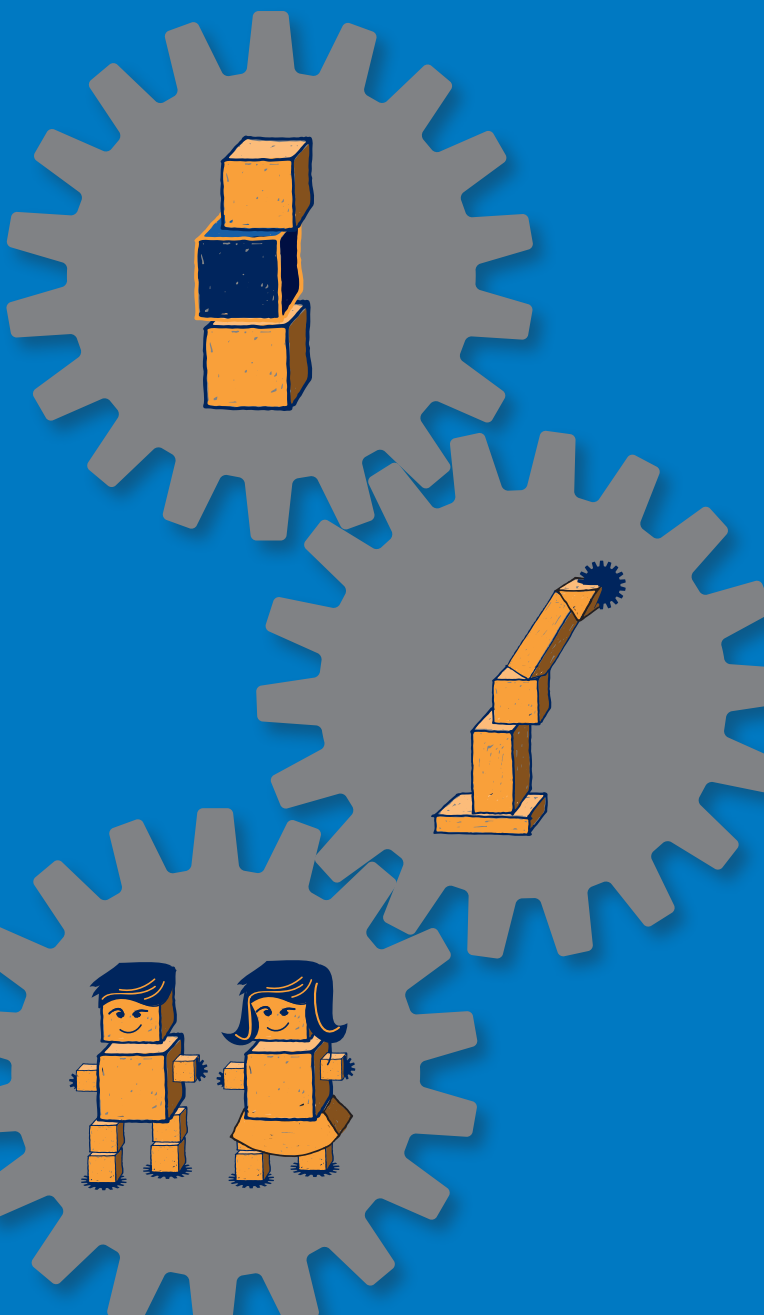
manufacturing

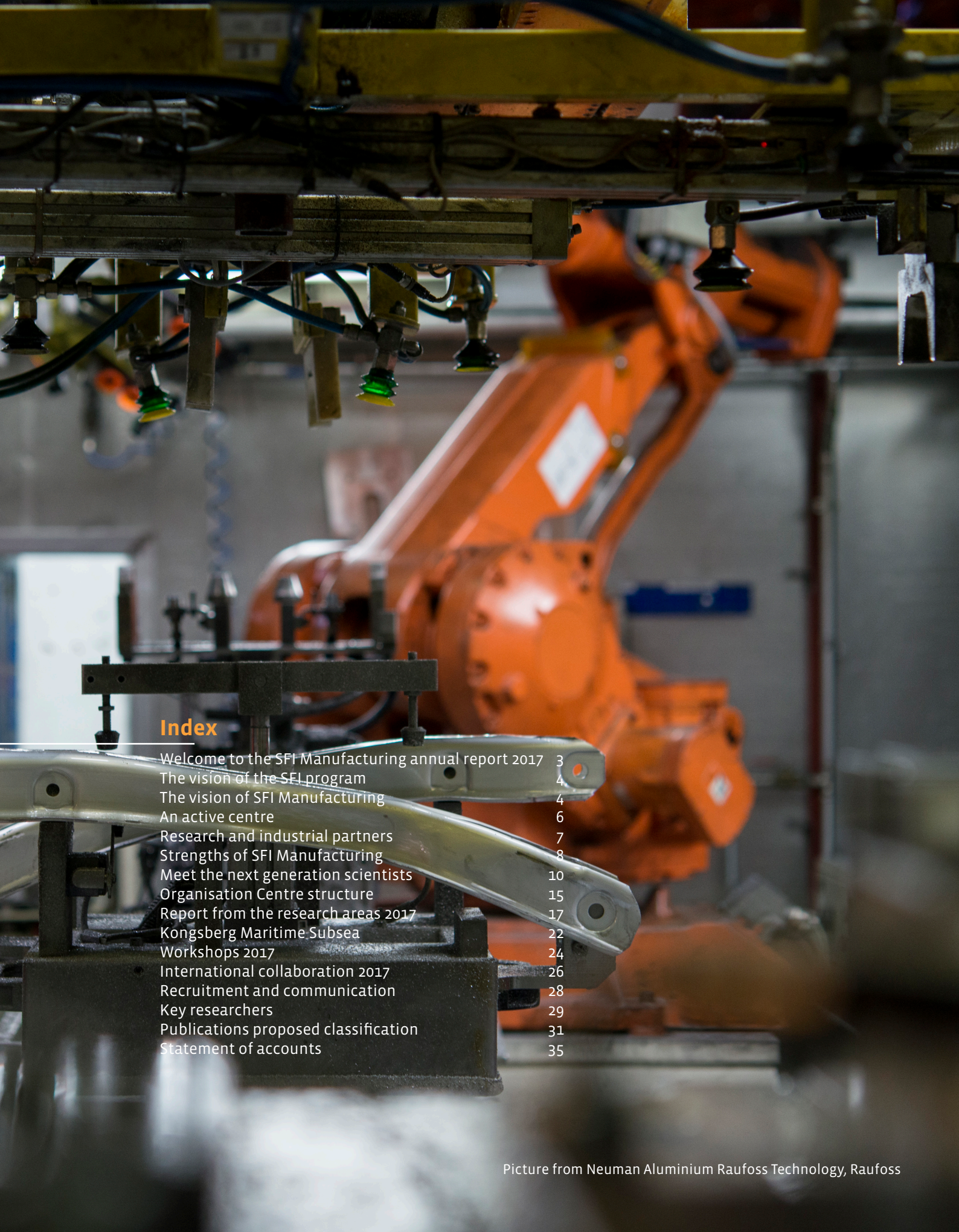
Annual report

2017



sfi = Centre for Research-based Innovation

The Research Council of Norway



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Picture from Neuman Aluminium Raufoss Technology, Raufoss

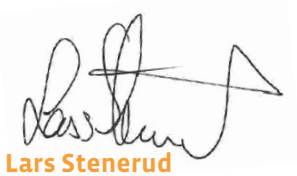
Welcome to the SFI Manufacturing annual report 2017

An important part of the impact of an SFI is the dissemination to other industrial companies within the thematic field of the SFI, as well as the dissemination to other branches. Since the very beginning of SFI Manufacturing, this topic has been discussed, and especially: How can typical small and medium sized enterprises (SMEs) be involved?

Our strategy so far has been to establish spin-off activities that can involve both SFI partners and other partners. During the period 2015-2017, a total number of 21 spin-off IPN projects has been granted support from the Research Council of Norway, representing a total budget of 593 million NOK, and involving 35 industrial partners, in addition to the 15 industrial partners of SFI Manufacturing. Many of these 35 partners are SMEs, which is a successful step in the dissemination strategy. This is strengthened through the continual exchange of generic results during the workshops and one-on-one meetings, as well as the involvement of PhD students funded by SFI Manufacturing within the IPNs projects.

During 2017, two new important initiatives have been established, which both have a basis in SFI Manufacturing: Manufacturing Technology Norwegian Catapult Centre (MTNC) and NCE Raufoss Omstillingsmotor Manufacturing (ROMa). Both are supported by national governmental funding schemes in Norway, and SFI Manufacturing has, especially during the development of the catapult, played an active role in giving input regarding the content and relevance for the Norwegian industry. MTNC has the ambition to develop and demonstrate innovative manufacturing processes and enabling technologies in mini-plants, through collaboration between industry, research and educational partners. ROMa is an initiative that stimulates SMEs to make use of more productive and innovative business models. Hence, ROMa is an important tool for enabling SMEs to take part in for instance MTNC.

Also in the next coming years, SFI Manufacturing will have a close link to MTNC and ROMa, and our ambition is to be the natural knowledge basis during their implementation and development. This implies that we shall deliver state-of-the-art research on the international manufacturing arena, and be an attractive collaboration partner for the global research community on manufacturing, and thereby secure knowledge on the research front for our partners. As Chair of the board of SFI Manufacturing, I feel that our centre is developing into the right direction to fulfil this ambition, and I hope that this annual report of SFI Manufacturing 2017 will give you the same impression.



Lars Stenerud
CEO, Plasto AS
Chair of the board, SFI Manufacturing
Raufoss, 28th of March, 2018

Centre for Research-based Innovation

The Research Council of Norway

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**

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:

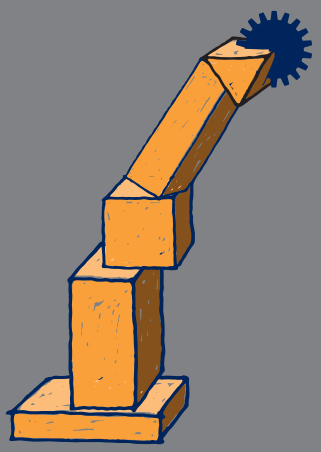
Multi-material products and processes
To develop the ability to optimise material choice, multi-materials geometry and processes simultaneously.

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.

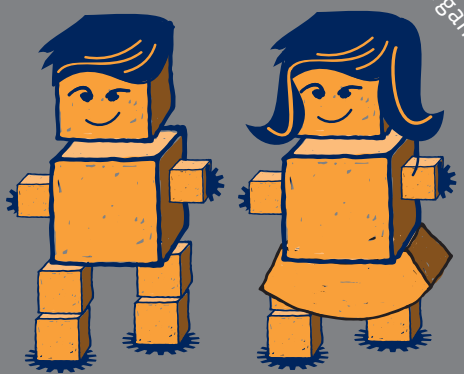
Innovative and sustainable organisations
To develop advanced work systems enabling utilisation of new technology and flexible and automated processes to manufacture sustainable multi-material product solutions.

Multi-Material Products and Processes

Robust and Flexible Automation



Innovative and Sustainable Organisations



Picture from Benteler Aluminium Systems Norway, Raufoss

An active centre

2017 has been a year where we have started to see the results of the activities and scholarships that we have started in the first two years of the centre period. A lot of the results have been presented in workshops, conferences and scientific papers. The table on page 34 shows that the centre is in good progress according to the key performance indicators from our original description of work.

In 2017 we have published 3 newsletters, one for each research area, which have been shared prior to the industrial workshops. In this annual report we have made a summary of the main scientific results and are referring to the newsletters as appendixes available at our website: www.sfimanufacturing.no. It is our intention that this will make our annual report more available for a broader audience.

Our PhD students are now well settled in their positions and within the centre, and we see that the number of scientific publications is increasing. This is an important delivery for SFI Manufacturing, and the acceptance of scientific papers with referee is an excellent way to measure the originality and quality of the research performed within SFI Manufacturing. Scientific publications are also a result of the research besides the PhD and Postdoc activities, and in this sense, I would like to mention the work of Jesper Friis et al. from SINTEF Industry: "The atomic simulation environment - a Python library for working with atoms", which was selected as highlight of the month in Psi-k in January 2017, and one of the official highlights of the year of Journal of Physics in 2017.

We have had 3 successful industrial workshops in 2017 hosted by Rolls-Royce in Ulsteinvik, Nammo Raufoss in Raufoss and Brødrene Aa in Hyen. I would like to express my sincere thanks to the hosts for their hospitality and effort to contribute to make this one of the most important arenas for sharing and networking within SFI Manufacturing. Furthermore, I would also like to thank all participants of these workshops for their active participation. Your involvement is absolutely necessary for the workshop concept, and we use your feedback in the Questback reports to improve the concept continually.

Finally, I would like to use the opportunity to welcome Kongsberg Maritime as a new industrial partner in SFI Manufacturing. The company entered the centre in the autumn of 2017, but has participated as a guest in the previous workshops. With Kongsberg Maritime we also have a partner that has competence in manufacturing of electronics for demanding applications, and the company is a valuable addition to the existing consortium. We are looking forward to further develop SFI Manufacturing with Kongsberg Maritime as an active partner.

Sverre Gulbrandsen-Dahl
Raufoss, 28th of March, 2018

Research and industrial partners

NTNU

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

SINTEF Raufoss manufacturing

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

SINTEF

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

BENTELER

PLASTO

SANDVIK Coromant

KONGSBERG AUTOMOTIVE

EKORNES

Nammo

NEUMAN ALUMINIUM

HYDRO

GKN AEROSPACE

Rolls-Royce

MJØS METALLVAREFABRIKK AS

HEXAGON RAGASCO

HyBond a bonding revolution

BRØDRENE AA

KONGSBERG

Strengths of SFI Manufacturing

In the past few years, SFI Manufacturing has established itself as the leading cross-disciplinary centre for research based innovation for competitive high value manufacturing in Norway. The centre is described as a birthplace for new projects, as well as a gate to information, expertise, partnership, contacts and influence on politics related to manufacturing research. Influence on politics? Yes. In the section below we will elucidate this, as well as the centre's other strengths.

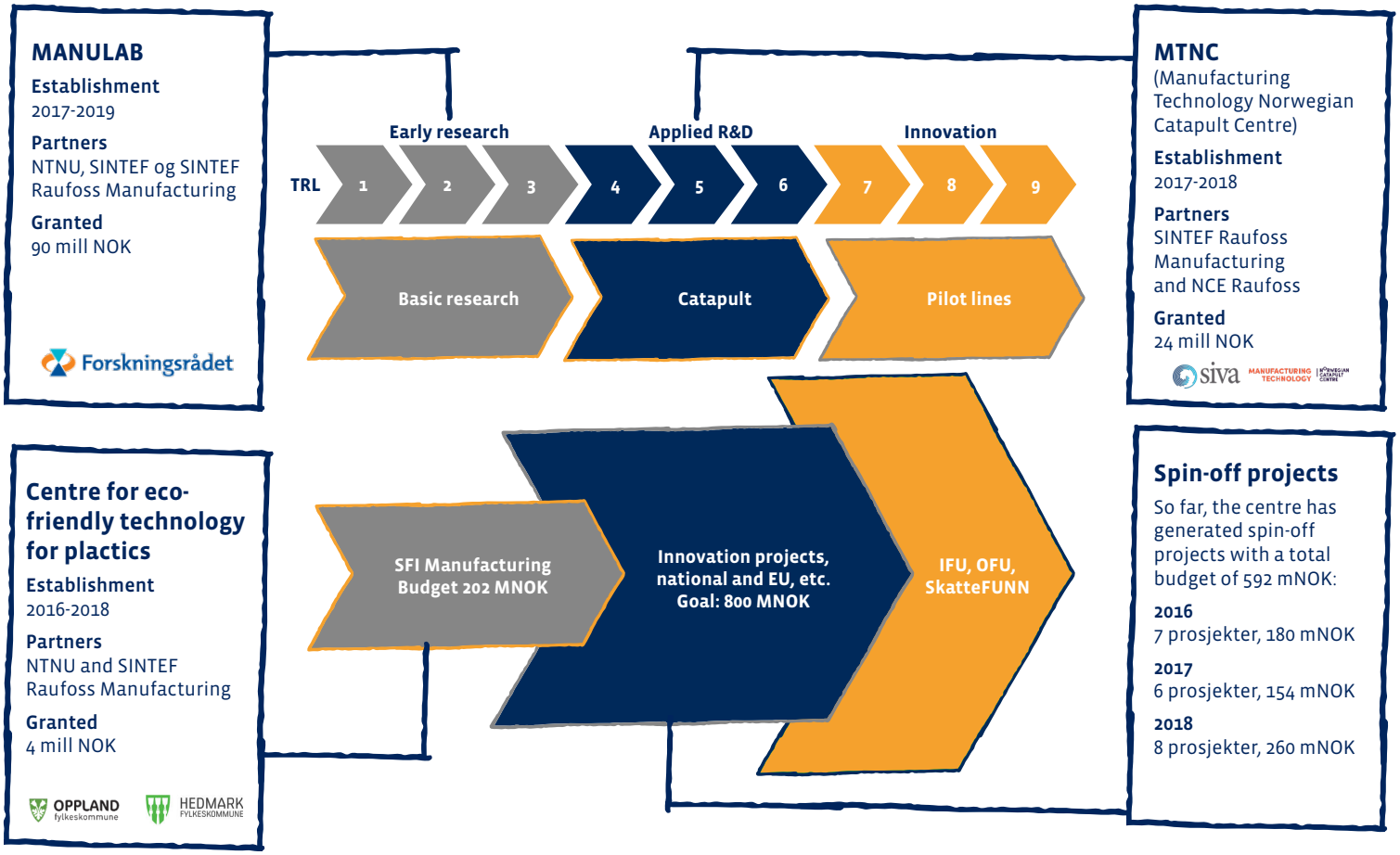
Birthplace for new projects
SFI Manufacturing is described as "a birthplace for new projects": An incubator for spin-off projects, such as user driven innovation projects (supported by the Research Council of Norway) and collaborative projects (supported by the European Commission). The centre's ambition is to generate a total portfolio of spin-off projects, with a total budget of 800 million NOK, providing a research activity of 1 billion NOK over the 8-year centre period. This ambition is associated with expectations on the centre's research portfolio to:

- Provide an attractive ground for international collaboration
- Bring research and innovation closer to the core business of each partner, due to smaller innovation project consortiums and stricter IPR regulations
- Further strengthen the SFI as an attractive arena for sharing of generic early research

In the past few years, we have developed a process model for the development and implementation of new project ideas, to ensure the complementarity and relevance of the research throughout the centre's period. This process model is divided into 3 phases:

- The collection of ideas and needs for new projects, organized through various centre activities, e.g. the 1-on-1 meetings and workshops (three times a year)
- The development of ideas to project initiatives, individually handled after workshops, and supported with in-kind resources of the partners
- Interaction and sharing between projects, arranged through the centre's various arenas

So far, the centre has generated spin-off projects with a total budget of 592 million NOK. In addition, the centre's budget has increased to 202 million NOK based on growth of the consortium and additional funding. Already after 2,5 years of operation, we have succeeded to establish a total activity exceeding 80% of the ambition of the 8-year period. The total activity of



the centre, which means the activity within SFI Manufacturing plus related user driven innovation projects and related spin-off projects, is over 1 milliard NOK.

Designing the manufacturing industry

Nowadays, the potential competitiveness of Norwegian manufacturing companies lies in their ability to efficiently utilize cross-functional knowledge and technology. Combining the fields of advanced materials, flexible and cost-effective production, and innovative and sustainable organisations, SFI Manufacturing aims to strengthen the Norwegian manufacturing companies' ability to innovate. This by doing research on multi-material product solutions, flexible automated manufacturing and organisational processes. The centre has a consortium of both research and industrial partners, and these industrial partners are leading companies in their niches, both nationally and internationally. We are thrilled by the thought that "the national team of manufacturing companies in Norway" has joined SFI Manufacturing, and this is something we allow ourselves to be proud of.

Companies joining SFI Manufacturing are given access to information, expertise, partnership and new contacts. By working together with the other companies in the consortium, they get an insight into how these companies have organised their work, and they can learn from and build on it, and in the end, create a strengthened position in the market they are operating in.

In addition to this, SFI Manufacturing is also platform for exerting influence on politics related to manufacturing research. In the past few years, we have been part of the application processes for 1) MANULAB, a national research infrastructure for manufacturing companies that is open to all researchers from all institutes and companies in Norway, 2) Norwegian Catapult Centre at Raufoss, a centre where industrial companies have the possibility to test new technologies and solutions, and 3) "Omstillingsmotoren", a national and open arena for learning and innovation across different industries in Norway, with a focus on Lean through the project "Produktivitetsspranget". We are proud of having contributed to the success of these applications, they were all accepted, and we are seeing this as an indicator of the centre's ability to structure and shape research related politics in Norway. By contributions like these, the centre is able to influence the future design of the Norwegian manufacturing industry.

Meet the next generation scientists

PhD candidates and postdoctoral researchers are essential resources within SFI Manufacturing. Siri Marthe, Tina, Muhammad, Mathias, Henrik, Marit and Vetle started their PhD studies in 2015/2016, and Linn, Signe, Eirik and Anna-Maria started in 2017. They will introduce themselves on the next pages, and will tell you a bit more about their background and the research they are doing.

Siri Marthe Arbo
New ways of joining steel and aluminium together
My name is Siri Marthe and I started my PhD in August 2015. Spring 2015 I finished my master degree in material science at NTNU, where I specialized in physical metallurgy. 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.

Tina Bergh
The interface between joined aluminium and steel
I am Tina and I started my PhD in the fall of 2016. My background is from the nanotechnology study programme at NTNU. During my master, I used transmission electron microscopy (TEM) to study silicon carbide from Saint-Gobain in Lillesand. In my PhD I will characterize the interface in joined materials, first and foremost joined aluminium and steel. 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.

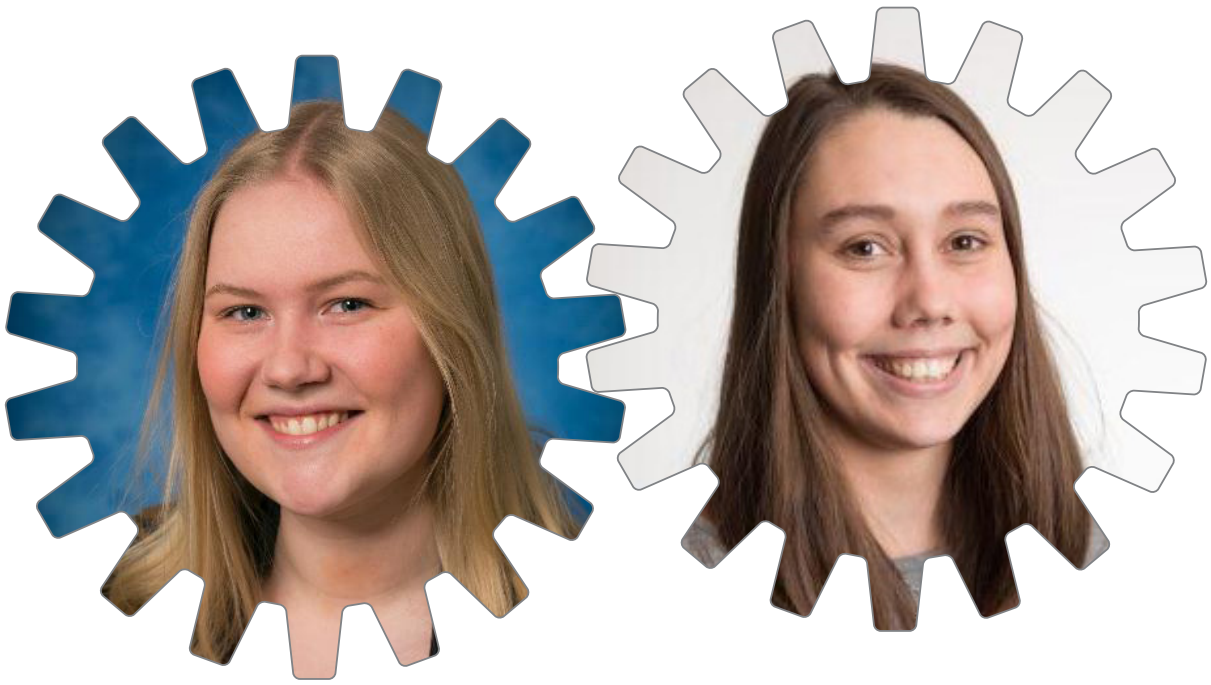
Muhammad Zeeshan Khalid
Atomistic modelling of multi-material interfaces
I am Muhammad and I started my PhD in October 2016. I did my Master in Applied Physics from University of engineering and technology, Pakistan. My master thesis focused on the mathematical modelling of high temperature thermal energy storage system for solar thermal power plant applications. During my PhD, I will focus on atomistic modelling of multi-material interfaces. My project will provide information about the nanostructure changing mechanisms during the welding of dissimilar materials.

Mathias Hauan Arbo
Robots interacting with flexible materials and objects
My name is Mathias and I started my PhD in the fall of 2015. 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 will look at assembly with articulated robots under uncertainty. My PhD focuses on robotic assembly and sensor fusion.

Henrik Brynthe Lund
Industrial networks, learning systems and cluster development
My name is Henrik and I started my PhD in August 2016. I finished my combined geography and teacher master's degree at the Department of Geography at NTNU in 2014. The topic of my master thesis was urban development. During my PhD, I will focus on industrial networks, learning systems and cluster development. 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 level.

Marit Moe Bjørnbet
LCA as a tool to facilitate the transition towards a green economy
I am Marit and I started my PhD in August 2016. My background is a master's degree in nanotechnology, with a specialization on materials, energy and industrial ecology. During my PhD, I will focus on life cycle assessments (LCA) as a management tool to facilitate the transition towards a green economy. My idea is that life cycle assessments can be utilized to develop tools, preparing the Norwegian manufacturing industry for the green shift, integrating environmental management into core business activities.

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



Linn Danielsen Evjemo
Large-scale, robotized additive manufacturing

My name is Linn Danielsen Evjemo, and I started my PhD work in December 2016. I will focus on large-scale, robotized additive manufacturing (AM) using industrial robot arms and cold metal transfer welding (CMT). I will try to see if it is possible to combine the large workspace of an industrial robot arm with the flexibility and relative affordability of traditional AM methods. More specifically, the aim is to deposit metal along a given trajectory, building the final metal structure gradually as the manipulator tracks this reference trajectory.

Combining CMT welding with robotised AM has the potential to build metal structures from scratch, not just perform robotised welding. This technology could also be useful in repair work, for example when having to close holes and tears in metal surfaces on ships or other large structures. AM by robot manipulator would free us from having to build structures layer by layer, which is the most common approach for traditional AM methods. This could allow us to print larger, and more complex geometries. Several robot manipulators could potentially also work simultaneously, with different materials. Images from proof-of-concept experiment using robot manipulator and a caulking gun.

Signe Moe
Set-based control of robotic systems and machine learning for manufacturing

My name is Signe Moe and I started my postdoc on the 1st of January, 2017. In 2013, I completed my master's degree at the department of engineering cybernetics at NTNU in Trondheim, and from there I embarked on a PhD at the same department.

My master thesis is titled "Path Following of Underactuated Marine Vessels in the Presence of Ocean Currents", a topic which I continued working on during my PhD. In addition, I developed a control method regarding set-based control of robotic systems. This highly generic and adaptable method may be applied to any robotic system, and for my postdoc I am working on extending set-based theory to industrial needs and developing a general, autonomous and user-friendly control system which will allow the user to easily define the tasks of the robotic system in a prioritized order. Set-based theory is especially suited for tasks such as collision avoidance and orientation control. I will also collaborate with PhD-candidate Linn Danielsen Evjemo on 3D-printing and additive manufacturing using robots.

Furthermore, machine learning and artificial intelligence are research areas that are currently making huge progress within a variety of applications, manufacturing included. I will also be involved in a project related to automatic bin picking by robot, where the control system is based on a 3D-camera and a neural network. Such networks may be used in combination with traditional control systems and represent a very large potential for increased autonomy.

Eirik Bådsvik Hamre Korsen
Aligning performance management across organisations
I am Eirik Bådsvik Hamre Korsen, and started my PhD in January 2017. After working more than ten years as a consultant within performance management, I have now the possibility to spend time and study the underling dynamics between how people in an organisation understand the management system.

In an organisation, we find number of management tools and systems, such as Balanced Scorecard with KPI reporting, quality system with deviation reporting, budgets with financial reporting, Lean with daily reporting of improvements initiatives, and so on. How are these systems aligned and do they create value for the organisation?

In my research, I will do a qualitative case study of a limited number of manufacturing organisations participating in SFI Manufacturing. In 2017, I started to look at how different tools like Balanced Scorecard, often driven from finance, and Hoshin Kanri, used in operations, can together contribute to the strategy implementation. I also started to look at how external audits for quality standards influence the management system.

In the upcoming analysis, I will try to understand how the management system interacts with the design of organisations, and their management and operational processes. I will also look at the how we define and use information across the organisation, and the impact of different ICT tools such as ERP and other reporting and analytical systems.

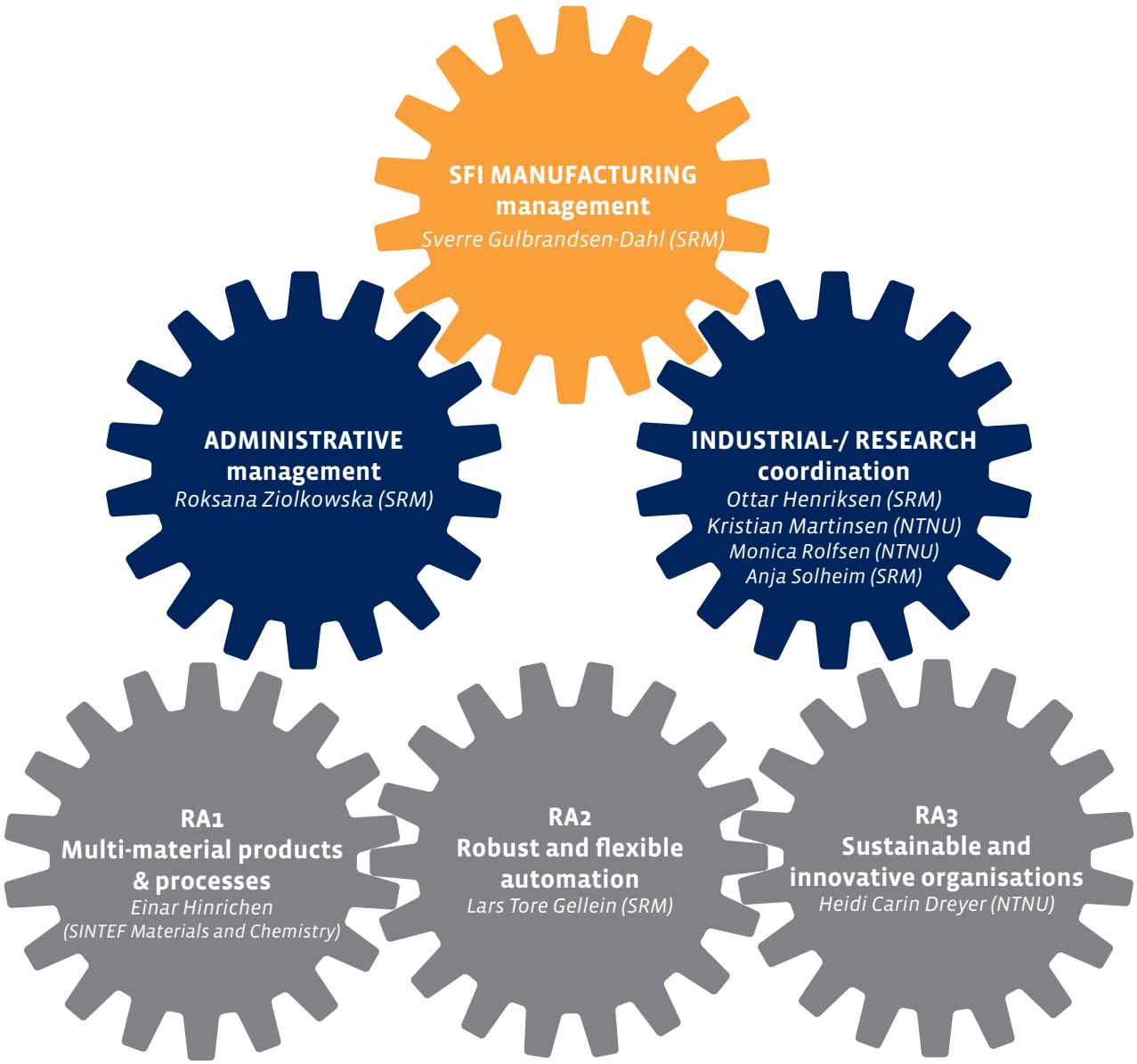
Anna-Maria Persson
Mechanical properties of thermoplastic elastomers
I am Anna-Maria Persson and I started my PhD at the 1st of February, 2017. My study is related to the field of mechanical properties of thermoplastic elastomers in injection moulded components. My PhD is a SINTEF Material and Chemistry funded industrial PhD, associated to SFI Manufacturing and admitted by NTNU.

I started my PhD with experimental studies of the elasto-visco-plastic response of a novel but commercialised thermoplastic elastomer prepared by vulcanization (TPV). One significant aspect is sample preparation and geometry, and another is handling and treating the experimental data (strain) output. As the experimental methodology in itself is a target for the PhD, a selected few more materials will be studied subsequently.

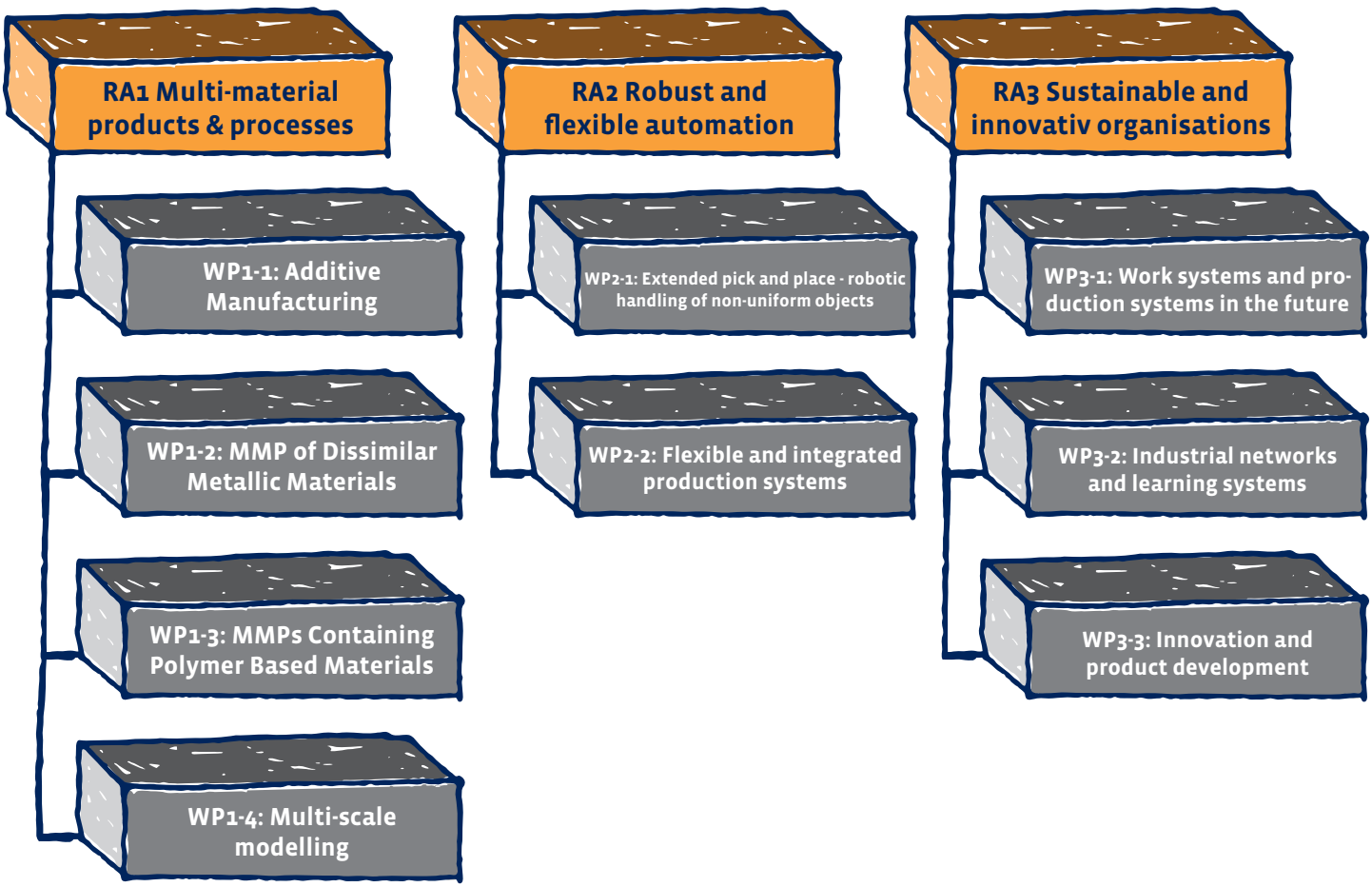
In parallel, materials models are intended calibrated and verified, primarily for a selection of published material models, including behavioural features of non-linear nature and time-temperature dependency. I am currently immerged in 10-15 years of publications of rubber and elastomer material models. One major challenge is to adequately describe the complex mechanical response with a model also suitable for industrial use.

During my PhD, I will have a close dialogue with Kongsberg Automotive's Couplings division to get the valuable industrial view feedback. To develop a response on how an integrated, free-geometry elastomer sealing can compete with a conventional o-ring in a demanding application, the material models will be used in simulation of two component injection moulded sealings. After this, the elastomer sealing performance needs to be related to the performance of a conventional rubber sealing.

Organisation
Centre structure



Organisation
Centre structure



Report from the research areas 2017

The potential competitiveness of Norwegian manufacturing companies lies in their ability to efficiently utilize knowledge and technology, by combining advanced materials, flexible and cost-effective production and an innovative and sustainable organisation. SFI Manufacturing builds on existing national capabilities and aims to strengthen the Norwegian manufacturing companies' ability to innovate, by doing research on multi-material product solutions, flexible automated manufacturing and organisational processes. In this part of the annual report, we will give an insight into the research that has been done in 2017. In the newsletters, which are available on the website www.sfimanufacturing.no, more background information can be found.

Multi-Material Products and Processes

The research area Multi-Material Products and Processes concerns the design and manufacturing processes of multi-material products, and the overall objective is to develop the ability to optimize material choice, multi-materials product design and processing simultaneously.

In 2017 we have studied different processes of joining dissimilar materials, as well as additive manufacturing of metals and polymers. Among various dissimilar material combinations, the joining of aluminium to steel has had extensive attention, both scientifically and in industry, due to the increasing relevance of lightweight solutions. Within SFI Manufacturing we have been tracking the state-of-the-art joining technologies and have identified six different approaches of joining these two metals. Within the SFI we have decide to work with three of the most promising technologies for joining these two metals. One PhD candidate has started investigating the cold pressure welding process for joining aluminium to steel, and two PhD candidates are focusing on material structure and properties in the vicinity of the interface, using advanced material characterisation methods and atomistic modelling respectively. The other two joining processes we have started to investigate are cold metal transfer and a hybrid metal extrusion and bonding technology patented by the partner company HyBond.

In addition to more conventional processes of producing multi-material products, we have in SFI Manufacturing a special focus on additive manufacturing as an important enabling production technology alone, or in combination with traditional production methods like welding, forging and casting. In order to strengthen knowledge on the Directed Energy Deposition technology, an additive manufacturing process in which focused thermal energy is used to fuse materials by melting as they are being

deposited. One PhD candidate together with a SINTEF researcher has used wire and arc additive manufacturing, a Directed Energy Deposition technology, to make an aluminum demonstrator, see Figure 1. This demonstration study is also a good example of cross-disciplinary collaboration (RA1 and RA2) in SFI Manufacturing. SFI Manufacturing invited all partners, students and professors related to this field to a lecture at Gløshaugen in the beginning of 2017. Furthermore, SFI Manufacturing has together with NTNU and Ecole Centrale de Lyon contributed on analytic and numerical prediction models of additive manufacturing processes.

Figure 1. Wire and arc additive manufacturing.

The global trend towards circular economical thinking will have a strong influence on product design and optimal choice of materials, taking the concept of Design-for-Disassembly and recycling into account. Sustainability in material selection and production processes, including high recyclability of materials in multi-material solutions, will therefore become a focus area of SFI Manufacturing in the coming years.

Case: Joining aluminium to steel
Making the impossible possible

Multi-material products made by joining aluminium to steel have attracted extensive attention both scientifically and practically due to increasing interests of sustainable, lightweight and high-performance products. One example of industrial aluminium-steel products is the crash management system, where an aluminium crash box is connected to a steel bracket plate. However, joining aluminium to steel is easier said than done. That is because they literally do not mix well with each other, especially when the two materials get hot. The biggest challenge of joining aluminium to steel is the formation of brittle intermetallic compounds. Controlling these intermetallic compounds is the key to producing a sound joint.

In SFI Manufacturing we aim to tackle the challenge of joining aluminium to steel through a multiscale approach, i.e., to understand the joining mechanisms at macroscale, mesoscale, microscale and nanoscale. Moreover, it is also important to establish the link between different length scales to obtain a complete understanding of the joining mechanisms. Both multiscale modelling and multiscale material characterization is being applied in these studies.

PhD students Siri Marthe Arbo, Tina Bergh and Muhammad Zeeshan Khalid are investigating the same research topic, i.e., joining aluminium to steel, with focuses on different length scale. Siri Marthe applies a "top-down approach", using the cold roll bonding technology to study the effect of different factors on the type and quantity of Al-Fe intermetallic phases, see Figure 2. Muhammad uses a "bottom-up approach" to gain insight in the details of the bonding properties of Al-Fe joint through density functional theory and atomic scale simulations. And Tina tries to establish a "handshaking region" to bridge the knowledge generated at different scales using advanced material characterization tools. More information about these studies can be found in the SFI Manufacturing Newsletter 3, which is available on sfimanufacturing.no.

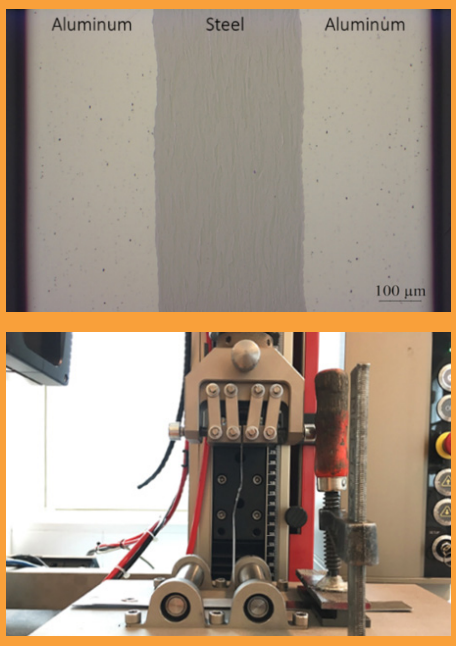


Figure 2. Three layered composite sheets produced by cold roll bonding.

Robust and Flexible Automation

The research area Robust and Flexible Automation concerns new ways of automation and robotics in manufacturing systems. The overall objective is to further develop and link novel technologies and methodologies within automation to support innovation processes and advanced work systems in manufacturing industries.

In 2017 further research has been done on grasping using deep learning, 3D point clouds for object localization and simulation for developing and virtual testing of production systems. Pose estimation of objects is one of the key problems for the automatic-grasping task of robotics. Within SFI Manufacturing, a long-term goal is to create a generic system for grasping 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, and can automatically extract high-level, complex abstractions from images. Instead of learning a traditional machine vision system each new object it should handle, a deep learning algorithm can be trained for

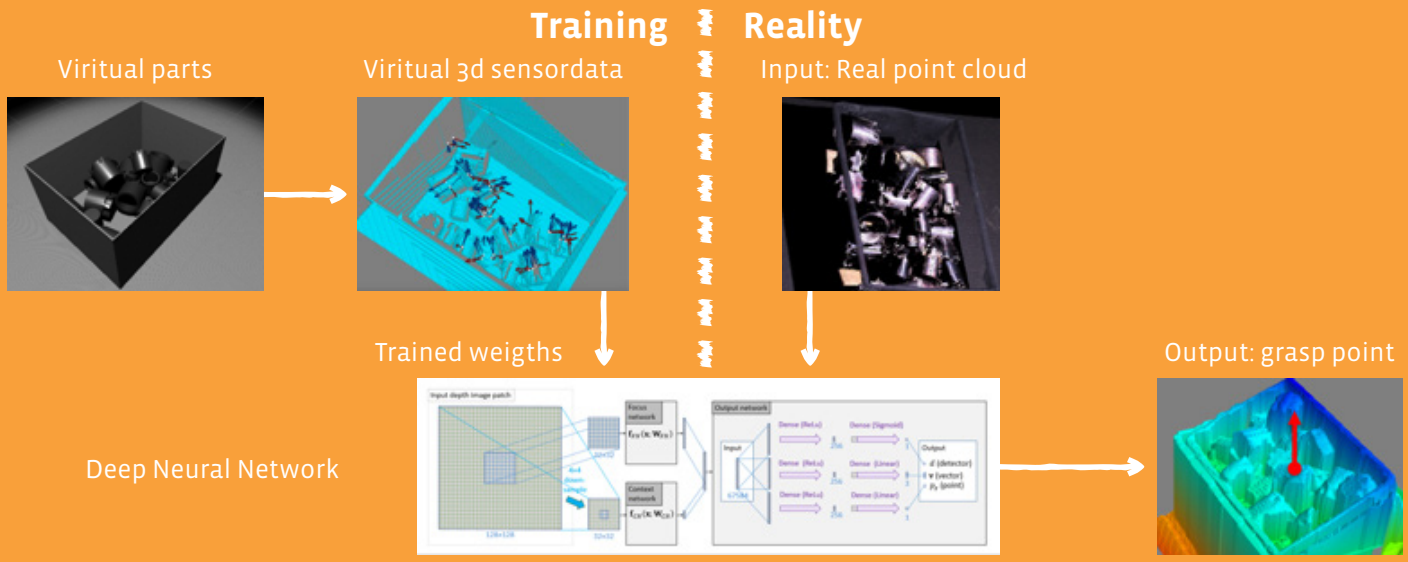


Figure 3. Deep neural network trained from virtual data to find a potential point from grasping.

handling a large specter of objects and objects in cluttered scenes. These strengths make deep learning an important tool to achieve a more generic system for grasping.

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 localization and makes inspection of more unconstrained scenes possible. In SFI Manufacturing we have two approaches to 3D vision. We work on developing new algorithms to locate objects in point clouds, and we use these algorithms as well as existing methods in available industrial vision systems to solve generic industrial issues, like bin-picking.

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. As an example, SFI Manufacturing has formulated research challenges related to a method for near simultaneous execution of a physical and a simulated environment. Within this topic, SFI researchers contributed to an application for the user-driven innovation project DAMP - Fast development of new automated manufacturing processes through digital integration and testing - that was approved for funding in 2017.

Case: Automatic grasping using Deep Learning

Vision-based grasping of objects is well-known as an approach that enables more flexible automation, as opposed to solutions based on fixed setups with an exact position of the object. However, picking objects from a bin poses several challenges from a computer vision point of view. These challenges include the fact that the parts are partially occluding each other, have random position and orientation, may have reflective surfaces, and may be of varied sizes and shapes not known in advance. Whereas the problem of picking a non-reflective object with a priori known CAD model is largely solved, we have established a vision-based robotic grasping system, which can handle several types of highly reflective objects. The solution is based on training a deep neural network on virtual 3D sensor data of virtual parts, in order to learn where on the surface the object should be grasped by the robot. Figure 3 illustrates this concept. The algorithm has been tested in a physical experiment with a 3D sensor and robot manipulator with vacuum gripper, as seen in Figure 4, and the results are promising.

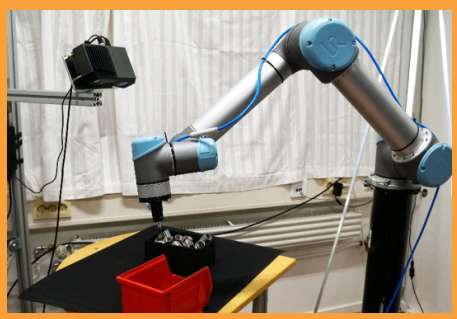


Figure 4. Experimental setup with 3D sensor and robot manipulator with vacuum gripper.

SINTEF Digital has lead this research so far, but in 2018 the research will also be supported by Postdoc Signe Moe at NTNU. In 2018 the goal is to improve the results by 1) attaching the 3D sensor to the robot, which will allow to capture images from different positions and orientations, and 2) improving the algorithm by also make it learn from physical experiments.

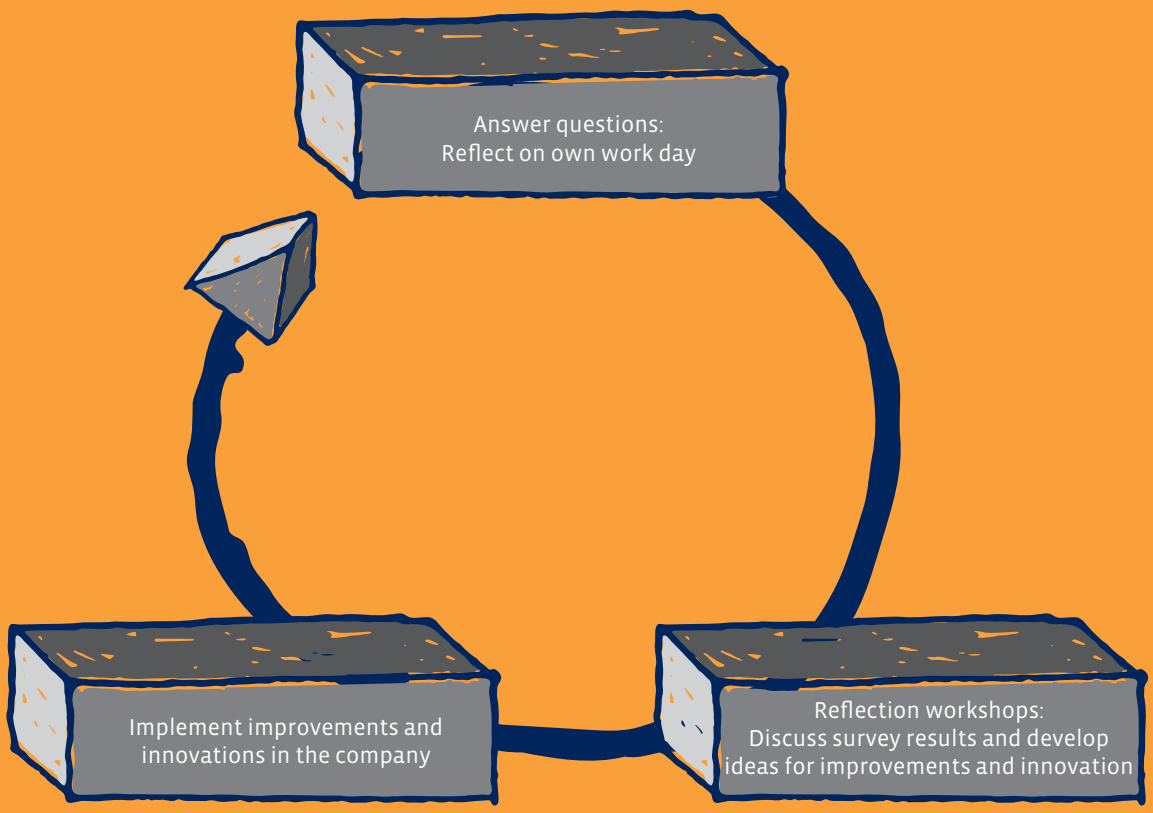


Figure 5. Model for implementing the Maturity Mapping.

Sustainable and Innovative Organisations

At the moment, two overall trends in society are digitalization and sustainability. Digitalization will influence the everyday life of employees and management in manufacturing companies: The interaction with technology, how and who are making decisions, the ability to simulate changes in production technology before physically implementing these changes, and a large amount of generated data will influence the development of new products and services. Similarly, a greener business development will affect the entire organisation: Manufacturing processes, development of products and production technology, and co-creation with external bodies.

The research area Sustainable and Innovative Organisations concerns the human and organisational aspects of advanced manufacturing companies. The overall objective is to develop knowledge and solutions for advanced work systems that are able to utilize new technology and flexible and automated processes to manufacture sustainable multi-material products. In 2017 we have focused on developing the SFI Manufacturing Maturity Mapping tool, a survey that can be used in order to reflect on organisations' status and level of maturity when it comes to applying and developing new technologies. In addition, research has been done on organisation 4.0, innovation and product development and industrial clusters and learning systems.

Companies are embedded in specific regional worlds of production (clusters), as well as in wider (potentially global) networks. Cluster firms ought to be exposed to external impulses and knowledge sources in order to avoid situations of lock-in to specific technological trajectories. Interesting clusters seem to develop differently, even in quite similar cultural and business contexts. In 2017 we have started research on how to understand the development of two important Norwegian clusters, Raufoss and Kongsberg. In studying the development of industrial networks and learning systems, important topics include organisations' absorptive and innovative capacity, the role of gatekeepers and inter-organisational collaboration locally and beyond.

Case: SFI Manufacturing Maturity Mapping

How mature are manufacturing companies in Norway to meet the challenges and opportunities ahead: Competitive production in a high cost country, digitalization and sustaina-

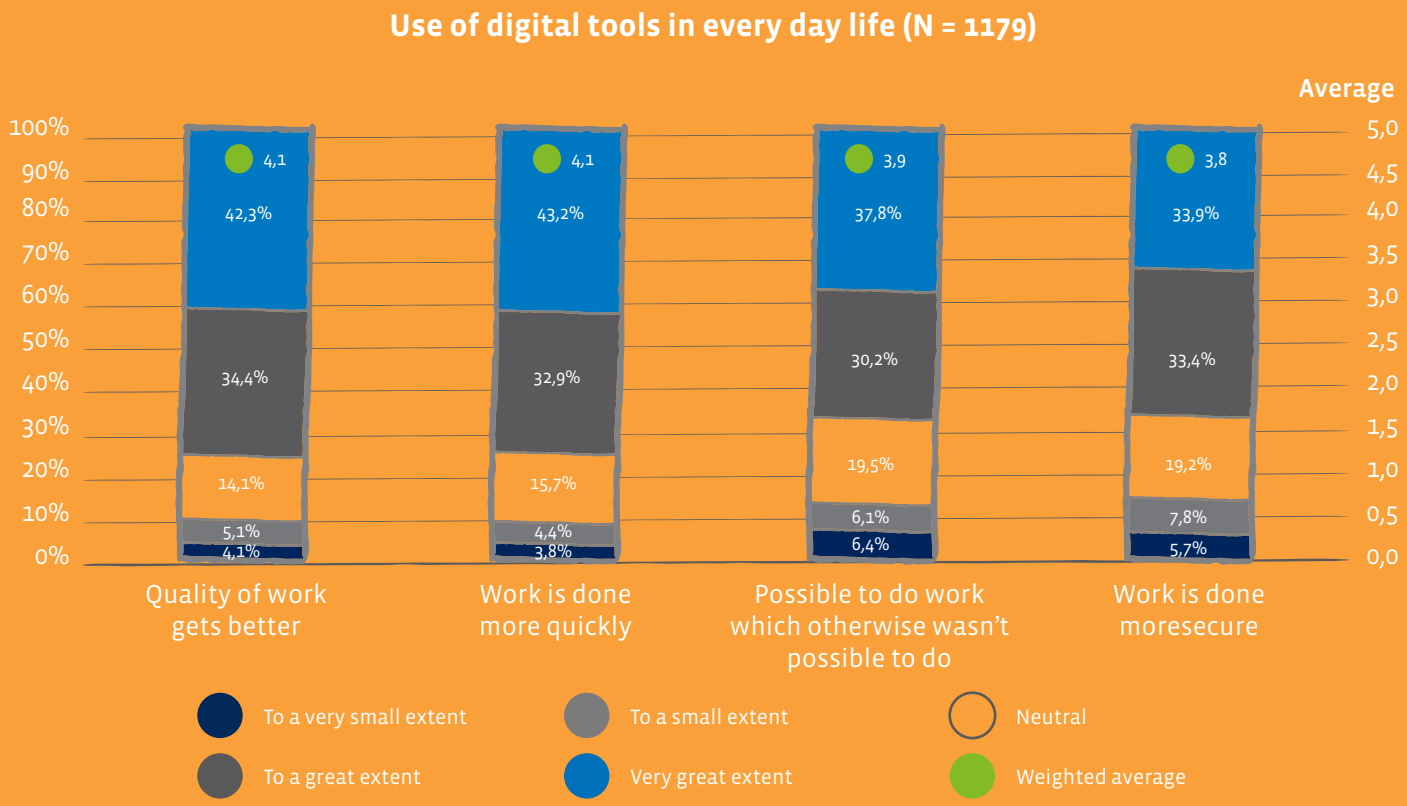


Figure 6. Perceived gains from digital tools.

ble development of the society? SFI Manufacturing Maturity Mapping will attempt to answer this question through a survey distributed to co-workers in the SFI Manufacturing companies and a series of follow-up workshops with each individual company.

By mapping companies with respect to state-of-art and international trends on digitalization and sustainability, the mapping will provide an overall understanding of weaknesses and strengths, as well as characteristics of Norwegian manufacturing companies. The plan is to repeat the survey during the lifetime of the center, and to monitor and support the development or the maturity of the companies. The first survey was launched in May 2017 and continued throughout the summer. The survey was distributed among employees, with or without management responsibility, involved in production, product and process development or other functions. In total, 10 SFI Manufacturing companies participated, and 1183 respondents completed the survey.

Preliminary results of the mapping regarding digitalization show that Norwegian manufacturing companies have had a good start. Digital tools such as laptops and smartphones have widespread use throughout the companies. Production information systems are important for most of the employees, but of course not all work with such tools. Tools like scanners and 3D printers are used significantly, while augmented reality, voice control and smart watches are used limitedly. We also found that the employees perceived the use of digital tools as valuable, because it enhances their productivity:

With regard to the companies' product and process development, results show that the companies work with both short-term improvements and strategic development projects, while there is less focus on ground research. The mapping demonstrates the complexity of product development as well, in multi-material products, advanced production systems and sustainability, among others. Results show that the development work becomes less complex when the involved employees are working cooperatively. The mapping shows that today's product development is a cooperative effort, with developers reaching out to colleagues, customers and suppliers in order to create a new product that meets the market demands.

Kongsberg Maritime Subsea awarded Norwegian Lean Organisation 2017

In 2017, Kongsberg Maritime Subsea has been awarded Norwegian Lean Organisation of the year. The SFI Manufacturing partner received the award during last year's Lean Conference in Fornebu.

The purpose of the prize is to create a stage for organisations leading in structural improvement work in Norway, both to recognize them and to learn from them. The four finalists DNB Livsforsikring, Kongsberg Maritime Subsea, Statoil Sture & Kollsnes and Stena Recycling were all praised for their structural work on improvements, good results so far and the high involvement among employees.

Kongsberg Maritime Subsea has been chosen as winner because of its success in applying Lean in a complicated and complex production process. The organisation's work on developing Lean competence and focus among its subcontractors is an example for other companies. Kongsberg Maritime Subsea's Lean work is well rooted internally, among both employees and managers, and is part of the overall strategy of the organisation, which has led to an improved position in a highly competitive market.

Kongsberg Maritime Subsea
Kongsberg Maritime Subsea provides solutions for subsea, such as echo sounders, sonars, autonomous underwater vehicles, subsea positioning and monitoring, acoustic communication and control. Last year, the organisation collaborated with the Norwegian Industrial Laboratory for example, during the mapping of a historically important WWII wreck in Tinnsjøen.

Foto: Sverre Hørnevik

Picture from Brødrene Aa, Hyen

The 2017 workshops

The three SFI Manufacturing workshops are three of the centre's most important cross-functional activities of the year. Researchers from all three research areas and strong industrial profiles from the 32 companies connected to the centre, come together under one roof in engaging discussions of current topics. In 2017, the meetings took place in Sunnmøre with Rolls-Royce as host, in Oppland with Nammo as host, and in Nordfjord with Brødrene Aa as host.

From evening to evening

The, typically between 65 and 80, participants gather in the evening at the carefully chosen site, to become up to date with trends and ongoing activities in the different environments directly connected to or around the SFI, and to have time to chat and rebond during the following dinner and social activities. Some go to bed early after a long day with work and travelling and some end up discussing all too interesting topics until break of day. After a good night sleep and breakfast at the hotel, the participants look forward to the exciting workshop activities, including visit to the hosting company, group discussions and research area presentations.

Visits to Norwegian world class industries

In 2017, we had interesting visits to the production sites of world-leading companies, showing ground-breaking applications of new technology and breath-taking Norwegian environments. During two of the visits, we this year happened to have a special focus on marine applications, luckily enough with boat ride included in one of the visits. In March, the participants were brought to the Rolls-Royce Technology and Training Centre in Ålesund, where they were shown the world's most advanced offshore simulator, and to Ulsteinvik to see parts of the impressive Rolls-Royce propulsion system production. In Raufoss in June, the participants were welcomed into the industrial park and the production facilities of Nammo for ammunition and rocket motor parts, with advanced equipment for e.g. quality measuring and CNC. We met with highly competent operators and technicians, e.g. Tobias Alm, the Norwegian CNC champion and participant in the world's greatest skill competition in Abu Dhabi. In Hyen in October, Brødrene Aa invited us to their

production site, situated on the shore of the stunning fjord, generously letting us board their youngest baby, the beautiful and award-winning hybrid-electric sightseeing vessel "Vision of the Fjords".

Inspirational research briefings

During the workshops of 2017, we have been inspired by the latest discoveries from the research areas of Multi-Material Products and Processes (RA1), Robust and Flexible Automation (RA2) and Innovative and Sustainable Organisations (RA3), during the presentations given by the highly motivated PhD students and postdocs. We have learnt about material joining, advanced modelling, additive manufacturing, Deep Learning, Organisation 4.0, innovation and product development, industrial cluster and learning systems, 3D vision and simulation. In addition to these research topics, the centre also launched the SFI Manufacturing Maturity Mapping, during the workshop in June, as a result of the research area RA3.

Vivid group discussions

With the production site visits and research briefings in mind, the participants take active part in the cross-functional group discussions towards the end of the workshop days. In 2017, these group discussions were focused on solving problems and discussing topics related to the business of the host, combined with the research area in focus: Rolls-Royce and RA2, Nammo and RA3 and Brødrene Aa and RA1. After vivid discussions, the results were presented to the audience, with the host representatives hurriedly taking notes in order to be able to bring back the valid comments to the organisations.

International collaboration 2017

In 2017, SFI Manufacturing has been involved in Manufuture work, as well as the international project INMAN: Intelligent circular manufacturing research and educational collaboration with Japan and India. Three members for the Advisory Board have been recruited as well.

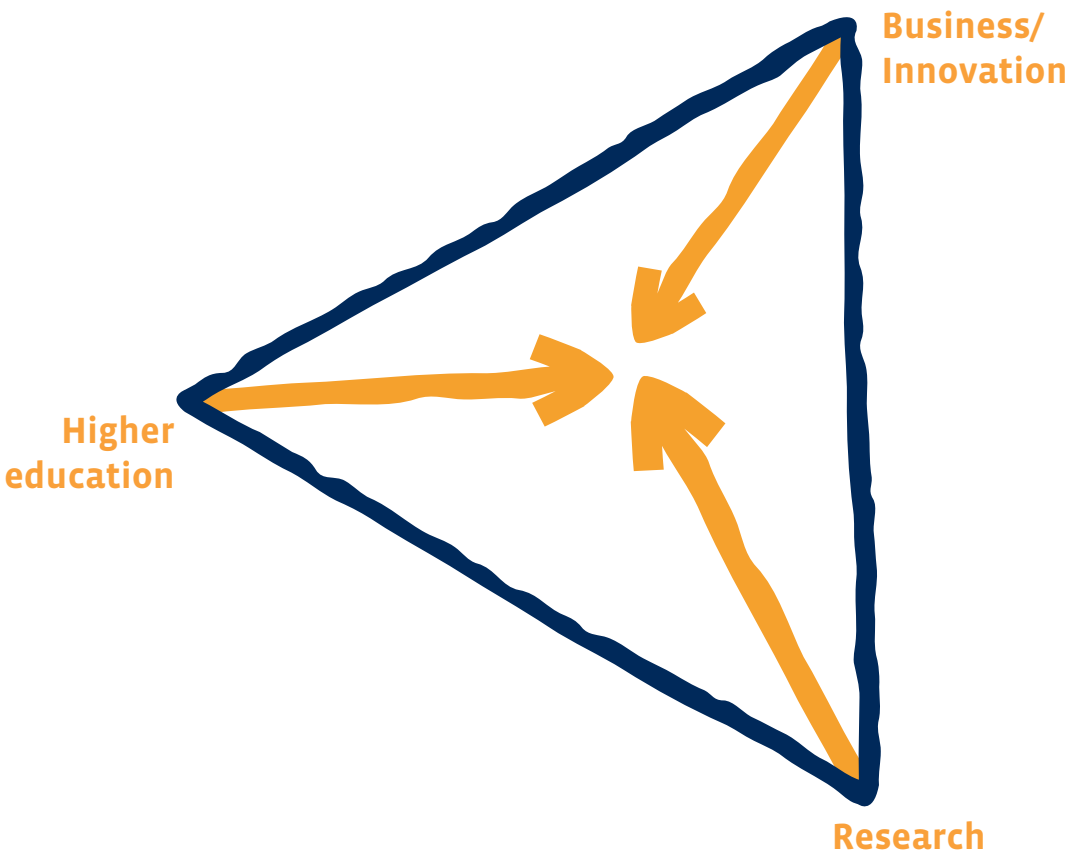
Manufuture

A document describing a vision for future research needs for European manufacturing, called Manufuture-Vision 2030, is being developed in the European Technology Platform mission: Manufuture. The document, which will be finished in 2018, comprises megatrends, challenges and scenarios for future manufacturing in Europe, as well as future innovation strategy and systems, sustainable manufacturing, new business models, new technology, education paradigms and employment. The current version of the document was discussed in the High Level Group (HLG)[1] at Nov 16th 2017, and at the Manufuture conference[2] in Tallin Oct 24th to 25th 2017. With five participants in total, the SFI Manufacturing was well represented at the Manufuture conference[3]. Dr. Odd Myklebust (SINTEF Raufoss Manufacturing) gave a presentation called: To What Extent Can Digitalisation Change Collaborative Innovation?

Intelligent circular manufacturing

SFI Manufacturing was successful in a proposal to the INTPART program of the Norwegian Research Council. The project is called INMAN: Intelligent circular manufacturing research and educational collaboration with Japan and India. Our main motivation is to strengthen the quality of our research and education by creating long-lasting international links with key research institutions in Japan and in India. Partners are NTNU (host institution), SFI Manufacturing and NCE Raufoss, Waseda University in Tokyo, National Institute of Advanced Industrial Science and Technology (AIST) in Tsukuba and Indian Institute of Technology in Hyderabad. The project goals are:

- Common research agendas and funding applications for all INMAN-institutions



- Open online course (MOOC) on circular manufacturing
- Joint PhD supervision and seminars
- Framework for a joint master degree program and joint PhD school
- Mobility of students, researchers and industry partners in Norway, Japan and India

International scientific Advisory Board
The following persons are recruited to our international scientific Advisory Board:

- Dr. Martin Kuhlman from the Soziol ogisches Forschungsinstitut (SOFI) in Göttingen, related to the Georg-August-Universität. His research is within organisation and work systems including lean and industry 4.0, and he has a lot of experience from German industry.
- Dr. Gerhard Goldbeck from university of Bristol. His main research area is numerical modelling of materials, including crystallography, polymers and complex fluid dynamics.
- Dr. Günther Hörcher is strategic research manager at the Fraunhofer Institute for Manufacturing Engineering and Automation (IPA) in Stuttgart. He is central in the development of the German strategy for Industry 4.0.

Each member will meet the SFI consortium at the workshop at Hydro Karmøy in April. The first rapport will be delivered before December 2018.

1) http://linpra.lt/wp-content/uploads/2017/12/Manufuture_Vision_2030.pdf
2) http://manufuture2017.eu/wp-content/uploads/2017/10/pdf-Jos%C3%A9-Carlos-Caldeira.pdf
3) http://manufuture2017.eu/

Recruitment and communication

The centre has succeeded with the recruitment of excellent PhD candidates through 2017 and we are according to plan with our PhD education. SFI Manufacturing has in total 10 PhD candidates now, and 1 Postdoc. We are pleased to inform that 50% of our candidates is female, and that all candidates are equally distributed over the different research areas.

During 2017, we have updated the website **www.sfimanufacturing.no**, which now includes more information about the centre, partners, research areas, PhD candidates and publications. The website includes a blog with news about mainly the workshops, PhD candidates and partners. We are sharing all blogposts on Twitter, and most of the blogposts on the website and social media of SINTEF Raufoss Manufacturing as well. We are using Twitter actively during conferences, workshops, meetings and other gatherings where the centre is involved. SFI Manufacturing has tweeted 155 times now, and has 255 followers.

In 2017, we started with the SFI Manufacturing Newsletter, which includes information about the research we are doing. The newsletter is published prior to each workshop, and its aim is to keep the community up to date with the current research that is being carried out within and related to the centre. The newsletters have been published three times in 2017 and can be found here: www.sfimanufacturing.no/newsletters. At last, in our communication, we try the make use of both text, photography and video, and we are using our communication channels cross medial.

Key Researchers

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

Lars Erik Wetterwald	SINTEF RM	Flexible and integrated production systems
Per Nyen	SINTEF RM	Flexible and integrated production systems
Lars Tore Gellein	SINTEF RM	Robotic handling of flexible objects, Flexible and integrated production systems
Gaute Knutstad	SINTEF T&S	Work systems and organization
Torbjørn Netland	SINTEF T&S	Work systems and organization
Marta Mathisen	SINTEF T&S	Work systems and organization
Eva A. Seim	SINTEF T&S	Work systems and organization
Kristoffer Magerøy	SINTEF T&S	Work systems and organization
Johan Ravn	SINTEF T&S	Work systems and organization
Hans Torvatn	SINTEF T&S	Work systems and organization
Gunnar Lamvik	SINTEF T&S	Work systems and organization
Kjersti Øverbø Schulte	SINTEF RM	Work systems and organization, Industrial clusters and learning systems, Innovation and product development
Silje Aschehoug	SINTEF RM	Work systems and organization, Industrial clusters and learning systems, Innovation and product development
Jonas Ingvaldsen	NTNU-Økonomi	Work systems and organization, Innovation and product development
Asbjørn Karlsen	NTNU-SU-GEO	Industrial clusters and learning systems
Markus Steen	SINTEF T&S	Industrial clusters and learning systems
Sverre Konrad Nilsen	SINTEF T&S	Industrial clusters and learning systems
Eli Fyhn Ullern	SINTEF T&S	Industrial clusters and learning systems
Tone Merethe Aasen	SINTEF T&S	Industrial clusters and learning systems
Monica Rolfsen	STINTEF-Økonomi	Work systems and organization, Industrial clusters and learning systems, Innovation and product development
Kristian Martinsen	NTNU-IV	Additive manufacturing, Work systems and organization

Postdoctoral researchers with financial support from the Centre budget

Name	Nationality	Period	Sex M/F	Topic
Signe Moe	Norwegian	2017-2018	F	Flexible and robust autmation

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
Eirik B.H. Korsen	Norwegian	2017-2020	M	Robustnes of MES and work systems

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
Anna Maria Persson	SINTEF Institute funding	Swedish	2017-2021	F	Characterisation of mechanical properties of thermoplastic elastomers for injection moulding

Master Degrees

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

Harald Solhaug	M	2017	Thermomechanical processing of an AA6082 - IF steel cold roll bonded composite material
Peter Sjølie	M	2017	Robust and Flexible Automated Assembly of Pneumatic Couplings
Maurice Muser Iv	M	2017	Can Lean Leadership promote social sustainability in the context of the Norwegian model
Thorbjørn Midthus	M	2017	Standardized work in a work organization that is based on Lean philosophy
Torbjørn Schjelderup Leirmo	M	2017	Additive Manufacturing: An integrated methodology for optimizing part allocation
Christina Marie Mitcheltree	F	2017	Innovation through a circular perspective - Creating shared value through networking

Scientific publications

Reporting year: 2017
Type: Article
Authors: M. Lall, E. A. Seim, H. Torvatn
Title of work: *Towards Industry 4.0: Increased need for situational awareness on the shop floor*
Book/compendium/journal: APMS 2017
Page no.: 322-329
ISSN/ISBN: ISBN 978-3-319-66922-9

Reporting year: 2017
Type: Article
Authors: M.H. Arbo, E.I. Grøtli, J.T. Gravdahl
Title of work: *On the globally exponentially convergent immersion and invariance speed observer for mechanical systems*
Book/compendium/journal: American Control Conference (ACC)
Page no.: 3294-3299
ISSN/ISBN: 2378-5861

Reporting year: 2017
Type: Article
Authors: M.H. Arbo, E.I. Grøtli, J.T. Gravdahl
Title of work: *Mid-Level MPC and 6 DOF output path following for robotic manipulators*
Book/compendium/journal: 2017 IEEE Conference on Control Technology and Applications (CCTA)
Page no.: 450-456
ISSN/ISBN: 2378-5861

Reporting year: 2017
Type: Article
Authors: J. Sverdrup-Thygeson, S. Moe, K. Y. Pettersen, J. T. Gravdahl
Title of work: *Kinematic singularity avoidance for robot manipulators using set-based manipulability tasks*
Book/compendium/journal: 1st IEEE Conference on Control Technology and Applications (CCTA), Kohala Coast, Hawai'i, August 27-30, 2017
Page no.: 142-149
ISSN/ISBN: 978-1-5090-2182-6

Reporting year: 2017
Type: Article
Authors: B.d.L. Batut, O. Fergani, V. Brøtan, M. Bambach, M.E. Mansouri
Title of work: *Analytical and Numerical Temperature Prediction in Direct Metal Deposition of Ti6Al4V*
Book/compendium/journal: Journal of Manufacturing and Materials Processing
Page no.: 686-691
Issue/Volume/Year: 1/3/2017
ISSN/ISBN: 2504-4494

Reporting year: 2017
Type: Article
Authors: O. Fergani, S.A. Tronvolld, V. Brøtan, T. Welo,K. Sørby
Title of work: *Additive-Manufactured Sandwich Lattice Structures: A Numerical and Experimental Investigation*
Book/compendium/journal: AIP Conference proceedings, ESAFORM 2017
Issue/Volume/Year: 2017

Reporting year: 2017
Type: Article
Authors: L.D. Evjemo, S. Moe, J.T. Gravdahl, O. Roulet-Dubonnet, L.T. Gellein, V. Brøtan
Title of work: *Additive manufacturing by robot manipulator: An overview of the state-of-the-art and proof-of-concept results.*
Book/compendium/journal: 22nd IEEE International Conference on Emerging Technologies And Factory Automation 2017
Issue/Volume/Year: 1/2017
ISSN/ISBN: 1946-0759

Reporting year: 2017
Type: Article
Authors: L.D. Evjemo, S. Moe, J.T. Gravdahl, V. Brøtan, O. Roulet-Dubonnet, L.T. Gellein
Title of work: *Additive Manufacturing by Robot Manipulator: An Overview of the State-of-the-Art and Proof-of-Concept Results.*
Book/compendium/journal: Conference on Emerging Technologies And Factory Automation
Issue/Volume/Year: 1/2017

Reporting year: 2017
Type: Article
Authors: O. Fergani, A. Wold, F. Berto, V. Brøtan, M. Bambach
Title of work: *Study of the effect of heat treatment on fatigue crack growth behaviour of 316L stainless steel produced by selective laser melting*
Book/compendium/journal: Fatigue & Fracture of Engineering Materials & Structures
Page no.: 1-18
Issue/Volume/Year: 1/2017
ISSN/ISBN: 1460-2695

Reporting year: 2017
Type: Article
Authors: M. H. Arbo, E.I. Grøtli, J.T. Gravdahl
Title of work: *On Model Predictive Path Following and Trajectory Tracking for Industrial Robots*
Book/compendium/journal: 13th IEEE Conference on Automation Science and Engineering
Issue/Volume/Year: 09.07.1905

Reporting year: 2017
Type: Article
Authors: M. Cheffena, M. K. Mohamed
Title of work: *Empirical Path Loss Models for Wireless Sensor Network Deployment in Snowy Environments*
Book/compendium/journal: IEEE Antennas and Wireless Propagation Letters
Page no.: 16
Issue/Volume/Year: 2017
ISSN/ISBN: 2877-2880

Reporting year: 2017
Type: Article
Authors: S. Gale, H. Rahmati, J. T. Gravdahl, H. Martens
Title of work: *Improvement of a Robotic Manipulator Model Based on Multivariate Residual Modeling*
Book/compendium/journal: Frontiers in Robotics and AI
Page no.: 4
Issue/Volume/Year: 2017

Reporting year: 2017
Type: Article
Authors: K. Martinsen, L. T. Gellein, K. M. Boivie
Title of work: *Sensors Embedded in Surface Coatings in Injection Moulding Dies*
Book/compendium/journal: Procedia CIRP
Page no.: 62
Issue/Volume/Year: 2017
ISSN/ISBN: 386-390

Reporting year: 2017
Type: Article
Authors: M. K. Mohamed, M. Cheffena, A. Moldsvor, F. P. Fontán
Title of work: *Physical-Statistical Channel Model for Off-body Area Network*
Book/compendium/journal: IEEE Antennas and Wireless Propagation Letters
Page no.: 16
Issue/Volume/Year: 2017
ISSN/ISBN: 1516-1519

Reporting year: 2017
Type: Article
Authors: A. Moldavska, T. Welo
Title of work: *The concept of sustainable manufacturing and its definitions: A content-analysis based literature review*
Book/compendium/journal: Journal of Cleaner Production
Page no.: 166
Issue/Volume/Year: 2017
ISSN/ISBN: 744-755

Reporting year: 2017
Type: Article
Authors: A. Moldavska, K. Martinsen
Title of work: *Defining sustainable manufacturing using a concept of attractor as a metaphor*
Book/compendium/journal: Procedia CIRP 2017

Reporting year: 2017
Type: Article
Authors: H. Holtskog
Title of work: *Defining the characteristics of an expert in a social context through subjective evaluation*
Book/compendium/journal: Journal of the Knowledge Economy 2017
Page no.: 1014-1031
Issue/Volume/Year: Volum 8 (3)

Reporting year: 2017
Type: Article
Authors: H. Holtskog
Title of work: *Forms of Innovation—Insights from Product Development*
Book/compendium/journal: Journal of the Knowledge Economy 2017
Page no.: 63-76
Issue/Volume/Year: Volum 8 (1)

Reporting year: 2017
Type: Del av bok
Authors: H. C. Garman Johnsen, R. Ennals, H. Holtskog
Title of work: *Balancing Organisational Design Principles: A Pragmatic Scandinavian Approach to CSR*
Book/compendium/journal: Stages of Corporate Social Responsibility : From Ideas to Impacts.
Page no.: 163-178
Issue/Volume/Year: 2017

Reporting year: 2017
Type: Article
Authors: O. Ogorodnyk, M. V. Granheim, H. Holtskog, L. Ogorodnyk
Title of work: *Roller Skis Assembly Line Learning Factory – Development and Learning Outcomes*
Book/compendium/journal: Procedia Manufacturing
Page no.: 9
Issue/Volume/Year: 2017
ISSN/ISBN: 121-126

Reporting year: 2017
Type: Article
Authors: M. Alizadeh, S. Khoramkhorshid, A. H. Taghvaei, P. Konda Gokuldoss
Title of work: *Characterization of Al/crystallized Al-based metallic glass composites produced by repeated roll bonding process*
Book/compendium/journal: Metals and Materials International 2017
Page no.: 823-830
Issue/Volume/Year: Volum 23 (4)

Reporting year: 2017
Type: Article
Authors: P. Konda Gokuldoss, R. Damodaram, T. Maity, P. Wang, J. Eckert
Title of work: *Friction welding of selective laser melted Ti6Al4V parts*
Book/compendium/journal: Materials Science & Engineering: A 2017
Page no.: 66-71
Issue/Volume/Year: Volum 704

Reporting year: 2017
Type: Article
Authors: P. Konda Gokuldoss, S. S. V. K. Kolla, J. Eckert
Title of work: *Additive Manufacturing Processes: Selective Laser Melting, Electron Beam Melting and Binder Jetting - Selection Guidelines*
Book/compendium/journal: Materials 2017
Issue/Volume/Year: Volum 10 (6)

Reporting year: 2017
Type: Article
Authors: P. Konda Gokuldoss, S. S. V. K. Kolla, J. Eckert
Title of work: *Additive Manufacturing Processes: Selective Laser Melting, Electron Beam Melting and Binder Jetting - Selection Guidelines*
Book/compendium/journal: Materials 2017
Issue/Volume/Year: Volum 10 (6)

Reporting year: 2017
Type: Article
Authors: X. Liu, C. Li, J. Eckert, P. Konda Gokuldoss, O. Renk, L. Teng, Y. Liu, R. Bao, J. Tao, S. Tao, J. Yi
Title of work: *Microstructure evolution and mechanical properties of carbon nanotubes reinforced Al matrix composites*
Book/compendium/journal: Materials Characterization 2017
Page no.: 122-132
Issue/Volume/Year: Volum 133

Reporting year: 2017
Type: Article
Authors: P. Ma, Y. Jia, P. Konda Gokuldoss, Z. Yu, C. Li, J. Zhao, S. Yang, L. Huang
Title of work: *Effect of Si content on the microstructure and properties of Al–Si alloys fabricated using hot extrusion*
Book/compendium/journal: Journal of Materials Research 2017
Page no.: 2210-2217
Issue/Volume/Year: Volum 32 (11)

Reporting year: 2017
Type: Article
Authors: P. Ma, Y. Jia, P. Konda Gokuldoss, Z. Yu, S. Yang, J. Zhao, C. Li
Title of work: *Effect of Al2O3 Nanoparticles as Reinforcement on the Tensile Behavior of Al-12Si Composites*
Book/compendium/journal: Metals 2017
Issue/Volume/Year: Volum 7 (9)

Reporting year: 2017
Type: Article
Authors: J. Suryawanshi, P. Konda Gokuldoss, U. Ramamurty
Title of work: *Mechanical behavior of selective laser melted 316L stainless steel*
Book/compendium/journal: Materials Science & Engineering: A 2017
Page no.: 113-121
Issue/Volume/Year: Volum 696

Reporting year: 2017
Type: Article
Authors: J. Suryawanshi, P. Konda Gokuldoss, U. Ramamurty
Title of work: *Tensile, fracture, and fatigue crack growth properties of a 3D printed maraging steel through selective laser melting*
Book/compendium/journal: Journal of Alloys and Compounds 2017
Page no.: 355-364
Issue/Volume/Year: Volum 275

Reporting year: 2017
Type: Article
Authors: Z. Wang, K. Georgarakis, W. W. Zhang, P. Konda Gokuldoss, J. Eckert, S. Scudino
Title of work: *Reciprocating sliding wear behavior of high-strength nanocrystalline Al84Ni7Gd6Co3 alloys*
Book/compendium/journal: Wear 2017
Page no.: 78-84
Issue/Volume/Year: Volum 382-383

Key performance indicators from our original description of work

	Plan 2015-2023	Sum 2015-2017	2015	2016	2017
Book about MMP manufacturing	1	0			
Scientific paper publish in international journals and conferences with peer review	112	36	1	7	28
Popular science articles	16	1			1
National and international conferences and seminars/workshops	2	1		1	
PhD candidates	17	10	2	7	1
Post docs	3	1			1

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	2017
The Research Council	14 314 794
The Host Institution (Sintef Raufoss Manufacturing AS)	974 823
Research Partners*	6 408 755
Enterprise Partners*	8 603 629
Total	**30 302 001**

Costs	
The Host Institution (Sintef Raufoss Manufacturing AS)	5 164 823
Research Partners	20 458 550
Enterprise Partners	4 678 629
Public Partners	
Equipment	
Total	**30 302 001**

Enterprise partners*

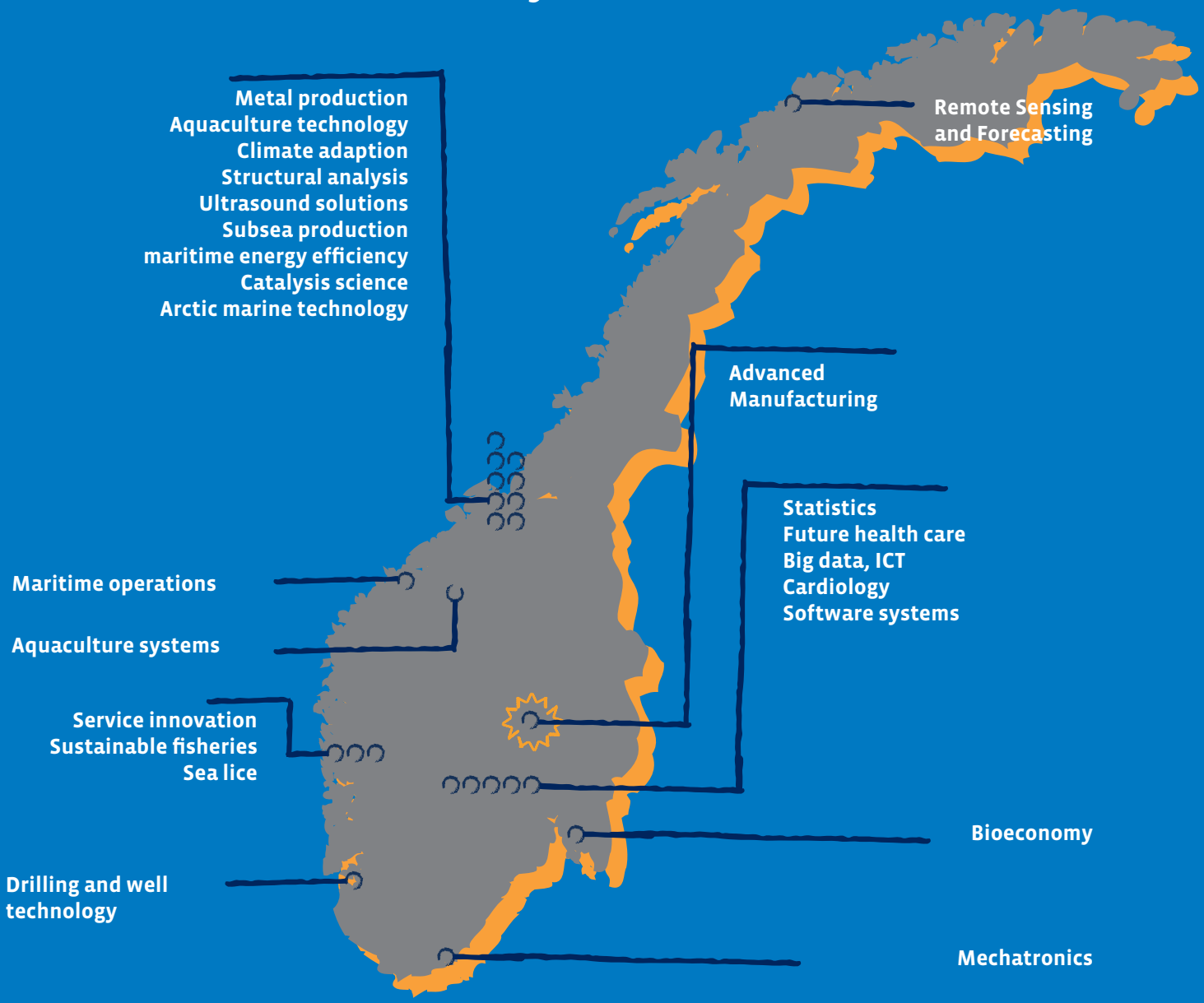
Brødrene Aa (private sector)
Benteler (private sector)
Ekornes (private sector)
GKN (private sector)
Hexagon (private sector)
Kongsberg Automotive (private sector)
Mjøs Metallvarefabrikk (private sector)
Nammo (private sector)
Norsk Hydro (private sector)
Plasto (private sector)
Raufoss Technology (private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

SFI Manufacturing

One of 24 SFIs in Norway



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

manufacturing

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