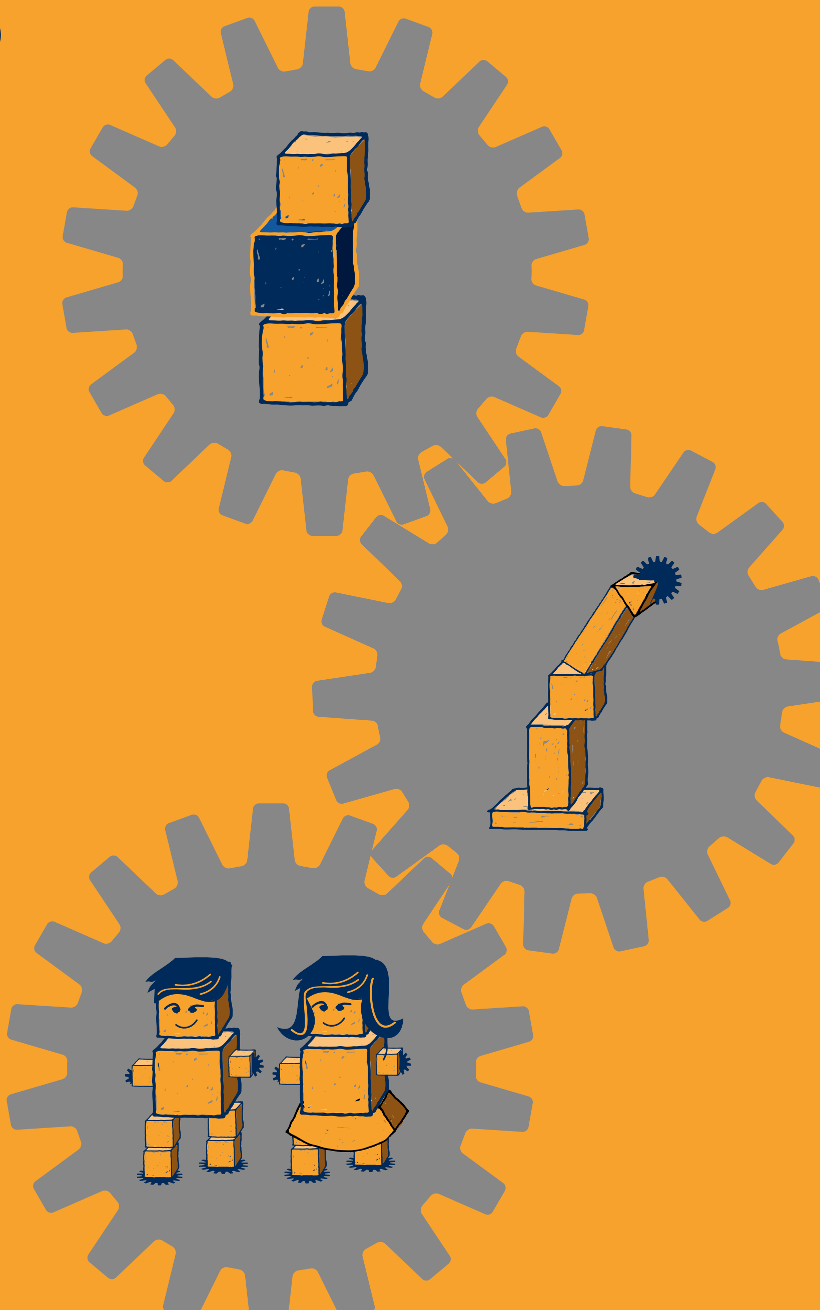
manufacturing

Annual report

2015



sfi Centre for Research-based Innovation

The Research Council of Norway

Index

“Cross-disciplinary research based innovation is our key to success”

Sverre Gulbrandsen-Dahl
Centre manager SFI Manufacturing

Picture from Benteler, Raufoss

Competence as an engine for change

The reduced growth of oil revenues and the need for change in the Norwegian economy highlights productivity as an increasingly important prerequisite for our competitiveness and common welfare.

In Norway. Competition is fierce, and the countries we compete with are all in a process for re-industrialising. Germany has its focused agenda in Industrie 4.0, the UK is betting on major technology centers through Catapult and Sweden have recently presented their national industrial stratgy "Nyindustrialiseringsstrategi för Sverige".

Industrial production in Norway employs 250 000 employees and contributes annually with a value of 200 billion. The sector accounts for 37% of R & D activity in the business sector.
The vision of SFI Manufacturing is to show how sustainable manufacturing in a high-cost country like Norway is possible, and what it takes to improve global competitiveness. Cross-disciplinary research in multi material products and - processes, automated production and innovative organizations will show how good the objective is to provide a knowledge based tool-box for future industrial innovations.

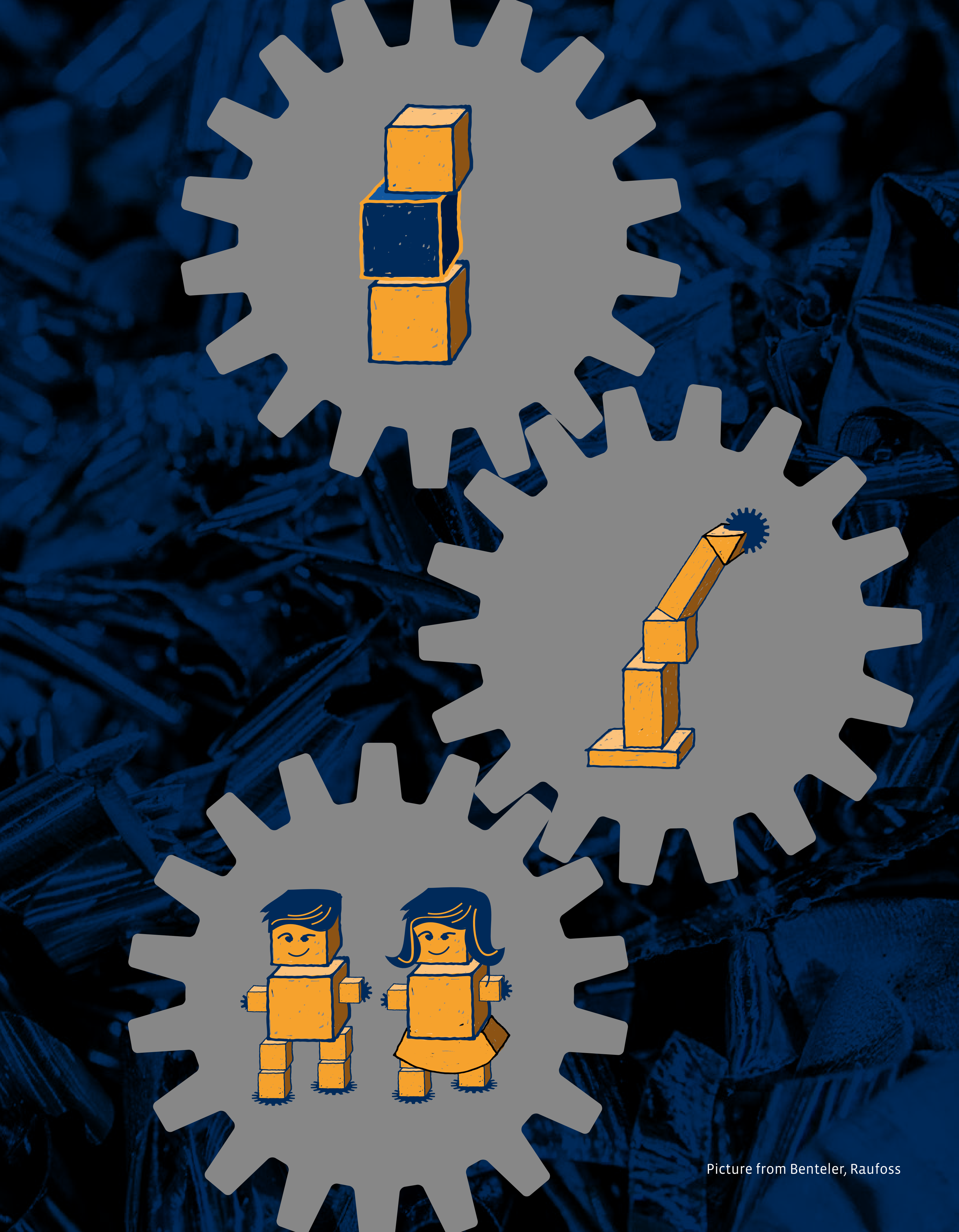
I am very pleased to see how our strong consortium of industrial- and academic partners are developing SFI Manufacturing into a vital research centre. The participation in our workshops in 2015 has been excellent, both in the number of attendees (approx. 60 pr work-shop) and the involvement in the work-shop activities. As a result, both the host industrial partner and the SFI have obtained valuable input in their development processes. The research activity in 2015 has mainly focused on defining focus areas for in-depth research, which have a generic influence. This has resulted in a detailed work plan for 2016, several state-of-the-art surveys, and recruitment of 2 highly qualified PhD candidates within the centre.

It is also encouraging that both Sandvik Teeness and Norsk Hydro has joined the consortium during 2015. We hope this is an indication of SFI Manufacturing's relevance and attractiveness for the Norwegian manufacturing industry. Our intention is to develop this further.

We know that Norway can gain global competiveness, also without a single oil-lubricated crown. Joint competence centres based on industrial clusters may be the Norwegian change engine.

Sverre Gulbrandsen-Dahl
Raufoss, 29th March 2016

Picture from Hexagon Ragasco, Raufoss



Picture from Benteler, 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 Organizational 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 is:

Mulit-Material Products and Processes

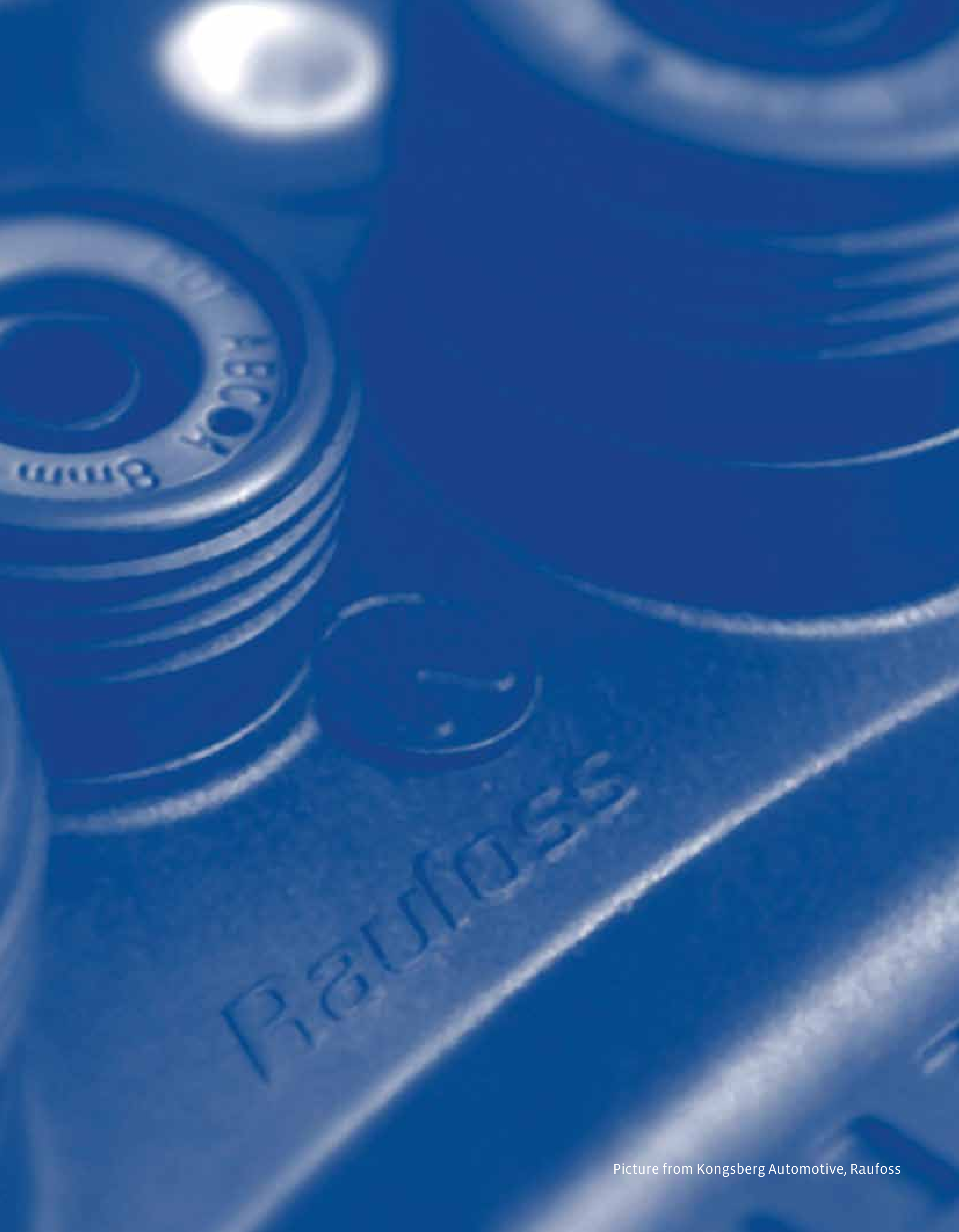
To develop the ability to optimize material choice, multi materials geometry and processes simultaneously.

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 organizations

To develop advanced work systems that are enabled to utilize new technology and flexible and automated processes to manufacture sustainable multi-material product solutions.



Picture from Kongsberg Automotive, Raufoss

Research plan/strategy 3

The research activities in SFI Manfuacturing are organised in three research areas:

- Multi-material Products and Processes
- Robust and Flexible Automation
- Innovative and sustainable organizations

Each of these research areas represents multidisciplinary approaches, and the ability of the partners to perform the research accordingly represents a key enabler for the relevance of the SFI Manufacturing research is to form research activities that links these three research areas. A primary goal of SFI Manufacturing.

In the following, the research plans within each of the areas are described.

Multi-material Products and Processes

Multi-Material Products development requires the ability to optimize material choice, multi materials geometry and processes simultaneously.

The centre utilizes the state-of-the art research methods, physical and virtual laboratories including numerical tools available with the partners.

The fundamental idea is to work in, and develop further SINTEF's "Knowledge and modelling Frameworks" relevant to reach the goals. Frameworks represent SINTEFs structured knowledge, often also termed our virtual laboratories. These frameworks prepare the basis for activities within the research area Multi-Material Product and Processes, and are competence built up in long-term research project portfolio, through former SFIs, KPNs, IPNs and internal projects.

Thus, by creating several virtual teams across our organization, operating in the required research infrastructure, relevant data collection, storage, modelling and simulation will be ensured.

The following research challenges are highlighted:

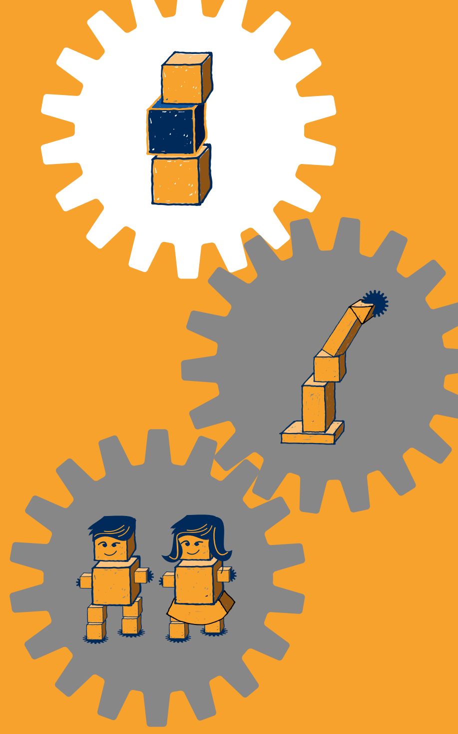
Design of MMP testing based on numerical modelling in order to identify critical and/or main mechanisms for failure in MMP.
New testing methodologies will be developed in order to evaluate the basic bonding property/quality of the newly developed technologies. SFI Manufacturing aims at understanding the basic bonding mechanisms and will provide the necessary inputs for the calibration of the developed numerical tools. The tests will be representative for components/structures in order to benchmark the developed technologies based on numerical models. The output will be a valuable input for evaluation of properties and sustainability for the chosen multi-material product solution. The test methodologies aim at early feedback in the innovation process.

Identify critical process, material mis-match situations and/or main mechanisms for failure in MMP.
SFI Manufacturing will gain knowledge of failure mechanisms, vital in the design phase in order to avoid structural failures in service. The work will be a combination of microstructural mechanical characterizatio and numerical modelling. The task will utilize access to state of the art infrastructure for advanced electron microscopy and mechanical testing provided by the consortium.
Analyses of possible failures due to:

(i) Design choice: (thermal expansion, galvanic contact, stress corrosion, etc.)

(ii) Processing: (formability gradients, heat capacity differences, bonding, etc.)

(iii) Exposure in service: (Thermal and load history, degradation, corrosion, ageing)



(iv) Robustness considerations, process monitoring and control in automated processes

Bridge the gap between the modelling scales.
The research challenge is to provide tools for test design, increased product knowledge and increased process knowledge, suitable for optimization algorithms and broad approach for product and process optimization. Local micromechanics approaches will be used to understand fundamental physical mechanisms, and as input to macroscopic models. The models will be calibrated, validated and utilized in the centre.
The following topics will be investigated:

(i) Damage development and crack propagation in adhesive layers

(ii) Fracture of mechanical connections

(iii) Interface properties with atomistic models

(iv) Process effect on the connection behaviour

(v) Ab initio based atomistic interface models to calculate bonding energies used as boundary conditions in continuum based models, making larger scale simulations possible.

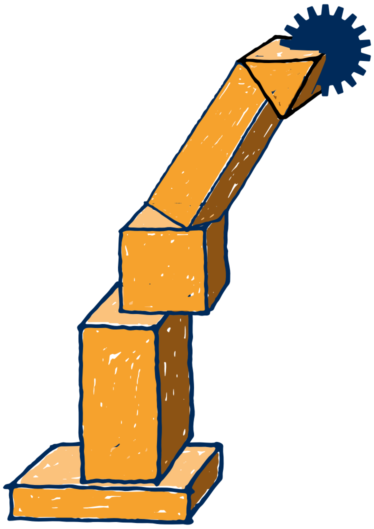
Novel advances in Additive Manufacturing Technology for multi-material products
Additive manufacturing is a key enabling technology that based on a three dimensional digital model builds parts by the successive addition of material. Additive manufacturing processes are very rarely used for manufacturing purposes, and hardly at all within Norwegian manufacturing industry, besides for pure prototyping purposes. In order unleash the true potential for innovation and value creation provided by additive manufacturing technology, different additive manufacturing processes need to be integrated as a part of the production system.

Joining of dissimilar materials
Joining is a key enabling technology for multi-material products. The SFI-Manufacturing will focus on developing laboratory scale joining technologies towards technology readiness levels for industrial innovations. The possibilities and limitations of existing joining technologies for multi-material products will be investigated, and knowledge-based improvement of existing joining technologies will be proposed.

The research methodology will be based on case studies which have relevance for industrial partners and addressing joining of:

I. Aluminium to steel
II. Dissimilar aluminium alloys
III. Polymer to metal
IV. Joining of multi polymer

Based on existing competence and infrastructure in the consortium, the proposed initial cases within metal-metal joining will be based on cold pressure welding, and within polymers the proposed initial focus will be on improved adhesion in adhesive joining and in mould bonding.



Robust and Flexible Automation

Recent developments within automation technologies increase the ability to rapidly adapt to changing conditions and open new ways to use automation and robotics in manufacturing systems.

Increased flexibility and robustness, in-process monitoring and real-time control, faster and easier reconfiguration, intuitive and adaptive manufacturing adapted to human needs, intuitive programming and tasking, trajectory planning with adaption to changing environments, sensor systems capable of mapping and analysing changing environments, multi-robot and human-robot coordination and cooperation, and real time sensor based control are some examples of advances based on novel technology.

The following research challenges will be addressed:

Real-time interaction control in order to achieve accurate control of the interaction forces between one or several robots and their environment

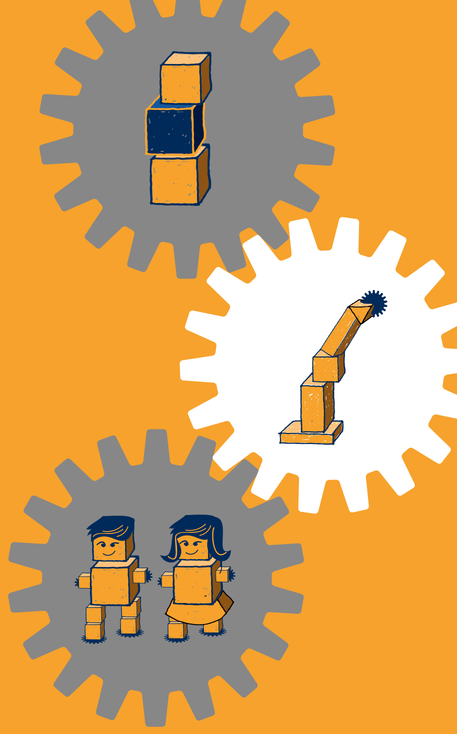
Methods such as parallel force/motion control will be investigated, implemented and tested in a laboratory environment in order to e.g. synchronize to other objects in the environment, enable human-robot collaboration and handle uncertainties and deviations during operations. Real-time interaction control is important for future innovation since it enables flexible manufacturing and reconfigurability by managing uncertainties and frequent changes in operations and operating conditions.

Motion planning, control and collision avoidance to enable multi-robot and human-robot operations

Robust collision avoidance is essential to secure equipment and humans in complex operations and unstructured environments. Synchronization strategies will be considered for adapting to dynamic objects in the workspaces and to incorporate collision avoidance schemes in the motion control system. Automatic path planning systems based on both model and real-time sensor data input will be investigated, adapted and tested for selected use cases. The robots (and possibly surrounding structures) will be equipped with sensors suitable for real-time three-dimensional mapping of their workspace.

3D object localization methods for grasping and tracking of solid and flexible MMP objects

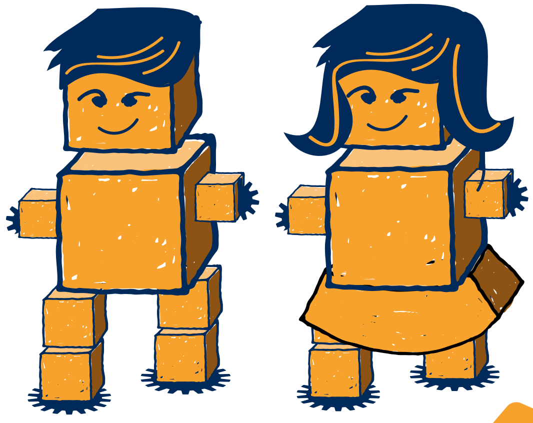
The research will aim at (i) Mature and improve state-of-the-art algorithms to make them sufficiently faster, more robust and applicable for a wider range of industrial scenarios, (ii) Develop algorithms for flexible objects, i.e. soft/deformable objects or objects that do not have a pre-determined shape, (iii) Develop virtual simulation models for 3D data acquisition to efficiently generate data sets without the need for physical access to the robot and the sensor, (iv) Develop intuitive user interface for easy training of the system and utilize CAD models of parts, and (v) Develop robust algorithms and filtering methods for tracking dynamic objects, where the robot needs to take the motion of the objects into account.



Systems for in-line monitoring of processes and quality control of products based on novel automated cognitive processes in order to increase robustness, mass customisation, enabling first-time-right manufacturing and reduced ramp-up time
Sensors and supporting software such as 3D vision will be used and further developed to monitor processes and products, such as detection of deviations in 3D shape, colour, texture, unsuccessful grasping of objects, etc. The research will include: (i) Automatic comparison of 3D measurement data with CAD models and geometrical parameters of either produced parts or relevant production tools, (ii) Model-based analysis of processes using real-time sensor data from e.g. 3D vision, force feedback and tactile sensors, (iii) Sensor fusion techniques for detection of surface anomalies in shape and appearance in a more robust manner, (iv) Process instrumentation with statistical analysis and pattern recognition techniques will be used to detect anomalies in the data that has been logged, and (v) Combination of vision and 3D data with other NDT methods such as ultrasound and X-ray.

Human-oriented automation through efficient and intuitive programming methods and interfaces based on sensor input and real-time control
Laboratories for research on human-oriented, efficient and intuitive programming of robots will be established with state of the art robot programming methods and sensor integrated real time control. The laboratories will be used to develop general tools and methods, and several industrial cases will be tested and used as feedback for improvement and qualification. Both the technical and user aspects of the methods will be subject for the research. By the use of intuitive and visual user interfaces like Augmented Reality (AR), insight into the automated process will lower the need for competence, increase the speed of setting up or reconfiguring a system, and increase the iterative innovations of industrializing new automated processes.

Socio-technical approach for integration of emerging technologies into existing and future manufacturing systems in order to test for maturity and applicability
The interfaces between different nodes and technologies in the manufacturing system must be investigated to ensure the applicability and exploitation of the technology. SFI Manufacturing will provide research on how to verify to what extent and in what way a novel technology can or may be brought to use in modern, advanced manufacturing. Suitable industrial cases will be identified for prototype implementation with the purpose of testing for technology maturity and applicability. The following research methods will be used: (i) Case-driven system modelling, design, and experimental implementation. (ii) Distributed control by cooperating and collaborating autonomous manufacturing entities, (iii) Realistic real-time emulation of manufacturing entities, (iv) Simulation based development of full scale, distributed manufacturing control systems, (v) Laboratory prototype integration of developed technologies, and (vi) Action research on social aspects of technology implementations.



Innovative and sustainable organizations

This research area aims at developing advanced work systems that are enabled to utilize new technology and flexible and automated processes to manufacture sustainable MMPs.

The development of this advanced work system is also framed by how companies co-create useful knowledge in their extended network.

The following Research Challenges are highlighted:

Work systems for process innovation
The design of effective and efficient work systems should build on the strengths of the Norwegian working life and selective incorporate technological and organizational best practice. The aim is to identify how extensive worker participation should be aligned with a systematic and cumulative approach to continuous improvement. In particular, the research will explore how MMPs and automation reshapes the division of labour, and which team structures are appropriate. This research task will identify how continuous improvement should be coordinated, and will pay special attention to the role of supervisors and middle managers.

Smart, dynamic and innovative clusters
Joint knowledge and innovation in industrial clusters are important for the innovation in each company. Research on this topic will investigate how clusters evolve and how the companies use their potential within the cluster.

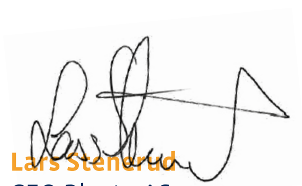
Product and process innovation
This research topic aims to define and understand critical enablers for front end innovation and successively implement and validate such enablers for further experimentation in living laboratories. New technology may also challenge existing work systems, and while the manufacturing industry becomes more flexible, adaptable and committed to shorter product life cycles and varying demand patterns, this trend also has to be reflected in the work system. Feedback slopes from the work system and the requirements anchored in extended producer responsibility (EPR) are crucial in improving understanding for design of next generation product or service life cycle. This research is an approach to develop new criteria and methodology, as a bottom up approach from product level to business strategy.

Meet the board

As chair of the board of SFI Manufacturing I am pleased to announce that the research centre has had a good start-up period and I am looking forward to the years to come. As CEO of a small company in Åndalsnes I value the competence that is brought to us by being an active participant in research and development projects for more than 15 years.

We will look into the re-industrialisation initiatives in Europe and the USA to get inspiration for a Norwegian approach to Industrie 4.0 and the digitalisation of the industries.

The board of SFI Manufacturing has a majority of industrial partners. That is an important principle though the ultimate goal is to make the partner companies increase their global competitiveness in their respective global markets as well as to keep and develop new manufacturing industry in Norway. The strategy of the centre is to develop cross-disciplinary research activities in order to solve problems with knowledge from several scientific fields. This is a great challenge and it requires a high level of trust between the research- and industrial partners of SFI Manfacturing.
The board is composed of five industry representatives and four representatives from the research institutions. It has established rules and routines for cooperation and dissemination in order to safeguard the interest of the researchers to publish results and the industry's interest of commercialise or licence the same results. SFI Manufacturing has many stakeholders and the board is fully committed to balance the hopes and expectations of all of them as well as prioritise the means and resources of the centre.



Lars Stenerud
CEO Plasto AS,
Chair of the board SFI Manufacturing

Board members

Lars Stenerud, Plasto
Ole Hoen, GKN Aerospace
Roger Kyseth, SINTEF Raufoss Manufacturing
Rudie Spooren, SINTEF
Torbjørn Skogsrød, HiG
Anne Borg, NTNU
Olav Holst-Dyrnes, Ekornes
Geir Liaklev, Kongsberg Automotive
Vegard Sande, Nammo

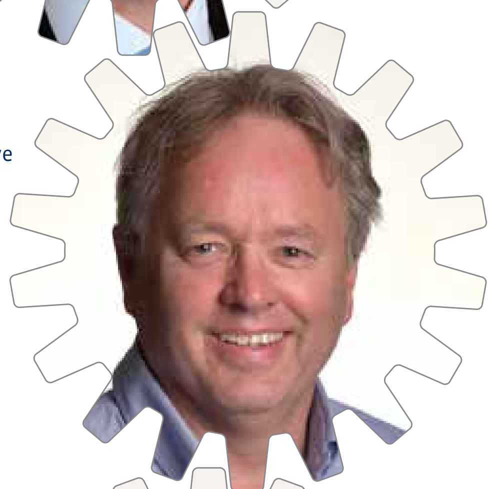
Anne Borg, NTNU

Ole Hoen, GKN Aerospace

Olav Holst-Dyrnes, Ekornes

Roger Kyseth, SINTEF Raufoss Manufacturing

Geir Liaklev, Kongsberg Automotive



Rudie Spooren, SINTEF

Vegard Sande, Nammo

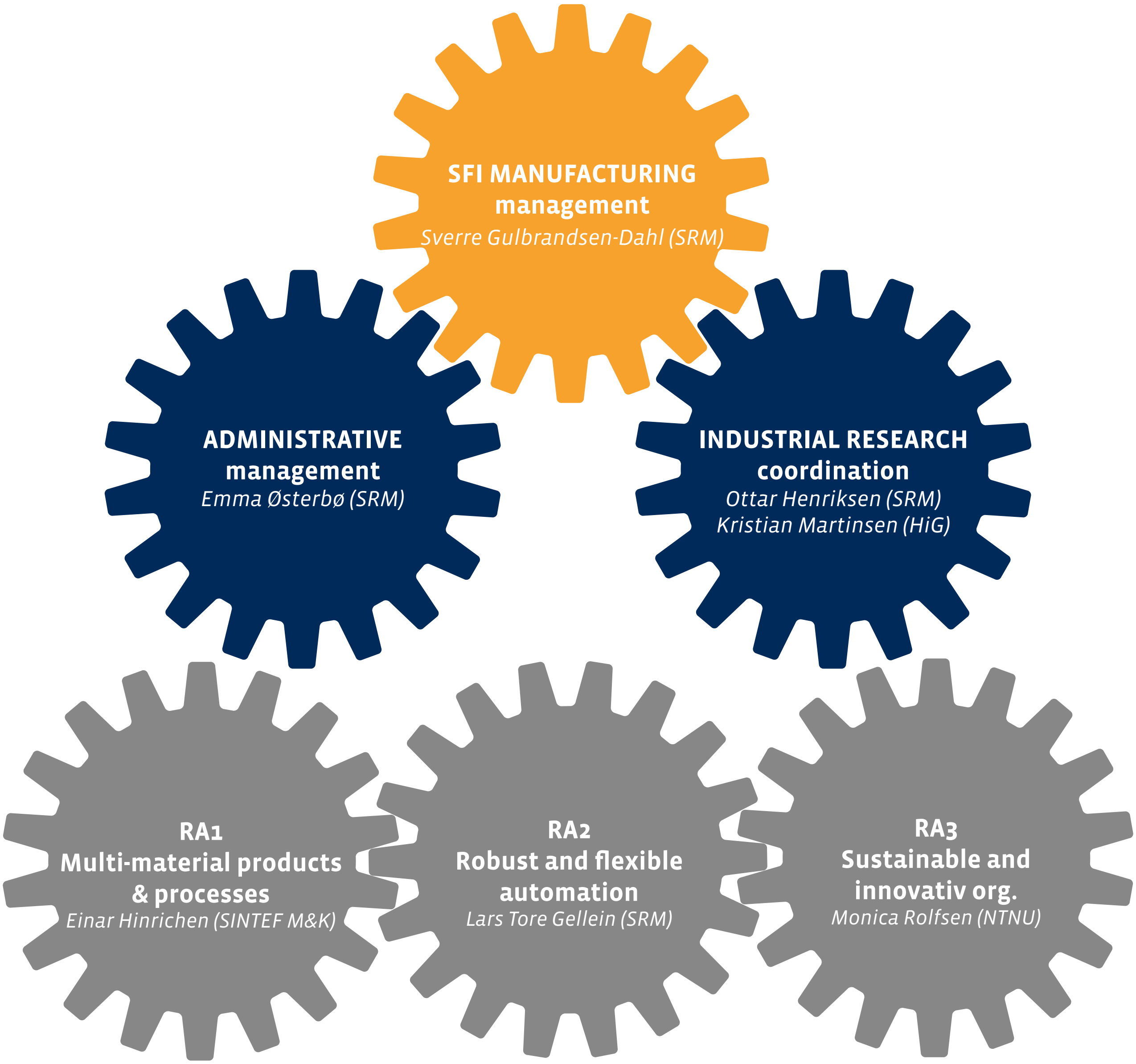
Torbjørn Skogsrød, HiG

“I value the competence that is bought to us in R&D projects for more than 15 years”

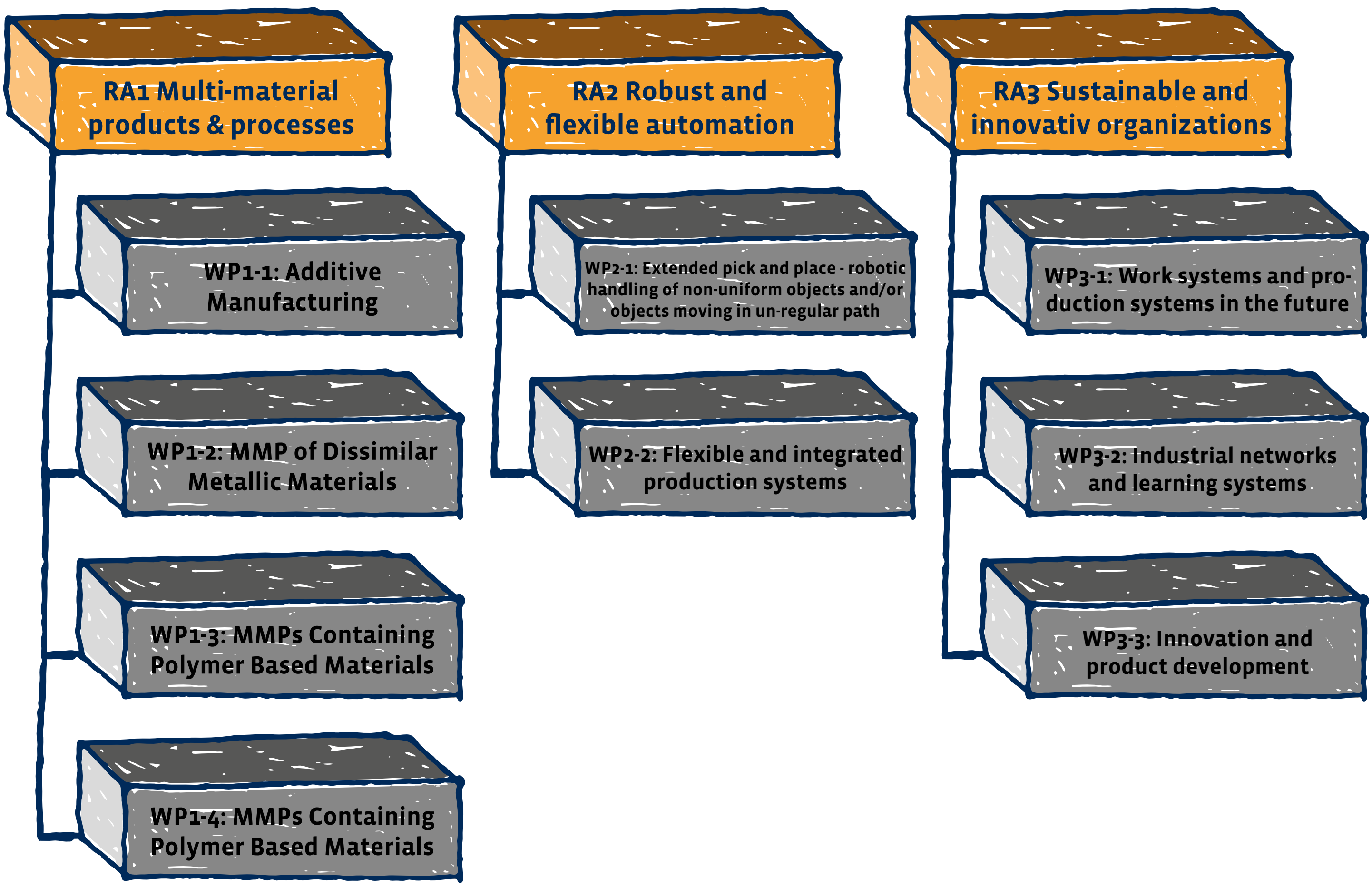
Lars Stenerud
CEO of Plasto and Chair of the board SFI Manufacturing

Picture from Benteler, Raufoss

Organization
Center structure



Organization
Center structure



Research partners

NTNU

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

HØGSKOLEN I GJØVIK

Education and Research:
Mechanical engineering, Additive manufacturing, Physics

SINTEF

Research:
Materials and Chemistry, ICT, Technology and society

SINTEF Raufoss manufacturing

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

Industrial partners

Workshops

SFI Manufacturing has arranged two workshops in 2015. The first one was the project kick off. It took place in Raufoss June 24th 2015. 46 participants gathered to discuss the structure, organization and content of SFI Manufacturing. In all workshops there are researchers from different scientific fields cooperating to solve common research challenges. It is an important arena to share, and create new knowledge, and stimulate to cross-diciplinary research

Trondheim
October 21st - 22nd 2015

In Trondheim 67 participants from both research and industrial partners gathered to work out the direction of the following years of SFI Manufacturing.

Group discussions around the content of the research areas, information of what Germany does in their Industrie 4.0- strategy, lab visits and a site visit at the plant of SFI-partner Sandvik Teeness. Sandvik Teeness hosted a fantastic session that was followed by case discussions with input from some 60 experts in various fields, all committed to contribute to the development of their fellow project partner Sandvik Teeness. This is a format that will be continued throughout the SFI Manufacturing project period.

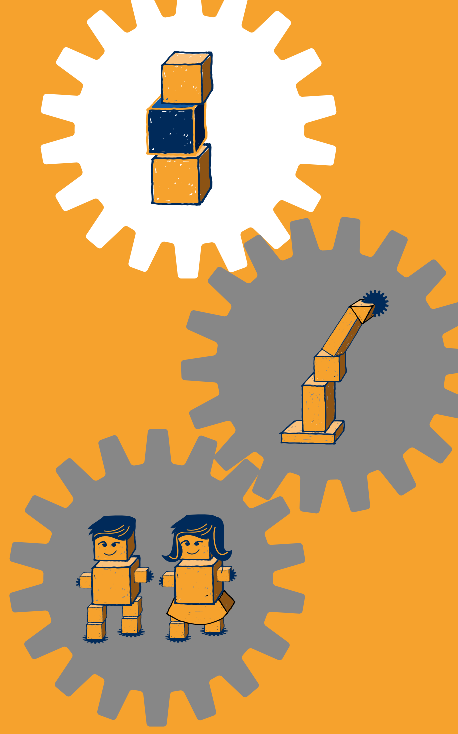
> *"The ability to work smarter is the decisive factor for how our country will do once our oil revenues flatten"*
>
> Sverre Narvesen
> NCE Raufoss

Picture from Hexagon Ragasco, Raufoss

Research activities in

Multi-material Products and Processes 2015

develop
workshop
kick-off
WP1-1
BIA IPN integrated
SOTA
microstructure
case
multiscale
industry
activities
optimization
modeling
KPN-MKRAM
multi
thesis
metallic
transistions
SFO
additive manufacturing
hybrid
material
bonding
techniques
PBF solutions
studies
potential
efficiency
DED
method
experiments
coordination
modelling
applications
interface
joining
HYB
NTNU
software
components
SFI



PhD Scholarship: *"Joining of steel and aluminum"*

The start of this PhD-work was in August 2015. The focus during the fall was first of all on performing a literature study and perform some initial tests. The work is summarized below.

1. Literature study
Performing an extensive literature study on the topic in order to achieve necessary information about the chosen metals and the existing joining methods was an important goal for 2015. The literature study has provided a good overview of ongoing research on the topic, which is important in order to be able to compare the work performed in this PhD with ongoing research.

It has been important to obtain a fundamental understanding of different joining techniques, identifying important process parameters. The main challenges associated with joining of dissimilar metals and how the different process parameters affects the final joints, especially the mechanical properties have been an important topic during this literature study.

A detailed project description was written based on the literature study. The project description provides a good introduction to the topic, including ongoing research and a detailed description of the research to be performed in this PhD work.

2. Sample geometry
In order to get a better understanding of the joining between steel and aluminum, Rune Østhus at SINTEF Raufoss, performed simulations of the joining process. The goal with the simulations were to determine the optimal sample geometries for the aluminum- and steel-rods to be joined achieving high surface expansion during compression. Figure 1 shows two images from the performed simulation of the compression of the samples.

Based on the optimal sample geometry concluded from the simulations, five tests were performed with slightly different process parameters in order to compare the actual deformation of the samples to the deformation observed in the simulations. During these initial tests, two different machines were utilized in order to compare the stability and alignment of the samples in the two machines. Figure 2 shows the experimental setup of the compression test in one of the machines, and in Figure 3 the deformed samples from one of the compressions tests are presented. The rods will now be further studied using light microscopy in order to study the deformed microstructure up close. This might also provide useful information about how the metal flows during deformation and might give some indications to temperatures achieved during the compression along the interface between the two rods.

The tests performed so far have not given the same degree of deformation as observed in the simulated compressions and more simulation and testing is necessary in order to find the optimal sample geometries of both rods.

PhD work – Siri Marthe Arbo

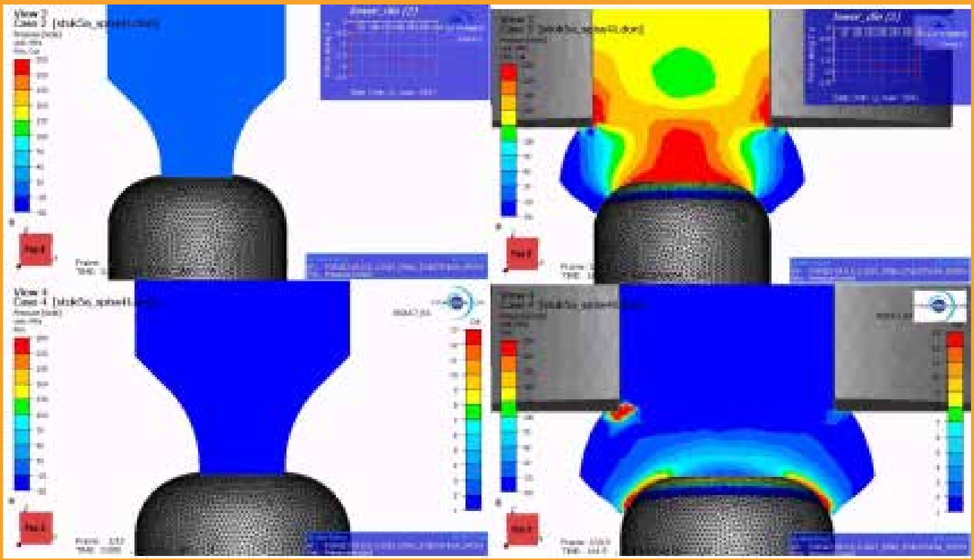
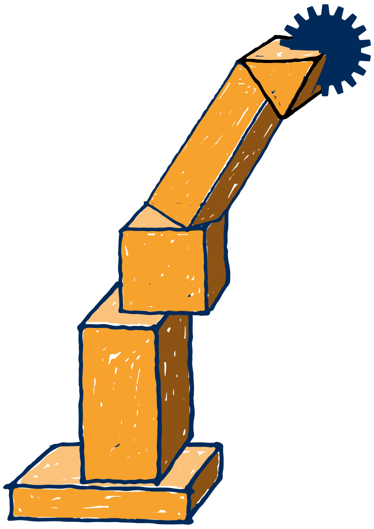


Figure 1:
Images showing how the metals deform during compression. Al-rod on top and steel-rod at the bottom.

Figure 2:
Experimental setup for one of the compression tests performed in machine 1.

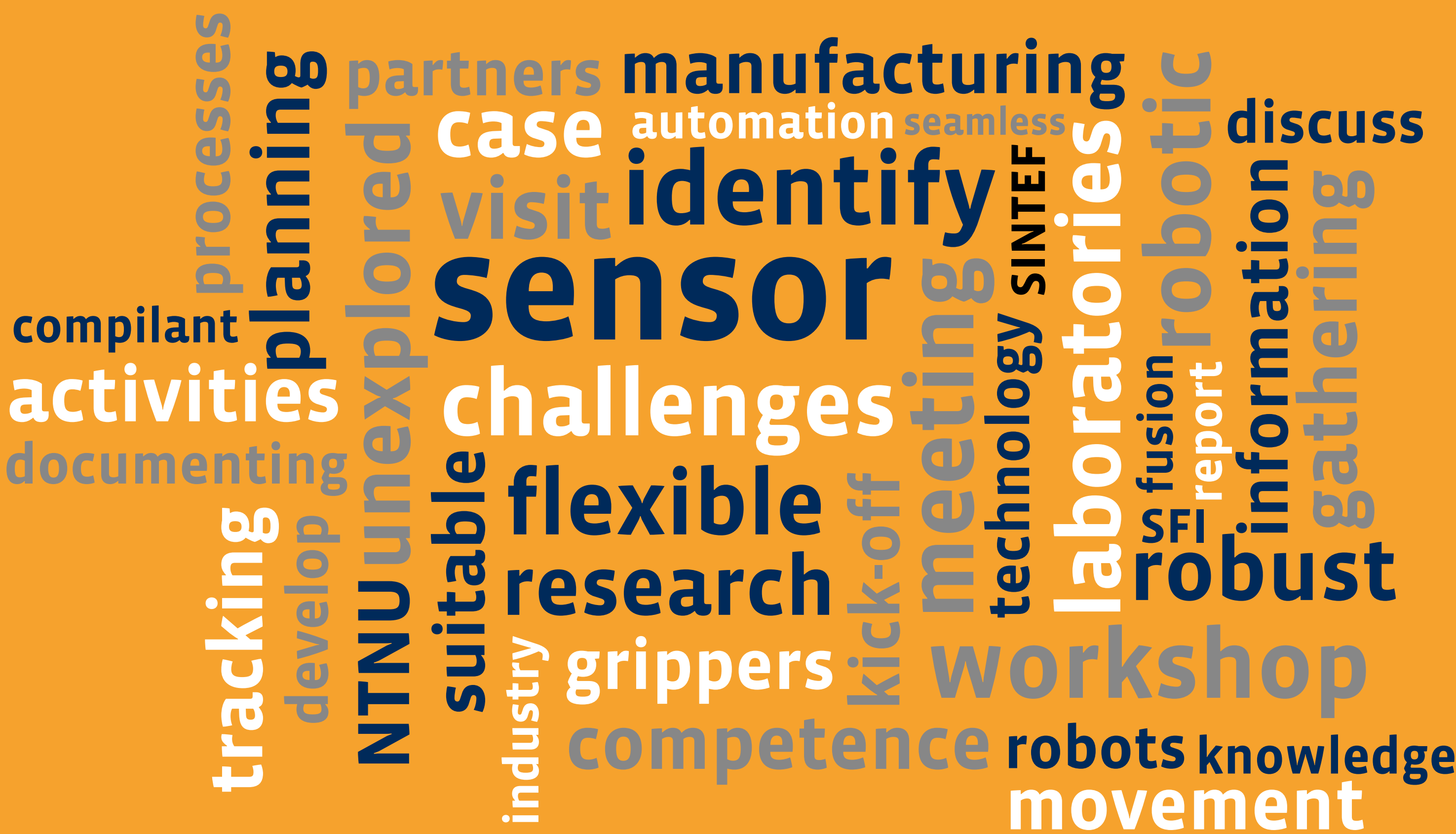
Figure 3:
Deformed samples after complete compression test. To the left: the steel-rod after compression. To the right: the Al-rod after compression.

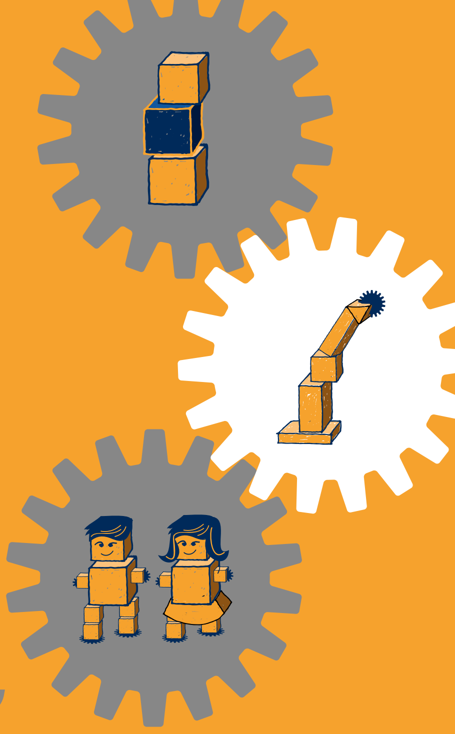
Picture from Benteler, Raufoss



Research activities in

Robust and Flexible Automation 2015





PhD Scholarship:
“Compliant Robotic Assembly Using Sensor Fusion”

This is a report summarizing the progress and work done for the PhD associated with Mathias Hauan Arbo in 2015.

Beginning

The PhD started in August 2015 with an initial assessment into the topic that was first chosen. Initially the topic of the PhD was tracking of flexible objects, and would involve combining visual tracking techniques with soft-body modelling. A preliminary literature survey was performed on this topic showing that the field was relatively new, and unexplored. Mainly due to the computational complexity of simulating true soft-body interaction for arbitrarily shaped objects. Without a predictive model that can be run in real-time, it was debatable whether a reasonable statistical tracking method could be devised.

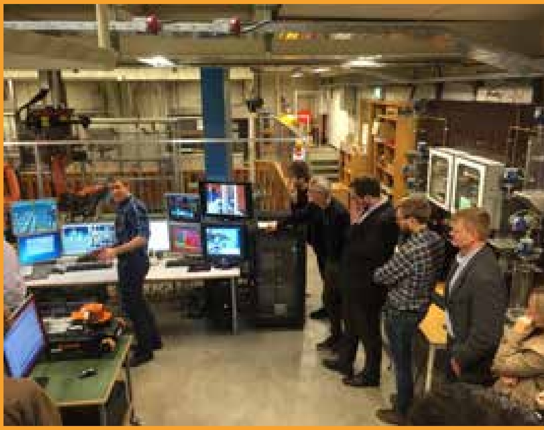
Impasse

Shortly thereafter, in discussions with industrial partners of the SFI, it became apparent that the tracking of flexible materials was not considered a significant issue in their area of manufacturing. Flexible objects are prevalent in many areas of manufacturing, but the question was whether robots handling them would need to track the objects’ movement, or just handle it in a more mechanical manner. As the objects are rarely moving freely, tracking was not considered relevant enough.

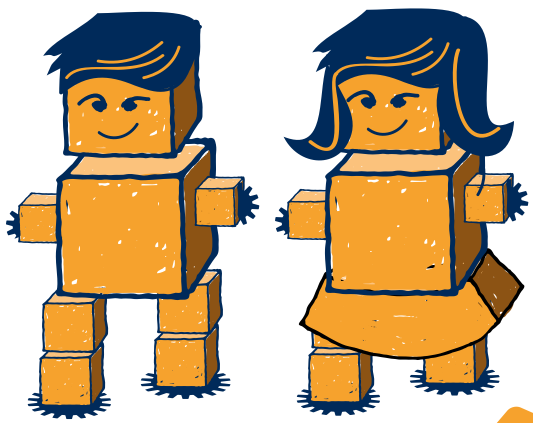
Resolution

A common trait among many of the industrial partners of the SFI is assembly. Based on the discussions and company visits conducted in 2015, as well as already available knowledge of the industrial processes and needs, it was decided to change the topic of the PhD to “Compliant Robotic Assembly Using Sensor Fusion”. This means that the topic has changed from looking at tracking of flexible objects, to looking at compliant assembly tasks, and which sensors benefit in what way. The main goal at the end of 2015 was to complete a preliminary project description, and a self-study syllabus that would contain a literature survey on the field.

PhD Work – Mathias Hauan Arbo



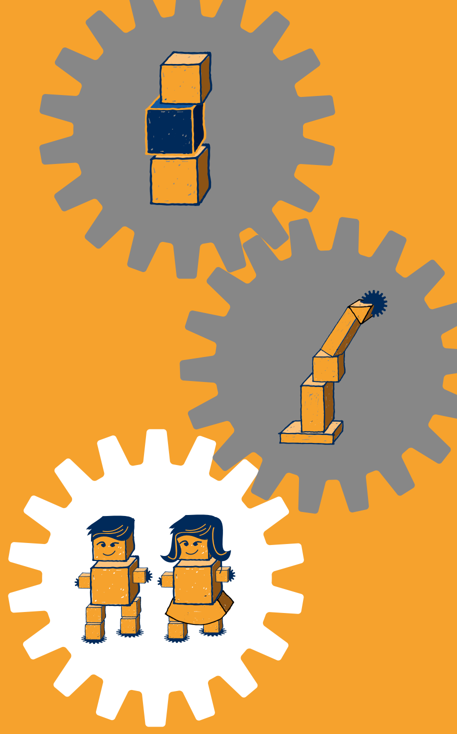
Picture 1
SINTEF ICT and NTNU IME robot lab.
In Trondheim



Research activities in

Innovative and sustainable organizations 2015

conferences research manufacturing NCE entrepreneurship cluster organization change abstracts engineering advantage SFI incubators success industrial network tool buddying workshop management participation framewok SRM thesis industry technology innovation readiness case learning development society study presentation outline



How to define the readiness level of organizations?

Discussions throughout the first two industry workshops in the SFI Manufacturing have addressed the challenge of developing a framework for how to decide whether an organization as a whole is ready to implement new technology.

The background for the discussions is TRL (Technology Readiness Level) that is applied by some of the industrial partners in SFI Manufacturing. Based on this realized gap between how we can decide when/how an organization is able to take on technology at defined levels – we have initiated a joint effort between the WPs in research area 3 to build more knowledge within this field and to develop an SFI Manufacturing Maturity Map.

The origin for the current TRL was developed for NASA in 1974. Around 2000 TRL was adapted by the United States Department of Defense (DoD), and has since been formally adapted in various organizations worldwide. DoD has also developed MRL (Manufacturing Readiness Level) to expand TRL to incorporate producibility (Sauser, Verma, Ramirez-Marquez, & Gove, 2006). Concurrently, since the 1970s numerous business process maturity models have been developed to assess and improve a company's capabilities to reach certain business goals (Van Looy, De Backer, Poels, & Snoeck, 2013), for example CMMI and OMG-BPMM.

The general purposes of maturity assessments can be descriptive: assessing strengths and weaknesses, prescriptive: foundations for improvements, or comparative: comparing a company towards other companies or best practice (Pigosso, Rozenfeld, & McAloone, 2013). For the SFI Manufacturing an additional purpose is to establish a common ground for communication and cooperation among industrial partners and researchers. Finally, the maturity mapping will be the basis for research contributions in RA3. We want to do a longitudinal study and plan to map the SFI Manufacturing maturity of the companies at three points of time during the SFI; for example year 2, year 4-5 and year 7. The recurring mapping will provide interesting knowledge on how a manufacturing company is developing, and overall it might provide an image of how technology shifts are influencing important characteristics of manufacturing companies.

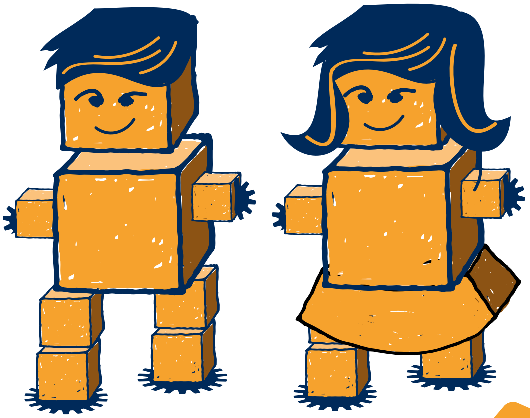
The tool will be based on state-of-the art within the three work packages:

Work systems and production systems in the future

Industrial networks and learning systems

Inavation and product development

The contribution from WP3, product and process innovation, will be to address specific challenges related to innovation and product development processes, for instance how these processes will be affected by sustainable measures, the coming manufacturing regime called Industrie 4.0, and not the least the organization's readiness to develop products with advanced multi-materials and production technology – in line with the scope of SFI Manufacturing.



How to define the readiness level of organizations?

In addition to state of art from the 3 work packages, the tool will be based on studies concerning maturity models. We are gathering information about technology readiness and search for eventual studies linked to organizational / manufacturing readiness. This work will continue in the first quarter of 2016 – with the aim to develop a survey to be continued along the timeline of the SFI Manufacturing to enable the definition of organizational readiness measures. The ultimate deliverable would be to have a maturity map – telling decision makers whether or not the organization is ready to take the next step change in technology innovation and implementation.

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Sauser, B., Verma, D., Ramirez-Marquez, J., & Gove, R. (2006). From TRL to SRL: The concept of systems readiness levels. Paper presented at the Conference on Systems Engineering Research, Los Angeles, CA.

Van Looy, A., De Backer, M., Poels, G., & Snoeck, M. (2013). Choosing the right business process maturity model. Information & Management, 50(7), 466-488. doi:http://dx.doi.org/10.1016/j.im.2013.06.002

International cooperation in 2015

The most important arenas for international cooperation for SFI Manufacturing is the European ETP Manufuture, Horizon 2020 and the international academy of Production Research, CIRP. Norway has a long tradition of participation in EU research framework programs (FP) and is a full member of the H2020 program [1].

The current challenges in Norwegian oil and gas sector highlights the need for a sustainable Norwegian manufacturing industry, and EU plays a major role in Research collaboration, suppliers and customers for Norwegian manufacturing industry.

1. SFI Manufacturing in EU Manufuture ETP

One of the major channels for external advice to the European commission (EC) regarding the funding of European research are European Technology Platforms (ETPs) and the Manufuture ETP is the Technology Platforms for manufacturing industry [3]. The ETPs are "industry-led stakeholder forum recognized by the European Commission as key actors in driving innovation, knowledge transfer and European competitiveness" [2]. The ETPs are developing strategic Research Agendas (SRA) and are giving advices on research topic and these are inputs to the texts in the FP calls for proposal. There are approx. 50 ETPs engaged by the EC, and Manufuture is one of the largest and longer lasting ETPs. Figure 1 shows the relation between Manufuture and some of the other ETPs.

Manufuture structure

A High Level Group (HLG) governs the Manufuture ETP, with support from the Implementation Support Group (ISG). Within the platform there is a number of technology focused sub-platforms, such as Additive Manufacturing [5] and Joining [6], as well as regional and national platforms, such as Manufuture Norge [7] in Norway. Manufuture has founded the European Factories of the Future Research Association (EFFRA) [8] to represent the private partners in the "Factories of the Future" (FoF)[9] public-private partnership (PPP) [10] in H2020.

Manufuture SRA 2030

The current EU framework for research, Horizon 2020 [11] will end in 2020 and the Manufuture ISG has started the work to prepare for a new strategy for 2030 (hopefully) to be implemented in EU 9th framework programme after H2020.

The SRA build for the H2020 Manufuture –a vision for 2020 [12] was focusing on European manufacturing competitiveness by transformation from cost orientation to adding value mostly where novel technology was major enablers. The new SRA will build on this and continue to focus on value creation and development of key enabling technologies for European manufacturing. In addition, it will develop strategies for how manufacturing takes a larger role in European social sustainability and on how to meet the European societal challenges. The new first draft of the SRA must

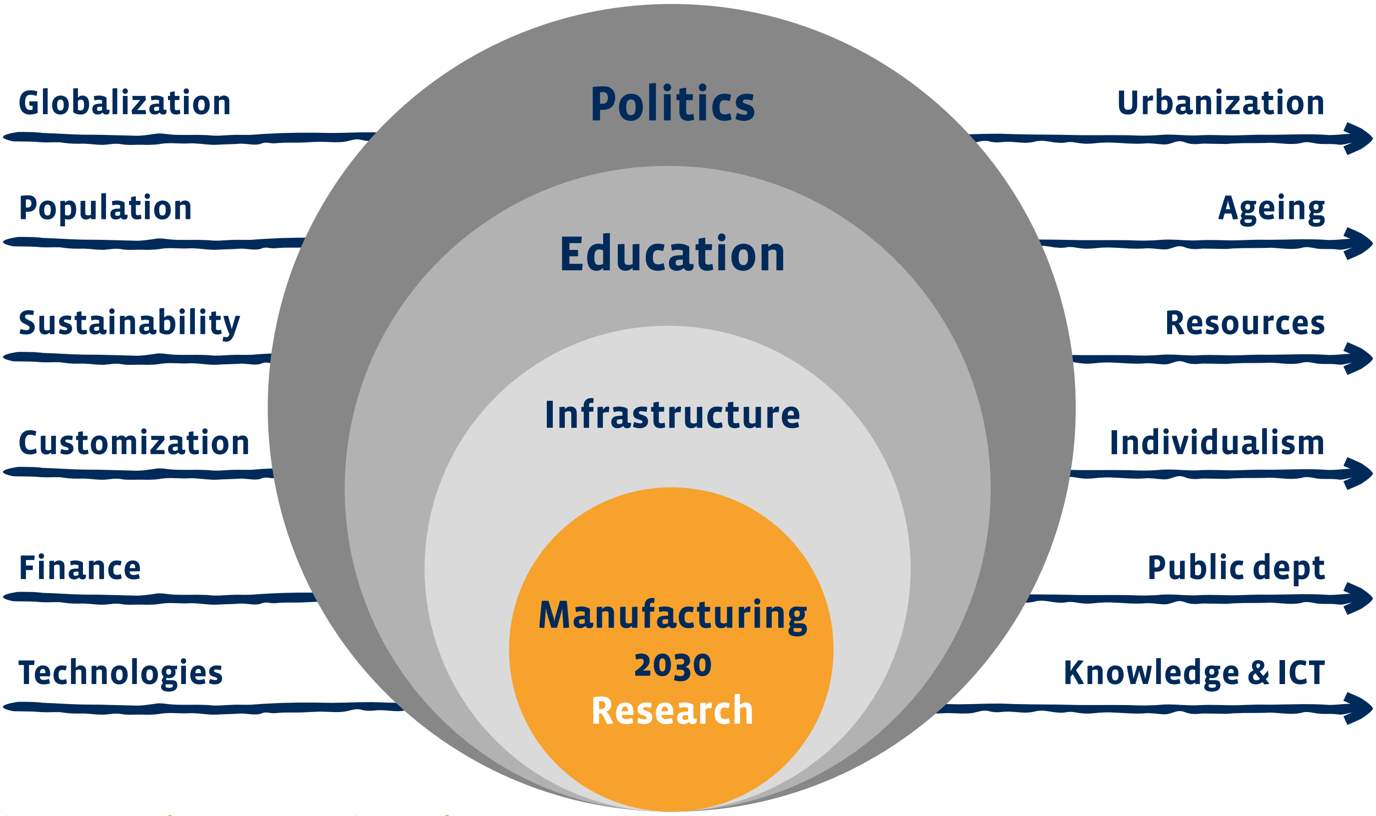


Figure 1: Manufuture SRA 2030 impact factors

be finished in 2017, in order to receive feedback from Manufuture members. A revised version should be approved by the HLG in 2018.

ISG and SRA
SFI Manufacturing is active in the Manufuture ETP and the shaping of the new SRA. The writing is organized by the ISG. SFI Manufacturing has a foothold in the on-going work through Prof. Kristian Martinsen who participates in the ISG. The objective is to strengthen the Norwegian influence on the new Manufuture SRA for 2030, making this SRA the best possible for Norwegian research and industry, and ensure relevant calls for Norwegian manufacturing industry in future EU Framework programs.

Manufuture HLG
Ottar Henriksen, Kristian Martinsen and Lars Stenerud are members of the HLG. The objective is both to ensure Norwegian Manufacturing influence as well as monitor the current European trends for manufacturing and manufacturing research.
Odd Myklebust is also the coordinator of the FOCUS –project which is a CSA (Coordination & Support Action) in the H2020 with focus on zero defects manufacturing, Robotics, Green Factories, Maintenance and High precision Micro Manufacturing. This CSA will be an important source for input to the SRA.

EFFRA
SFI Manufacturing participates at EFFRA meetings, Dr. Odd mykelbust has been most active.

Manufuture sub-platforms on Joining and additive manufacturing
The Manufuture organizes a number of sub-platforms. The most interesting for SFI Manufacturing are the ones on Additive Manufacturing[5] and Joining[6]. SFI Manufacturing participates in both. Kristian Martinsen is the chairman of the sub-platform on Joining [6] and Jon Sandvik is a part of the management committee.

Manufuture Norge
Manufuture Norge is the National Technology Platform (NTP) coordinated by Dr. Odd Myklebust at SINTEF Raufoss Manufacturing in collaboration with The Norwegian Research Council, Innovasjon Norge, Norsk Industri and Teknologisk Institutt. The NTP hosts a number of seminars each year, and has made a roadmap for Norwegian Manufacturing corresponding with the Manufuture SRA 2020.

2. SFI Manufacturing in H2020
SFI Manufacturing has a strong foothold in H2020 through the FOCUS-project (Factory Of the future CLUsterS). Factory of the Future (FoF) is one of

the Public Private Partnerships (PPPs) in H2020. The aim of FOCUS is to create clusters of FoF project activities, according to their objectives and addressed themes, in an effective way to enhance the impact of FoF projects. NTNU is the coordinator and Dr. Odd Myklebust is the coordinator.

Partners in the SFI Manufacturing consortium has prepared a number of proposals for calls in H2020 in 2015. The outcome of this will be reported later.

3. KIC AVM

The European Institute of Innovation and Technology (EiT) is a part of the EU Horizon 2020 program, and there is an open call for proposals for Knowledge and Innovation Communities (KIC) on Added-value Manufacturing (AVM). The deadline is July 2015, and SFI Manufacturing has participated in the preparation of a proposal based in the Manufuture Community. KICs are EIT's main operational arms. They are excellence-driven partnerships of: higher education institutions, research centers, and business and innovation stakeholders across Europe. A KIC typically has yearly budgets of 75 Mill € where EIT fund 25% of this. KIC AVM will have a head office in Germany and 5 Co-locations centers (CLC). In this setting, Norway is a part of "region North". The location of the CLC of region North is still to be decided, but SFI manufacturing will anyhow have an active participation in the KIC if we win the call.

4. CIRP

NTNU and SRM have members in the International Academy for Production Engineering (College International pour la Recherche en Productique, CIRP) and Rolls-Royce and Sandvik Coroment are examples of consortium industry partners that are members on corporate level. SFI Manufacturing was preparing and presenting a Keynote for the CIRP General Assembly in Cape Town in August 2015, with the title "Joining of Dissimilar Materials". NTNU, SRM and SFI manufacturing were given the task of organizing the 6th Conference on Learning Factories in June 2016 [14]. This will be an international conference with peer reviewed papers.

Impact on SFI Manufacturing

Participation in Manufuture and EFFRA gives SFI Manufacturing the advantage of direct insight and influence on EU reserach topics and priorities for the manufacturing area. Our SFI will have the possibility to influence the long-term strategic goals and vision by participating in the formation of a new Strategic Reserach Agenda (SRA) for Manufuture in 2020 to 2030, as well as direct influence on the formation of the last set of calls (2018, 19 ans 20) through EFFRA participation. CIRP membership gives the SFI an insight into the state-ofthe art of manufacturing research. An active participation in the discussions in the Scientific Technical Committees – where the keynote papers etc. are discussed are especially valuable. There will be reports from both CIRP, Manufuture and EFFRA for information and feedback from the SFI.

5. References

[1] http://ec.europa.eu/programmes/horizon2020/
[2] http://ec.europa.eu/research/innovation-union/index_en.cfm?pg=etp
[3] http://www.manufuture.org/manufacturing/wp-content/uploads/Manufuture-Technology-Platform-Brochure.pdf
[4] http://www.manufuture.org/documents/manufuture_vision_en%5B1%5D.pdf
[5] http://www.rm-platform.com/
[6] http://www.joining-platform.com/
[7] http://www.manufuture.no/?lang=no
[8] http://www.effra.eu/
[9] http://ec.europa.eu/research/industrial_technologies/factories-of-the-future_en.html
[10] http://ec.europa.eu/research/industrial_technologies/ppp-in-research_en.html
[11] http://ec.europa.eu/programmes/horizon2020/en/what-horizon-2020
[12] http://www.manufuture.org/documents/manufuture_vision_en%5B1%5D.pdf
[13] www.sfimanufacturing.no
[14] https://www.ntnu.edu/web/clf2016/

Picture from Hexagon Ragasco, Raufoss

Recruitment

The center has accelerated its recruitment plan of PhD candidates when we got the opportunity to hire two highly qualified and recommended students already in 2015. We are now working with them, their supervisors and planned mentors of new candidates in 2016 to establish a PhD network. A request for PhD candidates in 2016 was sent to the consortium and some potential candidates are proposed. A coordinated advertisement will be put out as soon as the work program for 2016 is approved.

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. 2015 started out with 10 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 on Twitter. So far, SFI Manufacturing has communicated 35 tweets and has 81 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
Jan Tommy Gravdahl	NTNU-IME	Senor fusion
Vegard Brøtan	SINTEF RM	Additive manufacturing, Multi material products cont. polymers
Olav Åsebø Berg	SINTEF RM	Additive manufacturing
Ben Alcock	SINTEF M&C	Additive manufacturing, Multi material products cont. polymers
Erik Andreassen	SINTEF M&C	Additive manufacturing
Kristian Martinsen	GUC	Additive manufacturing, Work systems and organization
Ida Westermann	NTNU-NT-IM	Multi material metallic products
Bjørn Holmedal	NTNU-NT-IM	Multi material metallic products
Per Erik Vullum	NTNU-NT-IF	Multi material metallic products
Randi Holmestad	NTNU-NT-IF	Multi material metallic products
Are Strandlie	GUC	Multi material metallic products, Multiscale modelling
Per Harald Ninive	GUC	Multi material metallic products, Multiscale modelling
Magnus Eriksson	SINTEF M&C	Multi material metallic products
Dirk Nolte	SINTEF M&C	Multi material metallic products
Hoang Hieu Nguyen	SINTEF M&C	Multi material metallic products
Giovanni Perillo	SINTEF M&C	Multi material products cont. polymers
Jesper Friis	SINTEF M&C	Multi material products cont. polymers, Multiscale modelling
Tèrence Coudert	SINTEF M&C	Multiscale modelling
Xiaobo Ren	SINTEF M&C	Multiscale modelling
Ole Martin Løvvik	SINTEF M&C	Multiscale modelling
Rune Østhus	SINTEF RM	Multiscale modelling
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 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
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
Geir Ringen,	SINTEF RM	Work systems and organization, Industrial clusters and learning systems, Innovation and product development
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-SVT	Work systems and organization, Innovation and product development
Asbjørn Karlsen	NTNU-SVT-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-SVT-IØT	Work systems and organization, Innovation and product development Industrial clusters and learning systems
Einar Hinrichsen	SINTEF M&K	Multi material
Lars Tore Gellein	SINTEF RM	Robotic handling of flexible objects, Flexible and integrated production systems
Kristian Martinsen	HiG	Additive manufacturing Multimaterial
Sverre Gulbrandsen-Dahl	SINTEF RM	Multimaterial
Emma Østerbø	SINTEF RM	Work systems and organization, Innovation and product development Industrial clusters and learning systems

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	2015-2018	F	Joining aluminium to steel
Mathias Hauan Arbo	Norwegian	2015-2018	M	Sensor fusion

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

Name	Funding	Nationality	Period	Sex M/F	Topic

Master Degrees

Name	Sex M/F	Period	Topic

Publications proposed classification

Journal Papers

Published Conference Papers

In 2015 SFI Manufacturing has presented one scientific paper: Author(s): K. Martinsen, S.J. Hu, B. E. Carlson
Title of the work Book/compendium/journal: Joining of dissimilar materials
CIRP Annal - Manufacturing Technology Page no.: 679-699
Issue/Volume/Year ISSN/ISBN: 2/64/2015 0007-8506

Books

Reports

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	2015
The Research Council	6.000
The Host Institution (Sintef Raufoss Manufacturing)	389
Research Partners*	2.114
Enterprise Partners*	4.110
Total	**12 612**

Costs	
The Host Institution (Sintef Raufoss Manufacturing)	5.098
Research Partners	5.204
Enterprise Partners	2.310
Public Partners	
Equipment	
Total	**12 612**

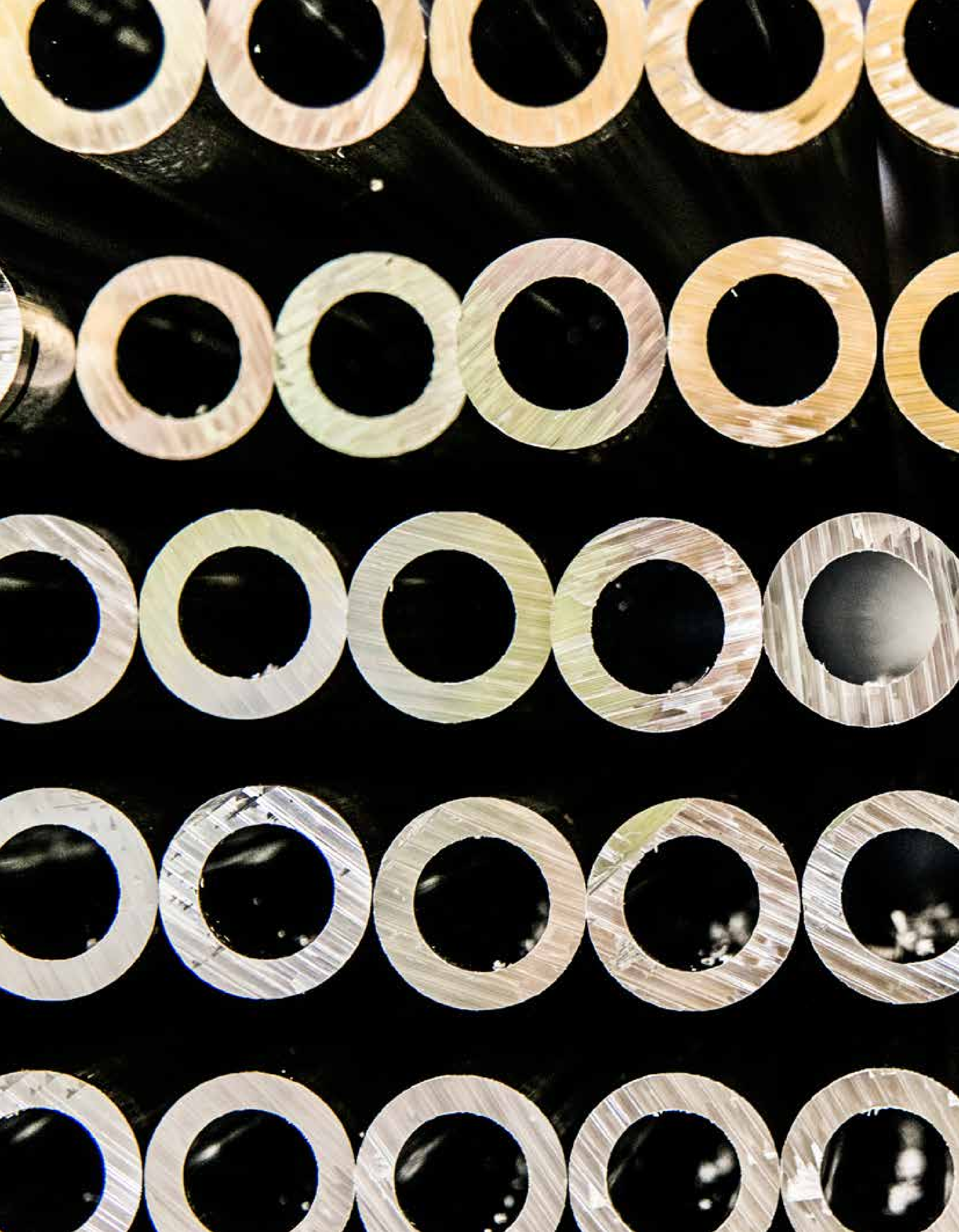
Enterprise partners*

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

Research Partners*

SINTEF IKT (Research Institute)
SINTEF MK (Research Institute)
SINTEF TS (Research Institute)
NTNU IME (university)
NTNU SVT (university)
NTNU NT (university)
HØGSKOLEN I GJØVIK (university)


Picture from Hexagon Ragasco, Raufoss




Picture from Benteler, Raufoss

Centre for Research-based Innovation
The Research Council of Norway

manufacturing

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