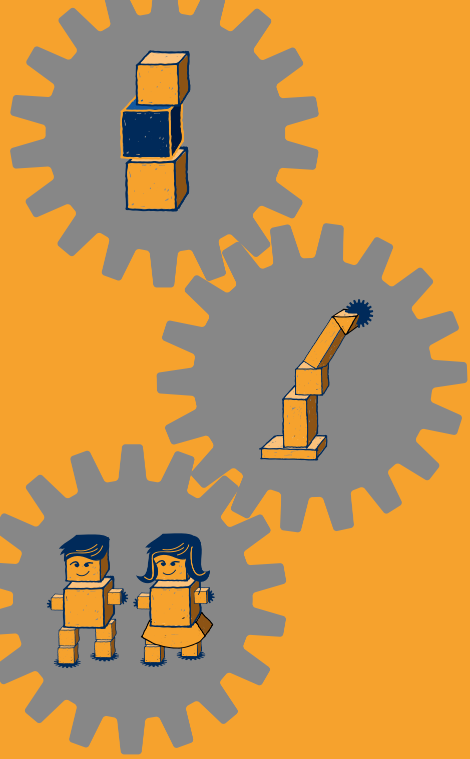
In SFI manufacturing we have two approaches to 3D vision. We work on developing new algorithms to locate objects in point clouds, using Deep Learning (see above), and we use these algorithms as well as existing methods in available industrial vision systems to solve generic industrial issues, like bin-picking. In 2016 we have been evaluating the open source Point Cloud Library (PCL) and the commercial systems Scorpion and Halcon, in order to compare them with the methods developed in SFI Manufacturing, as well as use them directly for object localisation and in-line inspection in industrial applications. In 2017 we will continue to focus on reducing the time necessary to setup an object localisation system based on 3D vision.



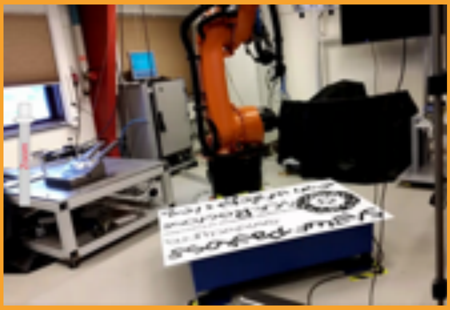
Detection of burrs using point cloud sensor. A) Workpiece with burrs, B) Detection of burrs (blue) in point cloud model.

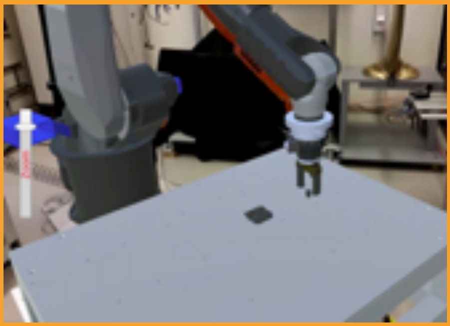
Simulation

Simulation has the potential to reduce development time for new processes drastically; by simulating alternative concepts, reducing errors in control software, training operators prior to launch, and by improving manufacturability of new product designs. Despite numerous commercial simulation products available and used in the industry, the potential for innovations remains huge. One focus area within SFI Manufacturing has been verification of control applications for production cells, lines etc., using simulation models. A second area related to extensive use of simulation is a method for near simultaneous execution of a physical environment and a simulated environment. This method has been further developed



based on earlier results from the innovation project Autoflex. To visualise the physical and simulated environment, augmented reality (AR) is used. The pictures below shows the environment before and after AR is used for visualisation.





(A) Setup of physical environment, and (B) the Visualisation of physical and simulated environment using AR.

One of the results of Autoflex is a method for effective and intuitive programming of robots and robot assembly applications, through restructuring and adding of required data to existing CAD-models. The structure of these models has been further developed in SFI Manufacturing, to simplify extraction of required data. The CAD-models is input to a simulated environment, where changes can be simulated and verified to be automation friendly.

Future organisation of production

The manufacturing industry is constantly faced with the diversity of automating more complex manufacturing processes, and at the same time lowering the complexity of setting up, programming and controlling these processes. In addition, manufacturing processes should support development and rapid introduction of new products. In SFI Manufacturing work systems for process innovation are considered as socio-technical systems in which raw materials are turned into products by networks of workers, tools and technology. Such work systems are often referred to as "team-based", "lean" or "high-performance" production and integrate those who perform direct work, improvement work, technical experts and managers. For manufacturing companies in high costs countries such as Norway, the aim is superior performance through increased employee involvement and commitment towards the work and the results they deliver.

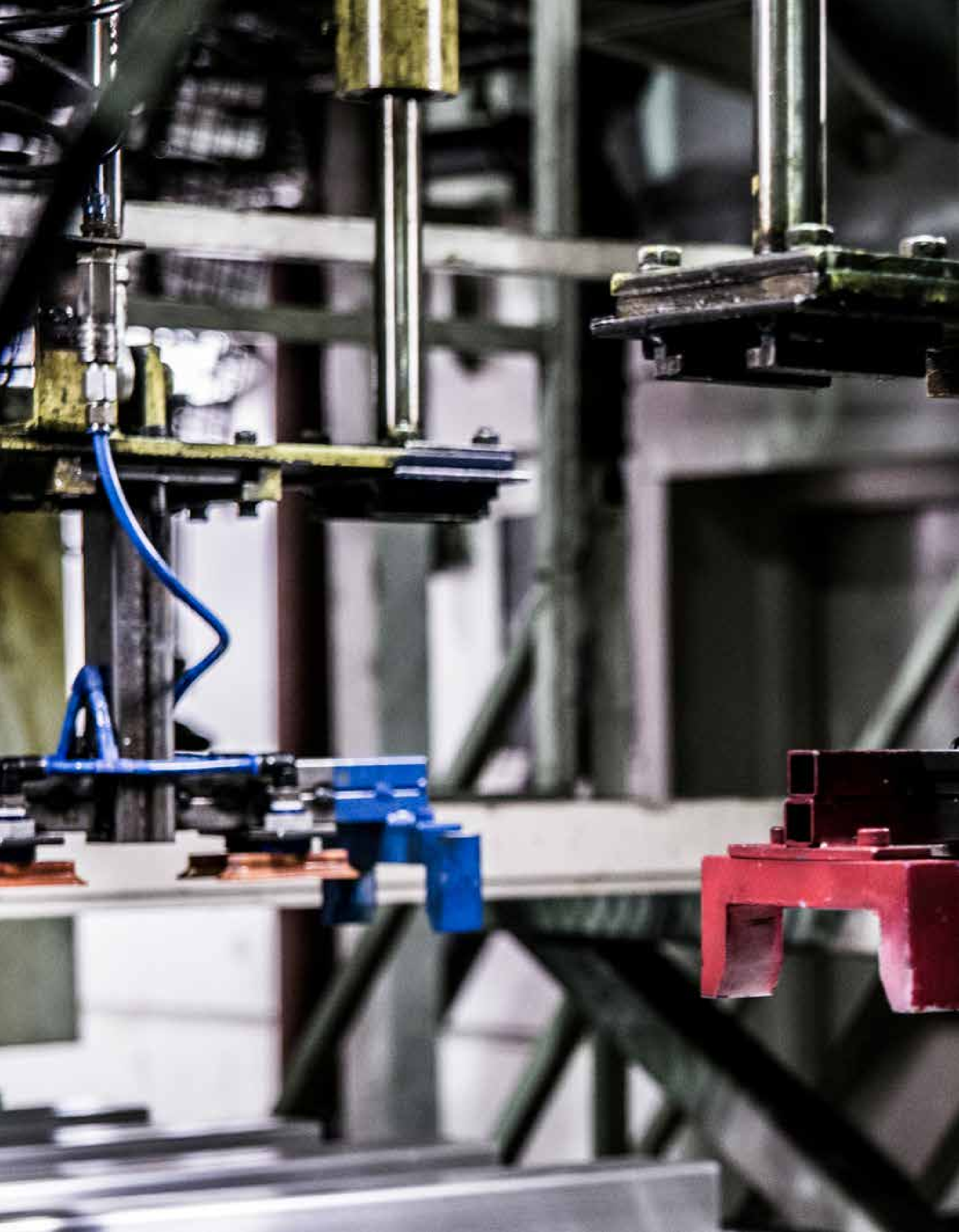
With increased digitalisation in advanced manufacturing, the interaction between the humans and the technology is changing; for example by the need for understanding systems that display vast amounts of data, acting on instant feedback systems, or in direct co-creation with robots. More complex production systems also expands the skills and knowledge base of workers. Supplementing manual skills and tacit knowledge, future workers are required to have a deeper theoretical understanding of the transformation processes and perform tasks such as machine set-up and programming, which until now mainly have been carried out by technicians and engineers. Therefore there is a need to rethink the role of skilled workers in future manufacturing and upgrade vocational education programs accordingly. Henrik Brynthe Lund will study learning systems in his PhD (page 17).

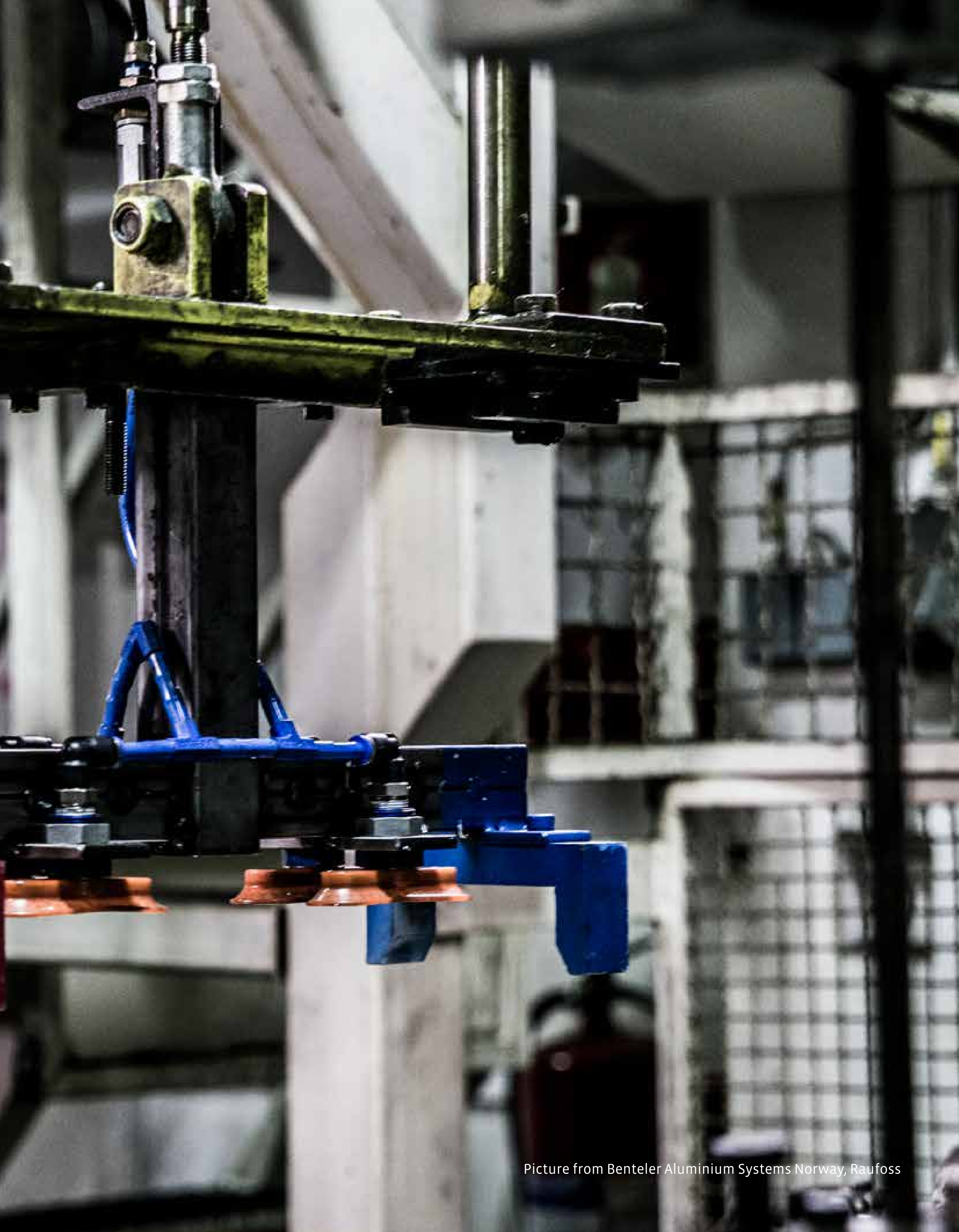
Learning systems and innovation
Firms innovative capacity is depending on their ability to develop inhouse knowledge and exploit different external sources of knowledge. Many firms rely on regional support for relevant education and training (access to skilled labour), but also on extra-local firms (collaborators, suppliers, customers etc.), R&D institutions and so on. Manufacturing companies are located and thereby part of regional production clusters as well as wider (potentially global) production networks. Together these cooperation provide local support as well as external impulses. In SFI Manufacturing, a comparison between the companies' learning systems in the Kongsberg and Raufoss clusters is carried out. New collaboration across different sectors and clusters will be crucial for maintaining a sustainable and innovative manufacturing industry.

Without a doubt, innovation in established manufacturing companies is increasingly more demanding; faster time to market requires accelerated innovation. In addition more complex products and production technologies are expected. Simultaneously, manufacturing companies should meet demands for a more sustainable society. Two PhD scholarship holders partly financed by SFI Manufacturing are working on innovation; Vetle Engesbak work on stepwise innovation in processing industry and Marit Moe Bjørnbet on green competitiveness (pages 15).

SFI Manufacturing Maturity Mapping
During the lifetime of SFI Manufacturing a longitudinal study of the industrial partners is planned. The objective is to develop a tool for the companies to assess their organisations' maturity to implement and develop new technology. The mapping is based on a quantitative survey with respect to process organisation, product and production technology development and the companies' learning systems. The first mapping will take place in 2017. The survey will be followed up in the companies by reflective workshops and organisational development activities. The mapping will shed light on how the manufacturing companies in SFI Manufacturing should meet the challenges ahead; competitive manufacturing in a high cost country, digitalisation and sustainable development.

Additional focus in the coming years
Multi-material and light weight products with high-performance is deemed necessary in many industrial sectors, not least to reach the Norwegian climate target of at least 40 % reduction of greenhouse gas emissions by 2030, compared to 1990 levels. Sustainability in material selection and production processes, including high recyclability of materials in multi-material solutions will therefore become a focus area in SFI Manufacturing in the coming years, combining competence and knowhow from all three research areas.





Picture from Benteler Aluminium Systems Norway, Raufoss

Research partners

NTNU

Education and Research:
Physics, Materials Science, Cybernetics, Industrial economics and technology management, Geography

SINTEF

Research:
SINTEF Materials and Chemistry,
SINTEF ICT, SINTEF Technology and society

SINTEF Raufoss manufacturing

Host institution Research:
Product- and process development, Production technology, Materials Technology

Industrial partners

Brødrene Aa awarded Ship of the year 2016

Brødrene Aa has been awarded Ship of the year 2016 by the magazine Skipsrevyen, for their hybrid-electric sightseeing vessel Vision of the Fjords.

The jury states: "This year's Ship of the Year is truly innovative, with efficient diesel propulsion for long distance transfer and electric propulsion for quiet and pollution-free sightseeing in the beautiful UNESCO-listed Norwegian fjords. The design of the vessel itself, a catamaran with a carbon-fibre hull and the modern passenger facilities adds to the overall feeling that this is something completely new."

It is an honour for us to be awarded Ship of the Year 2016. This project has been a challenging journey from day one, combining an ambitious exterior design with new hybrid propulsion technology, all executed within 12 months. Vision of the Fjords is a product of a collective effort from the yard, operator and suppliers in a constructive dialogue with Norwegian Maritime Directory, says managing director in Brødrene Aa, Tor Øyvin Aa.

Vision of the Fjords is a premium sightseeing vessel designed from the ground up to enhance passenger's sightseeing experience and reduce the vessels environmental footprint. The catamaran is certified for 400 passengers, 42 meter long, 15 meter wide and built in lightweight carbon fibre composite.

Foto: Sverre Hjørnevik

Picture from Brødrene Aa, Hyen


Foto: Norsk Industri

GKN Aerospace awarded smartest manufacturing company of Norway

In 2016, GKN Aerospace has been awarded Smartest Manufacturing Company of Norway. Plasto and Neuman Aluminium Raufoss Technology were first and second runner up.

60 companies signed up for the competition in total in 2016. Plasto, Neuman Aluminium Raufoss Technology and GKN Aerospace, all three industrial partners in SFI Manufacturing, were chosen as finalists, because of their effective and digitalised production processes. Of these finalists, GKN Aerospace got the title Smartest Manufacturing Company of Norway 2016.

GKN Aerospace
GKN Aerospace operates in one of the world's most advanced and demanding markets, and produces jet engine components for the world's largest aircraft engine manufacturers. Its machine park can operate up to 15 hours unmanned, and the company has managed to implement a smart way to staff the production line.

According to the jury, GKN Aerospace is at the forefront when it comes to the collaboration and sharing of knowledge, by being a part of the Kongsberg cluster, but also by lifting NTNU's and SINTEF's advanced research and development projects. Despite the fact that GKN Aerospace is a large manufacturer, they are able to create good economic results, and with such a high degree of industrial production, they prove that they are at the forefront of manufacturing technology.

– GKN Aerospace is able to show solid earnings on extremely complex production to perhaps the world's most demanding customer group, said Knut E. Sunde of Norsk Industri after the award.

About the price
The Norwegian industry faces a strongly developing international competition. To be viable, Norwegian manufacturers should think smart, be innovative and use modern technologies. Norsk Industri and Siemens want to inspire and reward those who are striving to ensure Norway's future competitiveness through its innovation and adaptability. To become Norway's smartest manufacturer, one should have an excellent score on:

- Productivity
- Uniqueness
- Cluster activities
- Innovation
- Use of technology, digitisation and development of skills
- Sustainability/environment/energy efficiency
- Market effects

From ideas to products

In October 2016, SFI Manufacturing gave an input to the Governments forthcoming white paper on industry policy. Our research program aims for strengthening Norwegian industry now as well as in the future.

In SFI Manufactuirng, the largest industrial and manufacturing companies participate, with the main geographical clusters Raufoss, Sunnmøre, Kongsberg and Trondheim.

Our research goal for the next eight years is to strengthen and further develop the Norwegian, mainland-based industry. The relevance of this work has increased significantly after the oil crisis. The situation today is that the mainland industry accounts for about 9 percent of the GDP, or 15 percent of the overall Norwegian production value. In addition, there are important effects in other goods and service industries. In recent years, companies have moved their production fascilities back from low-cost countries in considerable extent, through so-called home-sourcing. Further, there are important effects of a strong manufacturing industry in local schools, the public sector, innovation and new establishment of companies. In addition, the manufacturing industry is the largest user of research as an integral part of its strategy.

To strengthen the Norwegian industry further, it is important to take the inward benefits we have by producing in Norway, even with higher wages. We have a high level of knowledge in the population, a close collaboration between businesses, universities and research institutes through a number of research projects, a working life characterised by a high degree of trust and responsibility, creating less need for control and hierarchies. We also have a high degree of automation. Close interaction between the various levels and departments of the companies is also beneficial for innovation. It enables us to quickly develop and test new products, which is very crucial in the future work life.

Although we have many advantages, we have also significant challenges. The need for a rapid innovation rate in the future requires infrastructure and laboratories for the development and testing all the way from idea to finished product. We have a substantial infrastructure for basic research at NTNU and other universities, although this also requires continuous upgrading and new investments. Companies have their own infrastructure for end-testing of own products. But it is a step in the middle where we have a significant weakness. United Kingdom and Germany have in recent years built up Technology Centres to cover the gap between the research laboratory and finished, manufacturable products, through the so-called "Catapults" (Tech-Centre). Access to such infrastructure is critical. Another challenge is related to the knowledge and expertise needed, especially aimed at digitising.
What are the solutions to these challenges? We point at four topics:

1)
We must we develop a “Catapult”-technology centre to meet development needs for products on the road from the research laboratory at a University and to finished products.

2)
We need to continue the close cooperation between industry, research environment and the University, which is mutually beneficial to all parties, but essential for companies. There are good instruments today within the Norwegian Research Council, that can and should be extended and where one in the future should consider interaction across industries and include the public sector. There is a significant potential for learning across different sectors.

3)
Businesses gets better working together, through the sharing of knowledge, infrastructure, cooperation on research and mobility in relation to the employees. To continue to develop the industry clusters to the highly successful examples Raufoss, Sunnmøre and Kongsberg is absolutely essential, and Innovation Norway does an important job in this.

4)
Finally, the need for increased commitment to competence and learning. Access to reciprocal learning venues in the entrance to the Industry 4.0 is crucial in the future.

Picture from Benteler Aluminium Systems Norway, Raufoss

Workshops 2016

The workshop concept is the heart of SFI Manufacturing. Three times a year the industry, the researchers, the PhD- and Post Doc. candidates and their supervisors, local actors and the centre management meet to network and follow the progress of SFI Manfacturing. Each time, one of the research areas is the main focus of the workshop. Together with a hosting industry member the research team plane one full day of activities beneficiary for both the industry and the researchers. The evening before the workshop the SFI Manufacturing community meet for a seminar on a relevant theme and a network dinner.

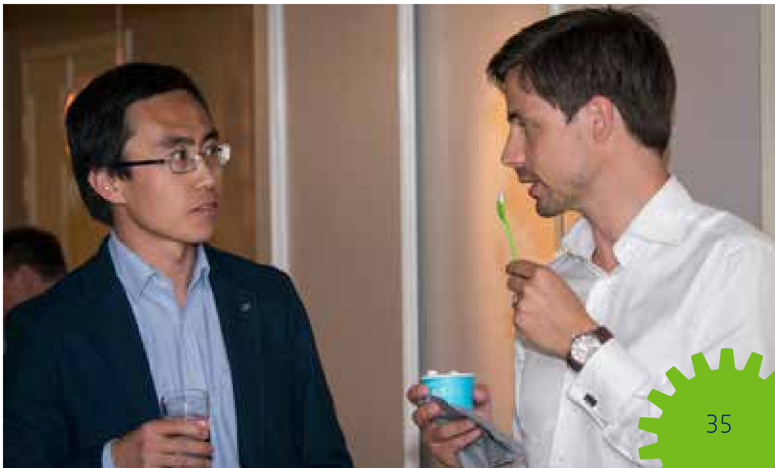
SFI Manufacturing Workshops 2016

Thanks to all contributors and participants in 2016! The workshops are the heart of SFI Manufacturing where research and industry meet in a concept developed through SFI Norman and SFI Manufacturing.

Åndalsnes, March 7-8
77 participants gathered in Åndalsnes to focus on RA3 Multi-material products and processes, visit Plasto and start the work on giving input to the Governments forthcoming white paper on industry policy

Gjøvik/Raufoss June 13-14
In June 67 participants met in Gjøvik and visited Benteler in Raufoss. This workshop focused mainly on RA2 Robust and flexible automation with some intersections with RA3 Sustainable and innovative organisations on the theme "Man – Machine interaction".

Kongsberg October 24-25
The last workshop of the year took place in Kongsberg where 54 participants learned more about sustainability in general and about RA3 Sustainable and innovative organisations in particular. The workshop ended up in the Technology park of Kongsberg with a visit to GKN Aerospace.



International collaboration 2016

SFI Manufacturing has arranged the CIRP international research conference on Learning Factories on June 29th to 30th. Furthermore SFI Manufacturing has been one of the leading partners in a proposal for a Knowledge and Innovation Centre (KIC) on Added Value Manufacturing, to a call from the European Institute of Innovation & Technology. SFI Manufacturing also made a significant footprint at the European Technology Platform, Manufuture.

Manufuture ISG Vision 2030

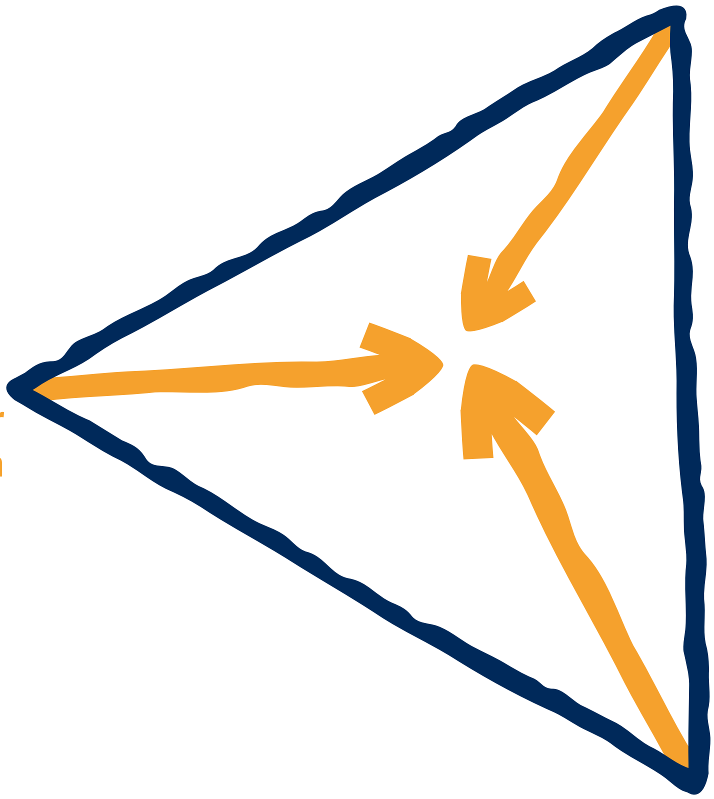
The EU technology platform for manufacturing, Manufuture is working on a vision document for Manufacturing research in Europe towards 2030. The work is done in the Implementation Support Group (ISG) where Kristian Martinsen attends and controlled by the High Level Group (HLG) where Lars Stenerud, Ottar Henriksen and Kristian Martinsen attend. The main stakeholder is the European Commission for the use in the construction of the 9th Framework program – after the finish of the H2020. The work will be intensified in 2017, and the Vision document shall be delivered by January 2018, followed by the work on a Strategic Research Agenda (SRA). There will be chapters on sustainability, innovation, science and technology, education, models for future manufacturing, importance on manufacturing for Europe, societal challenges, megatrends and employment. SFI Manufacturing has the responsibility for the chapter on employment.

Manufuture sub-platforms on Joining and Additive Manufacturing

SFI Manufacturing attends the Manufuture sub-platform on Joining, and Kristian Martinsen have had the responsibility to be the chairman for the sub-platform. The sub-platform has made an updated SRA and finished an industrial survey within industry. There have been 3 meetings including the General Assembly of the sub-platform. The main objective to assemble the industry needs for research and use this to promote joining technology and challenges for the H2020 calls. Similarily, SFI Manufacturing has attended the sub-platform on additive manufacturing. The AM-platform had two meetings in 2016, and was co-organising the Additive Manufacturing European Forum: 9th November 2016.

EIT KIC Proposal

SFI Manufacturing was a partner in the work on making a proposal for the European Institute of Innovation & Technology (EIT) to the call an a Knowledge and Innovation Community on Added Value Manufacturing (KIC AVM). The proposal was delivered on July 2016, but unfortunately the proposal was not successful. Beeing the only proposal for the KIC AVM this means there will be no KIC on manufacturing. There is a decision in the co-location centre North to keep the contact created through the KiC proposal for further proposals. There might be a new call for KIC AVM in 2018 but this is not yet decided.



CIRP Sponsored Conference: The 6th Conference on Learning Factories at NTNU Gjøvik, June 29th to 30th 2016
SFI manufacturing was co-organising The CIRP 6th Conference on Learning Factories.[1]
Date and place: 29th – 30th of June 2016, NTNU Gjøvik

Number of participants: 78 from 8 different countries:
Germany, Norway, Croatia, France, Austria, Sweden, Hungary, Greece

Number of papers received:	56
Number of papers accepted:	46
Number of papers presented:	43

Number of sessions and names:
On day one (starting at 12:00) there where a keynote session, a practical exercise in the Leanlab learning factory as well as a company visit at the Benteler Automotive plant at Raufoss. On day two there were keynote talks and 3 parallel paper sessions with 3 sessions each, in total – 9 sessions.

Keynotes – day one:
Knowledge management in the Raufoss industry cluster
Ottar Henriksen, Project director, SINTEF Raufoss Manufacturing AS

Industrial Experiences from LeanLab Learning factory
Tore Hjelmås, Plant manager, Nammo Raufoss AS

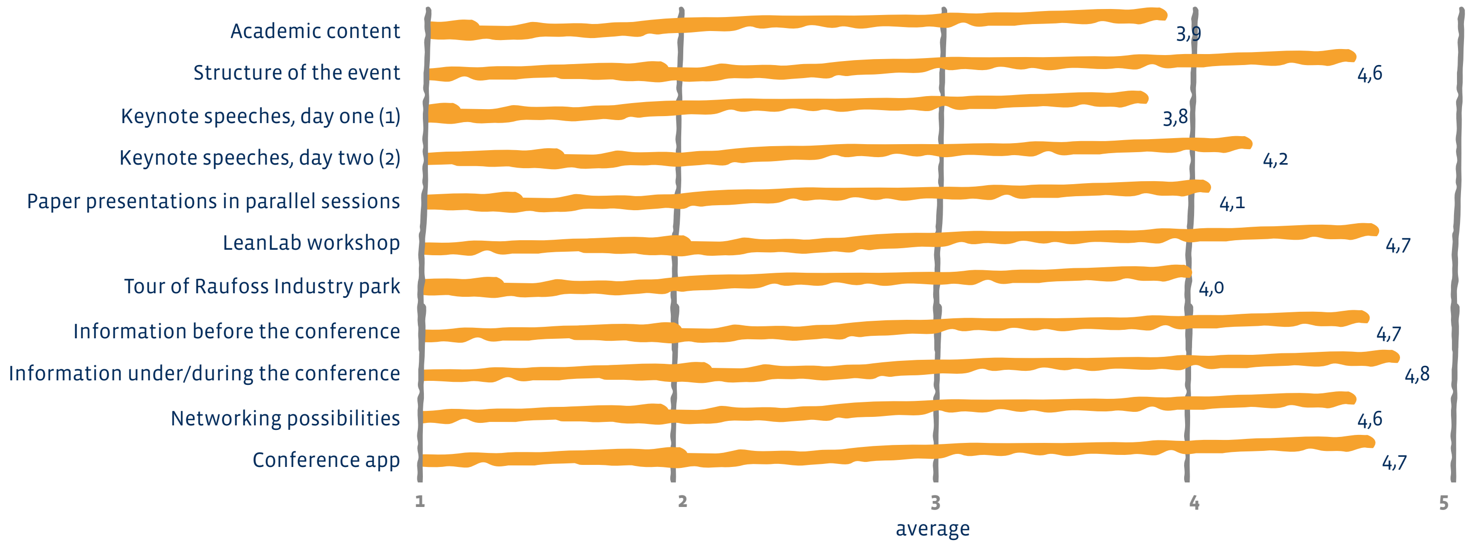
University Experiences from LeanLab learning Factory
Professor Kristian Martinsen, NTNU faculty of Technology, Economy and Management

Keynotes – day two:
Knowledge and Innovation Community on Added-value Manufacturing:
Professor Dimitris Mourtzis, Division Director, Division of Design & Manufacturing. University of Patras

Industry 4.0 in Lean Learning Factories
Professor Dr. Ing. Joachim Metternich
Associate Director, Institute of Production Management, Technology and Machine Tools, Technische Universität Darmstadt
President of the Initiative on European Learning Factories

Attendance to sessions
The attendance at the sessions was quite balanced in numbers. We registered, as expected, that the coffee breaks were of importance for the participants regarding networking and discussion of paper presentations. Networking and communication through the conference app were also well received.

(1): https://www.ntnu.edu/web/clf2016/the-6th-conference-on-learning-factories



Members of the Organising committee of the learning factories conference:

Kristian Martinsen,
Research director, SINTEF Raufoss manufacturing, Vice dean research/ Professor at NTNU:
Kristian.martinsen@ntnu.no

Aristidis Kaloudis,
aristidis.kaloudis@ntnu.no
Professor, NTNU

Finn Ola Rasch,
finn.o.rasch@ntnu.no
Professor Emeritus, NTNU

Terje Kristoffer Lien,
terje.k.lien@ntnu.no
Professor Emeritus, NTNU

Short description of the paper reviewing procedure

The Review process was following the Elsevier Editorial System procedures, where abstracts was submitted within the deadline December 15th 2015, Notification of accepted abstracts followed promptly and the deadline for full paper where February 15th 2016. Notification was given within April 15th, and final paper was due May 15th 2016. Each paper was reviewed by at least two reviewers. All of the reviewers are listed in the scientific committee list. Reviewers where selected according to the rule that reviewers should not be from the same country as the main author. 10 papers where rejected due to bad quality, 12 papers where accepted as-is and the rest was accepted if smaller or larger revisions could be done by the authors.

Papers availability

All papers were available for conference attendees through a conference app and secured web page before, during and after the conference(2)
Papers were published in a special issue of the Elsevier Open access Journal "Procedia CIRP"
Procedia CIRP, Volume 54, Pages 1-250 (2016), Edited by Kristian Martinsen(3)

Concluding notes

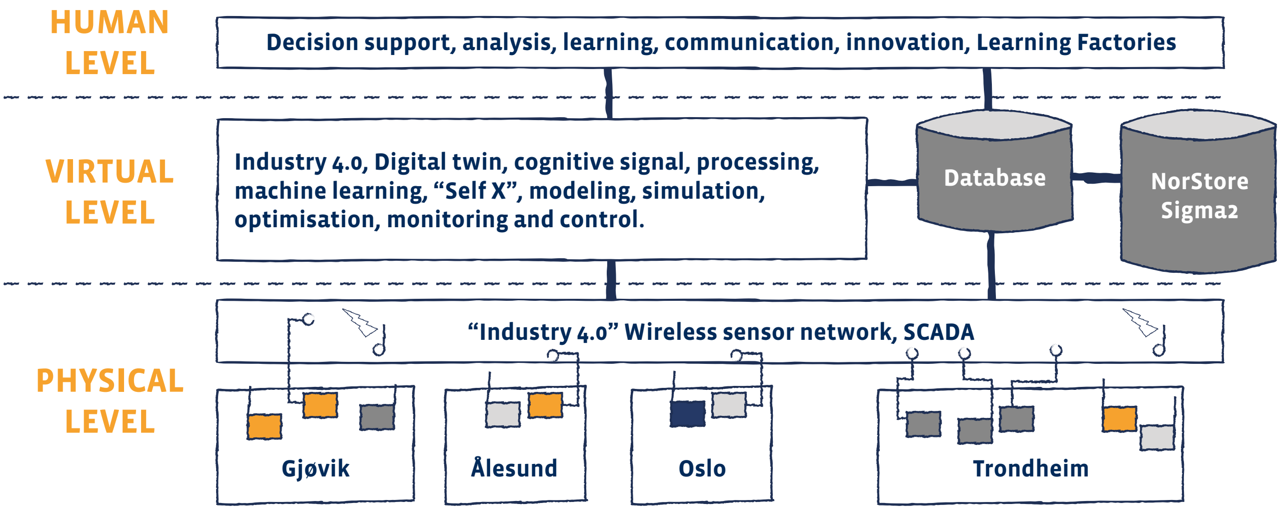
General considerations on the quality of the papers and presentations:
As always there was a sertain variation in the quality of the papers and the presentation. In general, however we believe the conference had a substantial share of high-quality papers and presentations bringing the scientific work on the field of learning factories one step ahead. Some of the papers will clearly be useful for the upcoming Keynote in CIRP GA.

General considerations on the success of the conference/seminar:
A survey was conducted right after the conference, available both through the app and by link. Overall, the different aspects got relatively high score. All scores were between 3.8 and 4.8, on a scale from 1-5

Prof. Metternichs keynote speech on day two and the practical experience of the LeanLab workshop on day one, both got a lot of positive feedback.

The organising committee received mostly positive remarks on both the execution and conference programme overall. We have learned that the German delegation need a lot of milk to their coffee, but other than that we will call the conference a great success. A comment from the survey seems fitting here: *"The LeanLab program was definitely the highlight of the conference - hands-on experience in a specific topic can be a very unique form of networking, too."*

(2): https://www.ntnu.edu/web/clf2016/conference-app
(3) http://www.sciencedirect.com/science/journal/22128271/54



Hardware/Machines; fully sensored, remote supervision, flexible and fast reconfigurable.
Additive Manufacturing, Joining Technologies, Robotics and Automation, Light weight materials.

MANULAB

In 2016 SFI Manufacturing has contributed to establish a proposal for infrastructure in cooperation with the university campus in Trondheim, Ålesund and Gjøvik.

SFI Manufacturing was central in a new proposal for national infrastructure for basic research for manufacturing submitted to The Norwegian Research Council on Oct. 12th 2016. The research council is expected to finish the proposal evaluation process within June 2017. NTNU is the host and SINTEF and SRM are partners in the proposed infrastructure. We ask for 160 MNOK for equipment to cover joining additive and robotics/automation processes, with an overall Industry 4.0 functionality. MANULAB should have capabilities to host research fitting all RAs in the SFI as well as cross-disciplinary research. The laboratory will focus on TRL levels 1-4 and will be complementary to a future Catapult (Tech centres).

MANULAB will have three levels: A Physical level of all instruments, machines, tools, robots, networks and computers. A Virtual level serving as a digital twin of the physical level, and with tools for visualisation, simulation, optimisation, monitoring and control, including novel AI/machine learning methods such as artificial neural networks and deep learning. Research data will be stored in a database in collaboration with the national infrastructure on research data Norstore/Sigma2.

Foto: Sverre Hjørnevik

Picture from Brødrene Aa, Hyen

Recruitment

The centre has succeeded with the recruitment of excellent PhD candidates through 2016 and we are now according to plan with the first cohort in our PhD education. In addition, SFI Manufacturing has entered collaboration with 2 associated projects and together we are co-funding two additional PhD's.

We are also pleased to report that we have maintained a level of 50% female PhD candidates within the centre and that that we have a fairly equal distribution over the different research areas.

In 2016 a PhD network is established for the PhD candidates funded by SFI Manufacturing and associated projects. This network is organised and developed by the PhD candidates themselves, and through this a yearly plan for a SFI Manufacturing PhD school is established.

Communication and dissemination

The website **www.sfimanufacturing.no** is established and includes a blog where news of SFI Manufacturing partners in the media or news from the centre are found as blogposts. **2016 started out with 21 blogposts**.

Twitter is targeted as the social media of preference for SFI Manufacturing. All blogposts are also tweeted. In addition, the centre is active on Twitter from conferences, workshops, gatherings, meetings and other occasions when the centre wants to communicate. So far, SFI Manufacturing has communicated 100 tweets and has 213 followers.

Key Researchers

Name	Institution	Main research area
Ida Westermann	NTNU-NT-IM	Joining aluminium to steel
Bjørn Holmedal	NTNU-NT-IM	Joining aluminium to steel
Vegard Brøtan	SINTEF Raufoss Manufacturing	Additive manufacturing products cont. polymers
Olav Åsebø Berg	SINTEF Raufoss Manufacturing	Additive manufacturing
Ben Alcock	SINTEF Materials and Chemistry	Additive manufacturing, Multi-material products cont. polymers
Erik Andreassen	SINTEF Materials and Chemistry	Additive manufacturing, Multi-material products cont. Polymers
Per Erik Vullum	NTNU-NT-IF	Multi-material metallic products
Randi Holmestad	NTNU-NT-IF	Multi-material metallic products
Are Strandlie	NTNU Gjøvik	Multi-material metallic products, Multiscale modelling
Per Harald Ninive	NTNU Gjøvik	Multi-material metallic products, Multiscale modelling
Magnus Eriksson	SINTEF Materials and Chemistry	Multi-material metallic products
Dirk Nolte	SINTEF Materials and Chemistry	Multi-material metallic products
Hoang Hieu Nguyen	SINTEF Materials and Chemistry	Multi-material metallic products
Giovanni Perillo	SINTEF Materials and Chemistry	Multi-material products cont. polymers
Jesper Friis	SINTEF Materials and Chemistry	Multiscale modelling
Tèrence Coudert	SINTEF Materials and Chemistry	Multiscale modelling
Xiaobo Ren	SINTEF Materials and Chemistry	Multi-material metallic products
Ole Martin Løvvik	SINTEF Materials and Chemistry	Multiscale modelling
Rune Østhus	SINTEF Raufoss Manufacturing	Multi-material metallic products
Einar Hinrichsen	SINTEF Materials and Chemistry	Multi-material
Sverre Gulbrandsen-Dahl	SINTEF Raufoss Manufacturing	Multimaterial
Jan Tommy Gravdahl	NTNU-IME	Senor fusion
Esten Ingar Grøtli	SINTEF ICT	Robotic handling of flexible objects, Flexible and integrated production systems
Magnus Bjerkeng	SINTEF ICT	Robotic handling of flexible objects
Trine Kirkhus	SINTEF ICT	Robotic handling of flexible objects
Marianne Bakken	SINTEF ICT	Robotic handling of flexible objects

Olivier R.-Dubonnet	SINTEF Raufoss Manufacturing	Robotic handling of flexible objects, Flexible and integrated production systems
Morten Lind	SINTEF Raufoss Manufacturing	Robotic handling of flexible objects, Flexible and integrated production systems
Lars Erik Wetterwald	SINTEF Raufoss Manufacturing	Flexible and integrated production systems
Per Nyen	SINTEF Raufoss Manufacturing	Flexible and integrated production systems
Lars Tore Gellein	SINTEF Raufoss Manufacturing	Robotic handling of flexible objects, Flexible and integrated production systems
Gaute Knutstad	SINTEF Technology and Society	Work systems and organisation
Torbjørn Netland	SINTEF Technology and Society	Work systems and organisation
Marta Mathisen	SINTEF Technology and Society	Work systems and organisation
Eva A. Seim	SINTEF Technology and Society	Work systems and organisation
Kristoffer Magerøy	SINTEF Technology and Society	Work systems and organisation
Johan Ravn	SINTEF Technology and Society	Work systems and organisation
Hans Torvatn	SINTEF Technology and Society	Work systems and organisation
Gunnar Lamvik	SINTEF Technology and Society	Work systems and organisation
Geir Ringen,	SINTEF Raufoss Manufacturing	Innovation and product development
Silje Aschehoug	SINTEF Raufoss Manufacturing	Innovation and product development
Emma Østerbø	SINTEF Raufoss Manufacturing	Innovation and product development
Kjersti Øverbø Schulte	NTNU-SVT	Work systems and organisation, Innovation and product development
Jonas Ingvaldsen	NTNU-SVT	Work systems and organisation, Innovation and product development
Asbjørn Karlsen	NTNU-SVT-GEO	Industrial clusters and learning systems
Markus Steen	SINTEF Technology and Society	Industrial clusters and learning systems
Sverre Konrad Nilsen	SINTEF Technology and Society	Industrial clusters and learning systems
Eli Fyhn Ullern	SINTEF Technology and Society	Industrial clusters and learning systems
Tone Merethe Aasen	SINTEF Technology and Society	Industrial clusters and learning systems
Monica Rolfsen	NTNU-SVT-IØT	Work systems and organisation, Industrial clusters and learning systems, Innovation and product development
Kristian Martinsen	NTNU Gjøvik	Additive manufacturing, Work systems and organisation

Visiting researchers

Name	Affiliation	Nationality	Sex M/F	Duration	Topic

Postdoctoral researchers with financial support from the Centre budget

Name	Nationality	Period	Sex M/F	Topic

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

Name	Funding	Nationality	Period	Sex M/F	Topic

PhD students with financial support from the Centre budget

Name	Nationality	Period	Sex M/F	Topic
Siri Marthe Arbo	Norwegian	2015-2019	F	Joining aluminium to steel
Mathias Hauan Arbo	Norwegian	2015-2018	M	Sensor fusion
Henrik Brynthe Lund	Norwegian	2016-2019	M	Learning in networks
Tina Bergh	Norwegian	2016-2019	F	Advanced characterisation
Muhammad Zeeshan Khalid	Pakistani	2016-2019	M	Atomistic modelling
Linn Danielsen	Norwegian	2016-2019	F	Automatisaton of additive manufacturing

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

Name	Funding	Nationality	Period	Sex M/F	Topic
Vetle Engesbak	IPN Sprangforbedring	Norwegian	2015-2019	M	Business management, innovation and implementation of changes
Marit Moe Bjørnbet	KPN SISVI	Norwegian	2016-2019	F	Life cycle assessment as a management tool

Master Degrees

Name	Sex M/F	Period	Topic
Audun Fjelldahl	M	2016	Knowledge sharing organisational learning
Line Larsen	F	2016	Entrepreneurship and innovation through spinn-offs

Publications

Scientific publications

Reporting year: 2015
Type: Article
Authors: K. Martinsen, S.J. Hu, B. E. Carlson
Title of work: *Joining of dissimilar materials*
Book/compendium/journal: CIRP Annal - Manufacturing Technology
Page no.: 679-699
Issue/Volume/Year: 2/64/2015
ISSN/ISBN: 0007-8506
Link: http://www.sciencedirect.com/science/article/pii/S0007850615001456

Reporting year: 2016
Type: Article
Authors: K. Martinsen, S. Gulbrandsen-Dahl
Title of work: *Use of Post-consumer Scrap in Aluminium Wrought Alloy Structural Components for the Transportation Sector*
Book/compendium/journal: Procedia CIRP
Page no.: 686–691
Issue/Volume/Year: 29/2015
ISSN/ISBN: 2212-8271
Link: http://www.sciencedirect.com/science/article/pii/S2212827115001158

Reporting year: 2016
Type: Article
Authors: M. Matsumoto, S. Yang, K. Martinsen, Y. Kainuma
Title of work: *Trends and research challenges in remanufacturing*
Book/compendium/journal: International Journal of Precision Enigineering and Manufacturing-Green Technology

Reporting year: 2016
Type: Article
Authors: J.L. Duigou, S. Gulbrandsen-Dahl, F. Vallet, R. Söderberg, B. Eynard, N. Perry
Title of work: *Optimization and Lifecycle engineering for Design and Manufacture of Recycled Aluminium Parts*
Book/compendium/journal: CIRP Annals - Manufacturing Technology
Page no.: 149-152
Issue/Volume/Year: 1/65/2016
ISSN/ISBN: 0007-8506

Reporting year: 2016
Type: Article
Authors: K.O. Schulte, M. Hatling, S. Aschehoug
Title of work: *Improving Innovation Culture by Demonstrator Design*
Book/compendium/journal: Procedia NordDesign
Page no.: 268-277
Issue/Volume/Year: 2/2016
ISSN/ISBN: 978-1-904670-80-3

Reporting year: 2016
Type: Article
Authors: O. Hoem, E. Lodgaard
Title of work: *Model for supporting lasting managerial efforts in continuous improvement: A case study in product engineering*
Book/compendium/journal: Procedia CIRP, 26th CIRP Design Conference
Page no.: 38 -43
Issue/Volume/Year: 50/2016

Reporting year: 2016
Type: Article
Authors: S. Aschehoug, K.O. Schulte
Title of work: *Design Driven Innovation in Clusters*
Book/compendium/journal: Procedia NordDesign
Page no.: 147-157
Issue/Volume/Year: 2/2016
ISSN/ISBN: 978-1-904670-80-3

Reporting year: 2016
Type: Article
Authors: T. Welo, G. Ringen
Title of work: *Beyond waste elimination: Assessing lean practices in product development*
Book/compendium/journal: Procedia CIRP, 26th CIRP Design Conference
Page no.: 179 - 185
Issue/Volume/Year: 50/2016

"It is important that research contributes to focus on prevention, rather than to understand in retrospect"

Svein Terje Strandlie
Benteler Aluminium Systems Norway

Picture from Neuman Aluminium Raufoss Technology, Raufoss

Statement of Accounts

As an option the funding and cost for each partner may be presented and also how funding and cost is allocated to the subprojects in the centre. All figures in 1000 NOK.

Funding	2016
The Research Council	11.060
The Host Institution (Sintef Raufoss Manufacturing)	556
Research Partners*	4.233
Enterprise Partners*	8.418
Total	**24.267**

Costs	
The Host Institution (Sintef Raufoss Manufacturing)	5.957
Research Partners	12.964
Enterprise Partners	5.346
Public Partners	
Equipment	
Total	**24.267**

Enterprise partners*

Brødrene Aa (private sector)
Benteler (private sector)
Ekornes (private sector)
GKN (private sector)
Hexagon (private sector)
Kongsberg Automotive (private sector)
Mjøs Metallvarefabrikk (private sector)
Nammo (private sector)
Norsk Hydro (private sector)
Plastal (private sector)
Plasto (private sector)
Raufoss Technology (private sector)
Rolls Royce Marine (private sector)
Hybond (private sector)
Sandvik Teeness (private sector)

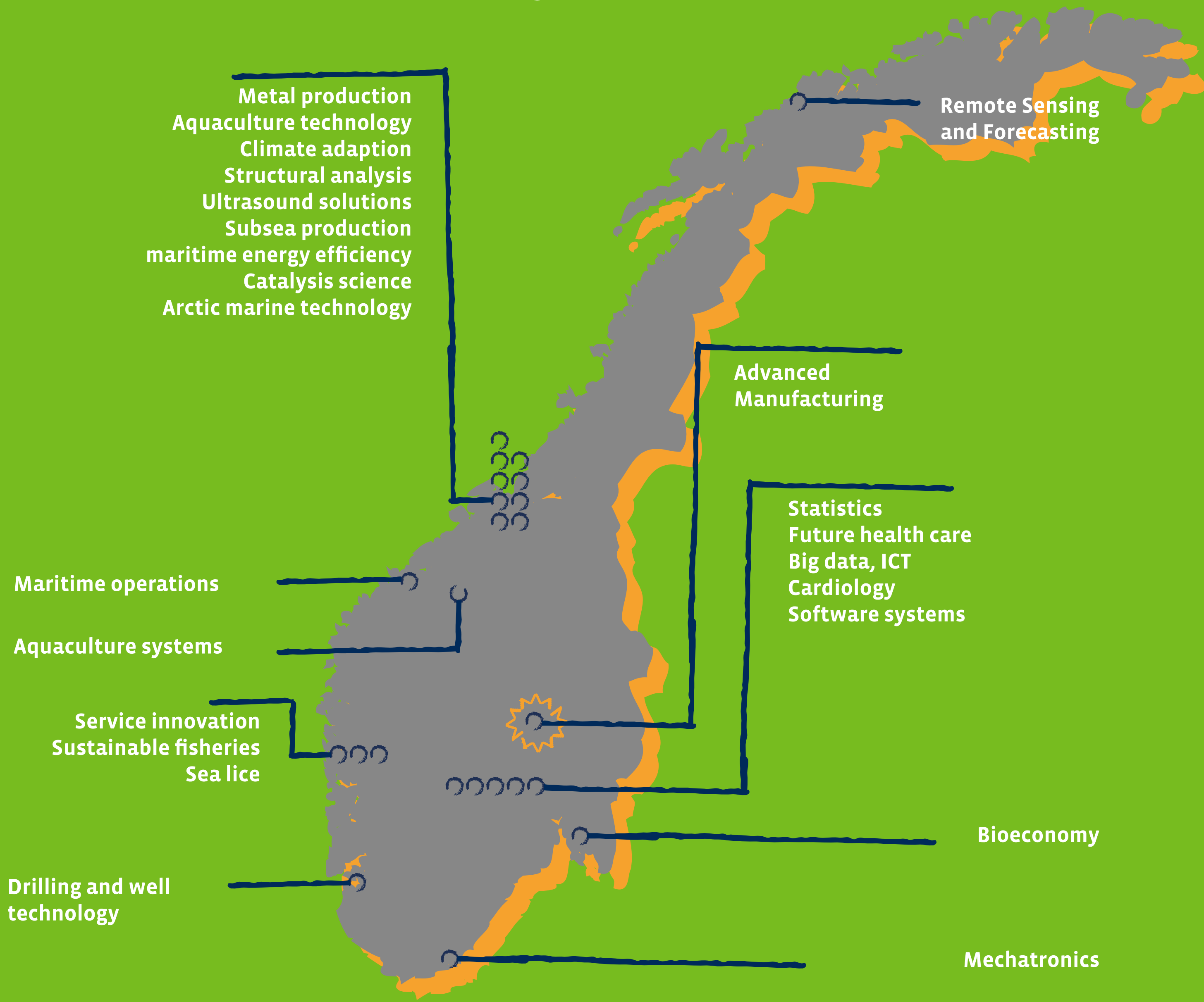
Research Partners*

SINTEF ICT (Research Institute)
SINTEF Material and Chemistry (Research Institute)
SINTEF Technology and Society (Research Institute)
NTNU IME (university)
NTNU SVT (university)
NTNU NT (university)
NTNU GJØVIK (university)


Picture from Hexagon Ragasco, Raufoss

SFI Manufacturing

One of 24 SFIs in Norway



sfi Centre for Research-based Innovation
The Research Council of Norway

manufacturing

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