SIMLab

FINAL REPORT

sfi Centre for Research-based Innovation

SINTEF

NTNU – Trondheim
Norwegian University of Science and Technology

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Industrial partners in 2014

PERFECT Behaviour

Have a look at this photo. It was taken in Trondheim last May.

The fact is, several of SIMLab's partners are more or less directly present in this image. They all behaved perfectly at the scene.

Take a tiny example. Henning Fransplass works at the Norwegian Public Roads Administration. The topic of his PhD work at SIMLab was the properties of the steel bolts that hold safety barriers in place. If they are too brittle, they snap when subjected to impact.

In this case the impacting mass was more than 1800 kilos at around 80 km/h. If the bolts had snapped, the material and human kilos would have continued over the edge before hitting some very rugged landscape.

See how the safety barrier absorbed the energy. It gave in to the point where a number of poles were ripped out of the ground, without breaking. At the same time it behaved like a hammock, preventing the car from being bounced back onto the road.

Take the Audi. First it went straight over a roundabout. Then it took off, cutting a lamp post in two while in the air. Then it hit the barrier. The driver escaped unhurt. His passenger was released with minor injuries after one night in hospital. So, the Audi absorbed massive amounts of energy as well, protecting the people inside.

Take SIMLab's other partners. Benteler Aluminium Systems makes Audi bumpers, Hydro produces aluminium for them.

No photo could better illustrate how the design of protective and crashworthy structures saves lives. This is what SIMLab has been all about. The photo shows a road accident, but it is no accident that it ended so well. We are proud of our partners.

This final report is about our common achievements after eight years of cooperation. We are extremely happy that our partners and advisors rate us best in the world of protection and that we have been granted another eight-year SFI programme, Centre for Advanced Structural Analysis.

We are also very pleased that nearly all our present partners wish to continue the journey with us and that some exciting new partners have joined.

ÅTTE ÅR med brutale møter

Da SIMLab startet i 2007, var visjonen å etablere et verdensledende senter for design av kollisjonssikre og beskyttende konstruksjoner. Det har de klart. Målet er oppfylt.

SIMLab er historie. I åtte år har senteret torturert stål, aluminium og polymerere til bristepunktet og lenger enn det. Ingen har gått mer detaljert til verks for å finne ut så mye som mulig om materialene. Målet har vært å beskytte. Her er noen av detaljene:

Mikroskopisk

Visste du at det er like mange korn i en kubikkmillimeter aluminium som det er sandkorn på en strand? SIMLab har studert materialene ned til minste kornnivå for å finne ut nøyaktig hva som skjer når de blir utsatt for store deformasjoner fra en kollisjon eller eksplosjon. De har dratt og bøyd og strukket og varmet opp og kjølt ned. De har sett på kjernene og veggene i kornene og mellomrommene mellom dem. De har samlet alle funnene og brukt dem til å utvikle numeriske modeller, og de har puttet alt i en verktøykasse.

Til sammen vil SIMLab produsere 22 doktorgrader, 159 mastergrader, 157 publikasjoner i fagfellevurderte tidsskrifter, 176 konferansebidrag og 30 inviterte foredrag. De fleste tallene er dobbelt så høye som de opprinnelige målene.

Verktøykassen

Masse mennesker driver verdifull forskning som blir publisert og vinner vid anerkjennelse. Dessverre havner mange av publikasjonene i skrivebordskuffer.

SIMLab var et Senter for forskningsdrevet innovasjon. De hadde et spesielt ansvar for å sikre at funnene kom til nytte. For å oppfylle ansvaret, utviklet de SIMLab Tool Box, som industripartnerne bruker i sitt eget innovasjonsarbeid, enten det dreier seg om utvikling av den ideelle aluminiumslegering til en støtfanger, en sikrere konstruksjonsdetalj eller en mer kollisjonssikker del av plast.

Og ja, SIMLab er historie, men arbeidet for å utvide og gjøre verktøykassen bedre og mer brukervennlig fortsetter i en samlet innsats med partnerne.

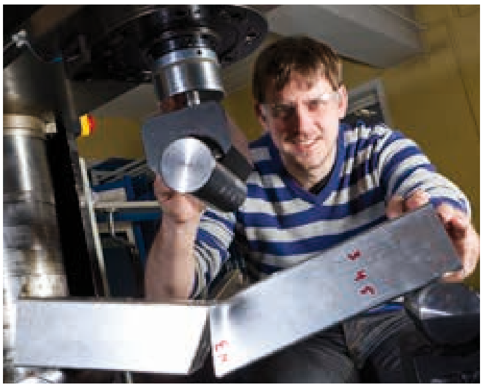
Alt på en gang

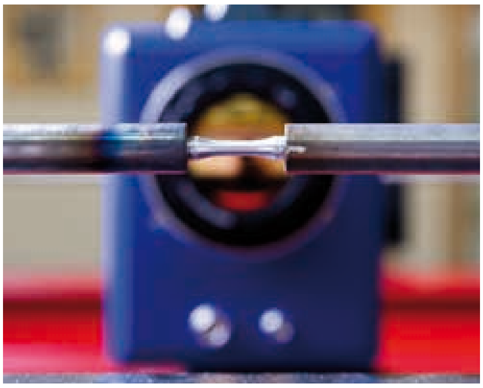
Hva gjorde SIMLab verdensledende? I følge de vitenskapelige rådgiverne og partnerne, var det kombinasjonen av sterke og dynamiske medarbeidere med bred, teknisk kunnskap og komplementær ekspertise, som alle jobbet sammen med et felles formål og med godt lederskap og driv.

Det var evnen til å behandle grunnleggende mekanikk og tester i laboratoriet, utvikle og implementere modeller og gjennomføre valideringstester, alt på en gang.

CASA

Dette er viktig, for det er stort behov for å lære mer om konstruksjoners integritet i olje og gass, transport og bygninger, om konstruksjoner som er sikre ved eksplosjoner og andre typer belastning. Heldigvis kan det verdensledende miljøet fortsette i samme retning. Når SIMLab stenger, åpnes et nytt kapittel. Forskerne har blitt tildelt et nytt SFI. Det nye Centre for Advanced Structural Analysis kommer til å kunne gå enda lenger i detalj, multi-skala testing og modellering koblet med brukervennlighet. Oljerigg-appen er på veg.





EIGHT YEARS of Brutal Encounters

When SIMLab started in 2007, the vision was to establish a world-leading centre for the design of crash-worthy and protective structures. That's exactly what they have done.

SIMLab is now history. For eight years the Centre has tortured steel, aluminium and polymers to the point of fracture and beyond. No one else has worked in greater detail to find out as much as possible about the materials. The aim has been to protect. Here are some of the details:

Microscopic

Did you know that there are as many grains in one cubic millimetre of aluminium as there are sand grains on a beach? SIMLab has studied the materials down to granular level to find out exactly what happens when the grains are subjected to large deformations from impact and explosion. The researchers have torn, bent and stretched, heated and cooled down. They have looked at the cores and the walls of the grains and the voids between them. They have gathered all the findings, used them to develop numerical models and put them all in a box.

All in all, SIMLab will produce 22 PhD and 159 master's degrees, 157 publications in peer-reviewed journals, 176 conference contributions and 30 keynotes. Most of these figures are twice the original goals.

The Tool Box

A lot of people do good research that is published in papers and wins wide acclaim. Unfortunately a lot of these papers end up in drawers.

SIMLab was a Centre for Research-based Innovation. It had a special responsibility to make sure the findings became useful. To fulfil that responsibility it developed the SIMLab Tool Box. This enables the partners to access massive amounts of information from their own computers to help them in their further innovation work. This will help them find the ideal aluminium alloy for a car bumper, a safer structural detail, or a more crashworthy part of fibre reinforced polymer.

And yes, SIMLab is history, but the work to amplify and make the Tool Box better and more user-friendly goes on in a joint effort between the partners.

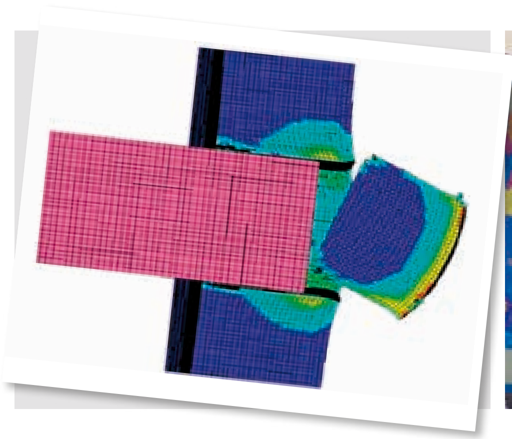
All at once

What made SIMLab world leaders? According to the scientific advisors and partners, it was the combination of strong, dynamic people with broad technical knowledge and complementary expertise who all worked together with a common purpose and good leadership and drive.

It was the ability to deal with basic mechanics and fundamental tests, to develop and implement models and validation tests and to incorporate failure in the simulating tools, all at once.

CASA

This is important, because there is a need to learn more about structural integrity in oil and gas, transportation and buildings, about secure structures against blasts and other kinds of loads. Luckily, the world-leading team can continue down that road. As SIMLab closes, a new chapter opens. The researchers have been granted another SFI. The new Centre for Advanced Structural Analysis will be able to go even further in detail, multi-scale and user-friendliness. The oil-rig app is coming up.



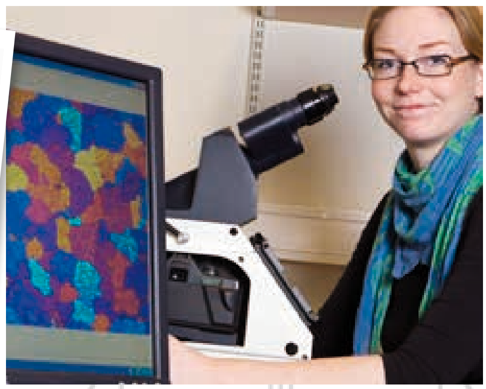


Photo: Ole Morten Melgård

Meet the SIMLabs

Outside observers, cooperating partners, host institution and students alike: amazingly many compare them to a family. Here's a quick introduction to the SIMLabs.

Most families have a father. In this case, it's Magnus Langseth. He's not just any father. When the Research Council of Norway wrote their Midway Evaluation of SIMLab, they described him like this: "of remarkable scientific and professional management quality".

Professor Langseth is Editor-in-Chief of the International Journal of Impact Engineering and sits on the editorial boards of the International Journal of Mechanics and Materials in Design, Multidiscipline Modelling in Materials and Structures, and Ships and Offshore Structures. In short, he is a world capacity in his field. He was awarded the "Médaille Albert Portevin 2005", Société Francaise de Métallurgie et de Materiaux. Finally, he is an honorary doctor at the University of Valenciennes and a moose hunter.

The core

Within each family there's usually a core. Here too. Odd Sture Hopperstad definitely belongs to the core. He is described by his colleagues, partners and scientific advisors as a key scientist at SIMLab. He is member of the Editorial Advisory Board of International Journal of Impact Engineering and Associate Editor in European Journal of Mechanics – A/Solids.

Tore Børvik is another prominent member of the core family. He is Associate Editor of the International Journal of Impact Engineering.

This makes for a total of three editors in international peer-reviewed journals, an indication that the SIMLabs differ slightly from your average family.

Best teacher

The SIMLabs are slightly more organized than most families. Professor Hopperstad heads the Fracture and Crack Propagation programme while Professor Børvik heads the Optimal Energy Absorption and Protection programme. There are three more: The Polymers programme is headed by Professor Arild Holm Clausen, the Multi-Scale Modelling of Metallic Materials programme by Professor Odd-Geir Lademo and the Connectors and Joints programme by Dr David Morin.

Holm Clausen was awarded the Norconsult prize as the best teacher in the Civil and Environmental Engineering programme at NTNU in 2011.

Always a woman

Luckily, there's always a woman behind or, as in this case, in front. Professor Aase Reyes is the female part of the core family. The final professor in the core is Knut Marthinsen, while Peter Karlsaune coordinates them all.

The SIMLabs have a home, of course. It's called the Department of Structural Engineering at the Norwegian

SIMLab's core family, from left: Peter Karlsaune, Knut Marthinsen, Odd-Geir Lademo, Tore Børvik, Magnus Langseth, Aase Reyes, Odd Sture Hopperstad, David Morin and Arild Holm Clausen.

University for Science and Technology (NTNU). The Department of Materials Science and Engineering and SINTEF Materials and Chemistry take good care of them, too.

The elders

Families with grandparents are privileged. They get sound advice from knowledgeable elders. SIMLab's grandparents are also known under the name Scientific Advisory Board. They come from six leading universities and research organizations in six countries:

Professor Ahmed Benallal, LMT-Cachan, France
Professor Em. David Embury, McMaster University, Canada
Professor John Hutchinson, Harvard University, USA
Professor Em. Norman Jones, University of Liverpool, UK
Professor Larsgunnar Nilsson, University of Linköping, Sweden
Professor Klaus Thoma, Ernst Mach Institute, Germany

Lots of friends

The SIMLabs have lots of friends. Some of them are called partners. Each partner has a member on the family board:

Host institution:
Karl Vincent Høiseth, Professor/Head of Department, Department of Structural Engineering, NTNU (Chairman)
Per Kr. Larsen, Professor Em., Department of Structural Engineering, NTNU
Astrid Vigtil, Head of Research Section, Faculty of Engineering Science and Technology, NTNU

Research partner:
Rudie Spooren, Vice President Research, SINTEF Materials and Chemistry

Industrial partners:
Thomas Hambrecht, Head of Functional Design Body, Audi AG
Håvar Ilstad, Manager Pipeline Technology, Statoil
Hans Erik Vatne, SVP, Head of Technology, Hydro
Joachim Larsson, Head of Product Development, SSAB Europe
Tsukatada Matsumoto, Senior Project Manager, Toyota Motor Europe
Thorsten Rolf, Teamleader, Methods Simulation – Body in White, BMW Group
Anders Artelius, Head of Aluminium Technology, Benteler Aluminium Systems
Eric Vaillant, Head of Department for Analysis, Behaviour and Environment Materials, Renault

Public partners:
Helge Langberg, Head of the National Centre for Protection of Buildings, Norwegian Defence Estates Agency (NDEA)
Sigurd Olav Olsen, Director of Civil Protection, Norwegian Public Roads Administration (NPRA)

"Incredible!"

Family life at the SIMLabs is quite structured. Work is done according to annual work plans and the core members meet once a week.

But what is it that they do that brings forward the comparison with a family over and over again? Grandfathers David Embury and John Hutchinson say a few words about it on page 19.

Anne Serine Ognedal put it like this shortly after entering her PhD project: *"Little me working with world-class scientists. When I entered the programme, the professors asked: "What would you like to do?" Incredible!"*

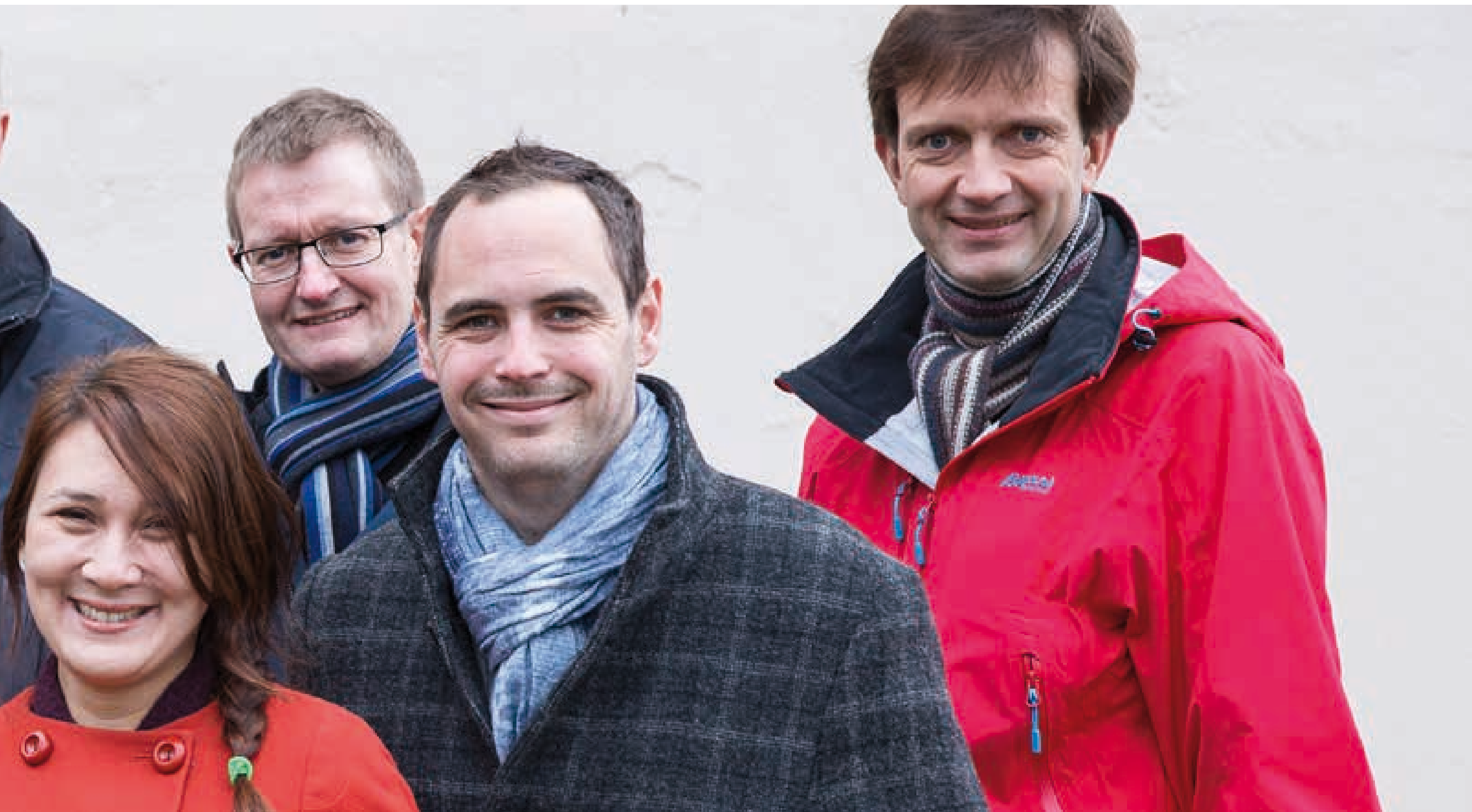


Photo: Ole Morten Melgård

The Oil Rigg App is Coming Up

Of course it is wonderful when our partners and advisors rate us best in our particular world of protection. But why is it so? What have we done?

Let's try to explain by the help of history. When the first Liberty ships in the Second World War sailed north, some of them literally broke in two. They were made of cheap steel that became brittle and fractured in the cold. Lack of knowledge and understanding was obvious.

Total control

Imagine on the other hand an oil rig in Arctic waters where you have total control of all material and structural details. You know exactly how your steel pipes will behave at minus 30 and how your aluminium parts will interact with rubber seals or ice at any given impact or temperature change. Everything has been calculated, measured and simulated and you can reach it all by an app on your mobile.

This isn't fantasy. The work to get there is going on now and it's essential. SIMLab is part of it.

Great detail

What SIMLab has done, is to study the behaviour of materials and structures to find out how they react when subjected to different kinds of impact and temperature change.

There are many kinds of impact: collisions, explosions, bullets. Through innumerable experiments under careful observation everything is registered and measured. On the basis of this, numerical models are developed for simulating what will happen in each case.

Liberty ship SS John P. Gaines broke in two and sank in a storm off the Alaskan coast on 24 November 1943. The steel became too brittle in the cold.

Millions of grains

To give an image about the operating level: One cubic millimetre of aluminium contains as many grains as there are grains of sand on a beach. SIMLab partner SINTEF is already moving down to atom level to find out even more. With good reason; it turns out that while the aluminium grains are sturdy little creatures, there are thinner zones between them that we know very little about. They may become soft in a collision, causing a car bumper or other protective structure to fracture. That would in turn increase the risk of somebody getting hurt.

Limited scope

SIMLab's scope is ambitious but limited. The aim has been to establish a world leading centre for the design of crashworthy and protective structures. Research has mainly focused on aluminium extrusions and plates, aluminium castings, high-strength steels and polymers.

The Centre has worked in three basic research areas: materials, solution techniques and structures. They have in turn been linked by five research programmes, also called work packages. Let's go through them by help of examples.

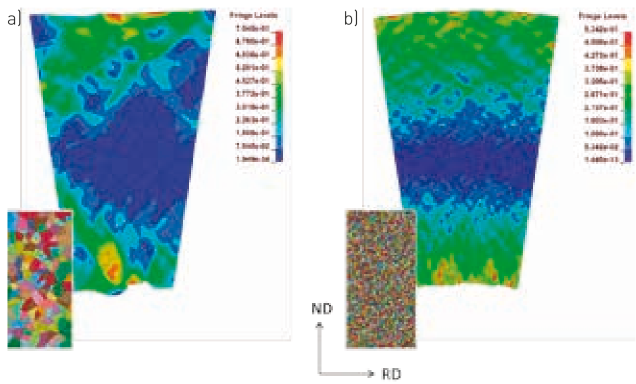
Fracture and Crack Propagation

In his PhD research Egil Fagerholt used a camera to study fracture and crack propagation. With the help of 10 000 high resolution exposures per second he generated massive amounts of field information directly from the test. Then he developed algorithm series to analyse these image series.

Gaute Gruben picked up where Egil left to develop new fracture models for steel and Octavian Knoll has done the same for aluminium pressure die castings.

Optimal Energy Absorption and Protection

Martin Kristoffersen's thesis dealt with the impact of trawl gear on a pipeline. He studied what happens first when the pipeline is hit and deformed, and when it rebounds due to axial tension forces. The findings are of considerable interest to Statoil. Knut Gaarder Rakvåg studied the response of structures subjected to blast and fragments.



Effect of texture and grain shape on the bendability of AA7108 in a) as cast and homogenized and b) rolled and recrystallized conditions. Fringes represent the predicted plastic strain.

Polymers

The topic of Anne Serine Ognedal's thesis was to help computers predict how polymers in a bumper deform when a car hits a pedestrian. The result helps to try out different designs of polymers on the computer in search of a bumper that doesn't hurt the pedestrian. Petter Holmstrøm's project is the modelling of fibre-reinforced materials.

Multi-scale Modelling of Metallic Materials

Mikhail Khadyko's thesis dealt with fundamentals of multi-scale modelling, Dmitry Vysochinskiy's with formability of sheet metals, Anizahyathi Alisibramusili's with capacity and ductility of welded structures and Vincent Vilamosa's with behaviour of aluminium at wide ranges of strain rate and temperature.

Connectors and Joints

Nguyen-Hieu Hoang investigated the possible use of self-piercing aluminium rivets in the car industry. Recycling of aluminium bodies would have become more eco-friendly and less costly without having to remove the thousands of steel rivets. Unfortunately, the thesis proved that this isn't feasible quite yet.

On the next few pages you will learn how the work packages unite in a common tool that industry can use and how the results of eight years' work are taken care of for future research and industrial applications.

Photo: Harald Pettersen, Statoil

How to Create a Tool Box

A bit into SIMLab's eight-year programme, the industrial partners started to ask with urgency: would the research give them the innovative tool they needed? Now this tool is in place.

Audi's Thomas Hambrecht first launched the idea of a tool box. He was familiar with similar tools elsewhere. In the beginning, the concept was met with considerable scepticism, not the least in the Scientific Advisory Board. There was fear that it would be costly to maintain both in money and manpower and have a negative impact on research.

Debate

A healthy debate followed. Odd-Geir Lademo became a key player. He heads two programmes at SIMLab: the one on Multi-scale Modelling of Metallic Materials and the one on Industrial Demonstrators. The exact objective of the latter is to facilitate industrial implementation of the results obtained.

As it happens, Lademo is also research director at SINTEF Materials and Chemistry. In that sense he is the personification of the tight links between NTNU and SINTEF.

Optimizes symbiosis

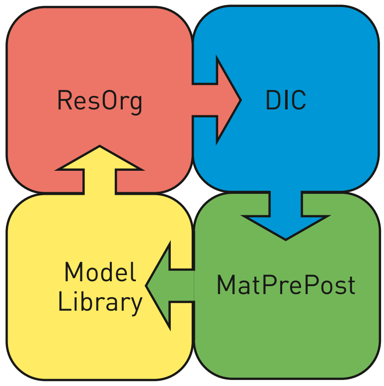
"The SIMLab Tool Box optimizes the symbiosis between NTNU and SINTEF. Each of us is too small alone. The development of the software was only possible through the symbiosis," he says. He is convinced the right decision was made:
"The Tool Box actually saves time. We have become more efficient."

The Tool Box is getting more user-friendly by the day. A bunch of dedicated researchers and students are steadily improving the software and constantly adding new features.

Inside the Box

The key elements in the Tool Box were first presented in the 2011 annual report. A value chain for non-linear numerical analyses was defined and a number of software products were introduced; a Results organizer, 'ResOrg', Digital Image Correlation, 'DIC', 'Mat-PrePost' and finally a 'Model Library' consisting of Solution techniques, 'SolT(s)' and user-defined material models, 'UMAT(s)').

The SIMLab Tool Box was defined as the resulting cluster of the software products, where components may be used separately or in combination. Here goes:



SIMLab Tool Box software products.

ResOrg

is designed to support experimental planning, execution and processing. The software includes order forms for machining of specimens, specimen geometries in the form of drawings and CAD files and test protocols. The software represents a Graphical User Interface.

DIC

allows determining the displacement field on material/structural tests based on digital images. The software is able to handle 2D as well as 3D measurements using what is termed a Q4 formulation. Unique features to deal with crack propagation are implemented, like element erosion and node splitting techniques. The computational part of the DIC software is heavily parallelized to get very efficient computation times.

MatPrePost

is a tool for parameter identification and tailored pre- and post-processing. The outcome of the pre-processing utility includes visualizations of the model concept, predicted Forming Limit Diagrams and fracture locus plots, and formatted and quality assured input for the user-defined material models. The tool supports output to various FE codes used by the partners in SIMLab.

This translation into language used by industry is fundamental to make the box useful as the innovation tool each partner is after.

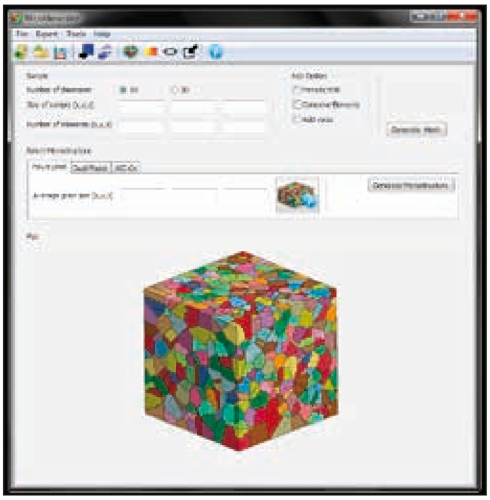
Photo: Ole Morten Melgård

PhD candidate Octavian Knoll is waiting for the fracture of the specimen.

The Model Library

is a collection of customized, user-defined material models, UMAT(s), and Solution techniques, SolT(s). The three most important UMAT(s) are the SIMLab Metal Model (SMM), the SIMLab Crystal Plasticity Model (SCPM), and the SIMLab Polymer Model (SPM). Each is built upon a modular strategy, includes options for speed and accuracy, and is thought to fit the needs for all partners in the consortium.

The Model Library can be linked to several FE codes, such as LS-DYNA, ABAQUS, PAM-CRASH and IMPETUS, used by the partners.



GUI for SIMLab MicroGenerator.

Back to the school bench

In November 2013 all user partners took part in the first SIMLab Tool Box workshop. After an in-depth presentation of the metal and polymer models, the partners got hands-on training. This included experimental work in the laboratory and material tests on steel, aluminium and polymers. The final part was dedicated to numerical analysis and case studies with validation. All partners were very satisfied with the workshop and presentations. At the same time they stressed the need for user-friendliness in the continuing development of the Tool Box.

Daily use

Renault, Toyota and Audi have dedicated staff working specifically to implement the use of the Tool Box in their respective companies. Several partners have spent weeks of intensive training at SIMLab, following one of the recommendations in the Midway Evaluation. Partners like Benteler and NDEA use the fracture models in their daily design work.

Very useful for CASA

Nearly all SIMLab partners are members of the new SFI CASA, where the Tool Box will be a vital instrument for further industrial innovation. A set of tutorials and example studies are on the way to further facilitate the implementation.

Deadly Serious FUN

Smashing something to smithereens can bring out the purest of childhood joys. Seeing SIMLab's brand new shock tube at work is definitely a thrill. The backdrop, unfortunately, is deadly serious.

22 July 2011 will go down in history as one of Norway's darkest moments. The bomb attack on the Norwegian government's offices killed 8. A further 69 were killed on the island of Utøya.

Just months before, SIMLab director Magnus Langseth had challenged the Scientific Advisory Board (SAB) on where to go next. The answer was anti-terror.

Not clairvoyant

When terror struck, the advice seemed almost spooky in its déjà vu character. But it had nothing to do with clairvoyance. It had to do with some basic facts.

First, NTNU's collaboration with the Norwegian Defence Estates Agency dates much further back than the establishment of SIMLab as an SFI. It dates from times when both institutions had other names.

Second, SAB knew this well. They also knew that SIMLab had the personnel and equipment to make them better suited for the task than anyone else in Norway.

Third, the SAB itself was well equipped to give advice on this topic. In particular, John Hutchinson, for one, had decades of experience as advisor to the US armed forces.

Fourth, developments on the international scene made the choice logical. In that sense, 22 July was only terrifying confirmation.

The inauguration of SIMLab's new shock tube attracted large interest from a number of government bodies, partners and the media. PhD candidate Vegard Aune explains.

Glass is dangerous

Lucky Vegard Aune: he ended up with the conclusion. The work on his PhD thesis is all about destruction. And he's got a brand new toy to do it. It cost NOK 6 million. For years, SIMLab had worked to get one very important instrument in place to further strengthen their test facilities. The shock tube is a well-known experimental set-up in gas dynamics to investigate the response of materials and structures subjected to blast waves.

The relevance was strongly confirmed by the 22 July bomb explosion. Windows were shattered 500 metres away. In addition to eight killed, 209 were injured, very many by flying glass.

Inauguration

The SIMLab Shock Tube was inaugurated on 20 October 2014. Partners and representatives from several government bodies on national security and building safety were present. The Norwegian National Security Authority has contributed significantly to the funding of the tube.

The first official test was performed on laminated glass. This represents an amplification of SIMLab's scope from the original concentration on metal and polymers. It also marks the transition to CASA, the next SFI Centre that takes over where SIMLab stops.

Compressed air

The guests at the inauguration were able to see the fragments flying when a shock wave hits a window pane. Pressure is generated in a closed section at the end of the tube. The section is separated from the rest of the rig with a diaphragm and is filled with compressed air. The diaphragm bursts at a given pressure and releases a shock wave. The characteristics of the wave can be studied by measuring the shock velocity and pressure downstream the diaphragm. Test objects can be placed in a test section and in the dump tank where windows allow video recordings with high-speed camera. The pressure can be measured at 20 locations enabling the measurement of the shock velocity.

The shock tube will be used to obtain experimental data on structures exposed to shock loading. These experiments will then be used to validate computational methods in terms of robustness and effectiveness.

The high-rise symbol

Anyone who has seen a photo of the Norwegian government's office building after the 22 July explosion remembers the windows that are not broken. They symbolize the value of increased expertise in the field of anti-terror.

Photo: Øyvind Buljo, NTNU

The Contrast

Sometimes a contrast illustrates matters better than the real thing. While at SIMLab, Ida Westermann and Gaute Gruben created the perfect example. Nothing is less crashworthy than a baby.

In their PhD theses, Ida Westermann heated aluminium to provoke artificial ageing while Gaute Gruben tormented steel plates to the point of fracture; nothing near baby care. Still, there is a connection. The heating and tormenting both serve SIMLab's vision: the design of crashworthy and protective structures. The exact aim of these structures is to protect little Idunn and the rest of us.

How to hook

So where does this story start? Ida Westermann fell in love with aluminium at the age of eighteen. Raised in the Danish village of Bredebro, she was invited to spend two weeks at the nearby plant of the Norwegian aluminium firm Hydro. After learning about extruding and plastic forming, she was invited to visit NTNU in Trondheim and the Hydro plants in Sunndalsøra and Raufoss. She was hooked: her future was in metal.
Gaute Gruben is as Norwegian as they get. He started out as a carpenter in the northern town of Mo i Rana. Before long, he realized he had an appetite for more. Towards the end of his fourth year at NTNU, SIMLab director Magnus Langseth turned up in class. He had been given five minutes. That was enough to trigger further interest. "I soon learned that the Department of Structural Engineering held a reputation as particularly competent with a number of especially gifted researchers. A few of us were also offered competitive salaries as there was extra work waiting to be done," Gaute adds.

How to bake a bumper

At SIMLab, Ida baked bumpers. As is the case with bread, finding the right balance between time and temperature is crucial. Possible aims are to reduce weight and find strength. Strong metal may become crunchy. Reducing strength increases bendability and ductility: sought-after qualities in bumpers when you want to reduce injuries to people.
Gaute tortured steel plates for SSAB, a Swedish manufacturer and SIMLab partner. Pulling the plates until they broke in the middle, he continued simulating the experiments with numerical models. From there he collected data to determine the fracture characteristics of the material. The data were used to calibrate different types of fracture criteria. He also tested numerical techniques for simulating crack propagation.

Particularly positive

Ida sums up her stay at SIMLab like this:
"The atmosphere was particularly positive, both professionally and socially. The dialogue was good between the PhD candidates and between the candidates and professors."
She had a lot of contact with fellow students in other places and feels confident that communication with the professors was much better at SIMLab than elsewhere. She thinks part of the explanation is the physical surroundings, with everyone located next door to each other. This helped bring about a degree of personal relations with the peers that she had never expected upon arrival.
Gaute agrees: "As a master's student you don't get that close. You don't really get to see this side of the professors until you start as a PhD candidate. It was a very pleasant experience."

On to SINTEF

After defending her PhD thesis, Ida was hired by SIMLab partner SINTEF. "I worked mostly on aluminium, but have also assisted my former colleagues at SIMLab," she says. In particular she provided very useful data for Martin Kristoffersen's thesis on how to design subsea pipelines.
One of her former peers, Professor Tore Børvik, happily hands out credits: "Ida is probably the most versatile among those who have defended their PhDs with us. Her complementary expertise has come in useful on numerous occasions," he says.
Ida has just left SINTEF and returned to NTNU as associate professor at the Department of Materials Science and Engineering. In the time to come, she will mainly work with steel.

EU programme

Gaute's former supervisor, Professor Odd Sture Hopperstad, points out Gaute's contribution in the development of new fracture models for steel. Today they are incorporated in one of SIMLab's most important achievements, the Toolbox.
Gaute presently holds a post doc position at SIMLab verifying and validating numerical models in much the same way as he did for his PhD. His work is part of an EU Eurostars programme where NTNU, Norwegian/Swedish software firm IMPETUS Afea, NVIDIA Corporation and Fiat are partners.
IMPETUS Afea offer services in computational mechanics and are mainly active in offshore, automotive, fortification and aeronautics.
"My models help verify the compatibility of programme updates," Gaute explains.

Tangible result

Daughter Idunn hasn't had time yet to reveal if she prefers steel or aluminium, automotive or fortifications. In either case she will most likely become a very strong girl and probably the most charming and tangible result of SFI SIMLab.

Photo: Ole Morten Melgård

GENERIC is the NEW SEXY

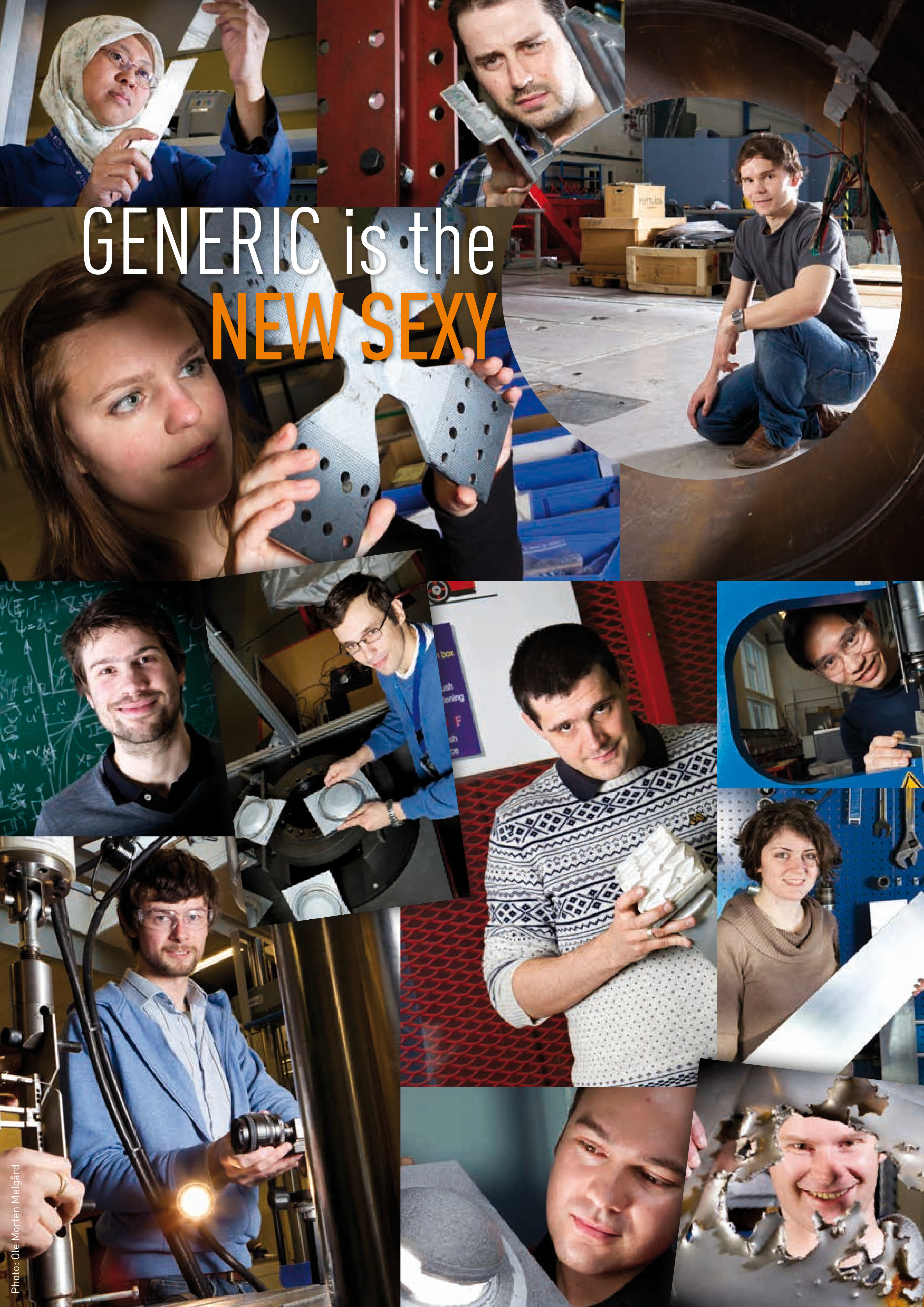


Photo: Ole Morten Melgård

When Virgile Delhaye joined SIMLab as a PhD candidate, he came from Renault. The plan was to return, but love conquers all. Now he's with Aker Solutions. They wanted a car guy.

The fact is, in some aspects the people in oil and gas have a lot to learn from the automotive industry. The fierce, world-wide competition has sparked some pretty advanced methods for material testing, modelling and numerical simulations that may save the oil and gas industry vast amounts of money. Therefore, Delhaye's expertise on ductile thermoplastics for crash applications is useful in the work with other materials as well. The methodology is the same.

The beauty of science

That's the beauty of science. It's generic. It makes Delhaye and his fellow PhD graduates from SIMLab very attractive on the work market.

Being recruited to Aker Solutions in August 2014, in a time of lower activity on the Norwegian continental shelf, is something of a feat, but then Delhaye hasn't been fooling around since finishing his PhD in 2010. He continued his research in SINTEF until Aker Solutions hired him.

"For my master's degree, I wanted to work closely with industry. Through my engagement with Renault, I got to know SIMLab. Taking my PhD there was a positive experience. They have excellent people and research, strong industrial contacts and a very good network in Norway," he sums up.

Best among 1500

Delhaye is far from the only one doing well. At the 32nd International Conference on Ocean, Offshore and Arctic Engineering in France in 2013, Martin Kristoffersen's paper "Damage and Failure in an X65 Steel Pipeline Caused by Trawl Gear Impact" was selected best among nearly a thousand contributions from the Structures, Safety and Reliability Symposium.

The basis for his research was an incident in the North Sea that forced a platform to close down production for half a year, costing millions of dollars in delayed production and repair.

"The stay at SIMLab was very rewarding," says Kristoffersen. "My supervisors, Professors Børvik, Hopperstad and Langseth are extremely able and they complement each other in an excellent manner. From a professional point of view I couldn't have asked for a better team and on the personal level it has been very pleasant as well."

Kristoffersen isn't finished with research. After defending his PhD thesis at the end of 2014 he entered a three year post doc financed by the Norwegian Public Roads Administration. The aim is to find out how one best can protect a submerged floating tunnel crossing the Sognefjord against internal explosions. If built, the 3.7 km crossing will be the first of its kind in the world.

Full circle

Anne Serine Ognedal has gone full circle. She's back where she came from, at Laerdal Medical. Before entering her PhD programme, she worked on advanced manikins; the anatomical models that give correct responses to all kinds of impulses, pupils expanding with increased adrenalin and all.

"I love plastic! It's a fantastic material with endless possibilities," Ognedal said. She felt extremely privileged to be at SIMLab:

"People don't know how great it is to do a PhD. Little me working with world class scientists. When I entered the programme, the professors asked: "What would you like to do?" Incredible!"

Personal efforts needed

These three examples and the story on the Westermann/Gruben family hopefully illustrate the diversity and generic skills of the SIMLab PhD graduates, their usefulness to industry and to society as a whole.

Some of the latest candidates to be recruited comment on the importance of early efforts to trigger interest:

"Arild Holm Clausen's lectures were crucial. He was very active in his approach. He was our tutor during summer jobs with Statoil and encouraged us to apply for the vacant PhD positions."

They emphasize that advertising PhD positions is not sufficient. "We need to have a relationship with the people that recruit. In that sense Arild Holm Clausen and Tore Børvik's personal efforts made a whole lot of difference to us."

Twice the goals

SIMLab will produce 22 PhDs and 159 master's degrees. Both figures are twice the original goals. This is a function of active recruitment campaigns as well as the excellent national and international reputation of the research group. A practically oriented course has been developed to expose students to the Centre's activities.

Members of the core team have taught courses relevant to the Centre both at master's and PhD levels. This visibility has been important for recruitment. In addition, an annual seminar has been held to recruit master's students and PhD candidates with contribution from the industrial partners.

The Centre has been very successful in recruiting Norwegian PhD candidates.

Photo: Ole Morten Melgård

BEWARE of the Sparring Partners

They might be of retirement age, but only a fool would doubt their intellect.
David Embury and John Hutchinson on SIMLab's Scientific Advisory Board have been invaluable sparring partners.

The scene was classic: at SIMLab's final seminar in Trondheim, November 2014, everyone was present. Research and industrial partners, programme heads, researchers, students; the room packed with scientific expertise. Who put the most questions? Embury and Hutchinson. Seated on the front row, they would frequently lean over and whisper in each other's ears. Then, at the end of a presentation, their hands went up. Questions and remarks followed, always to the point. Indeed, the body language of the presenters spoke for itself. Remarkably many of them had their attention fixed on the two 75-year-olds, as if they wondered: Have I convinced them? Will they criticize my viewpoint?

"Our role"

"Our role has been to be critical," Hutchinson confirms the morning after, comfortably seated in the hotel lobby with Embury at his side.
And critical they've been. The very idea of a software tool box was met with considerable scepticism by the Scientific Advisory Board (SAB). The scepticism is still there, so much so that we had to ask Hutchinson:
"In your speech you almost made the tool box sound like a trap. Is it?"
"That's our concern exactly. Maintaining software like this is a huge time sink. Commercial companies like Granta have lots of employees doing it. The question is: who is going to maintain SIMLab's tool box? Because if you don't, it will die within a year."
Embury agrees:
"The landscape is littered with examples. It takes an enormous investment to keep such things current."

Commit the partners

Now, here's the big modification: the SAB did not oppose the tool box. Scepticism is something else:
"We know Magnus shares our worries. The tool box is a tremendous tool if you can keep it going. There are at least two options: you can establish a spin-off where partners buy access, or you can make each partner hire someone to interact with the tool box. Magnus is well aware of this. I think he goes for the latter," Hutchinson speculates.

Open ears

Enough scepticism. SIMLab's ability to listen to their industrial partners has contributed significantly to their success. The idea of the tool box came from Audi's Thomas Hambrecht. Renault's long-time representative Francois Moussy has been another valued contributor. Hutchinson has fond memories:
"I remember a wonderful lecture by Moussy. He explained what they were missing. That's where SIMLab has advanced. That's why they are the only world class research centre to cover all aspects of ductile fracture and at the same time translate it so industry can use it."
Embury agrees:
"The way they bring together materials and mechanics is unique."

The French Connection

Life is more than industry. There are academics. SIMLab has taken good care of them, too. David Embury puts it like this:
"People like Odd Sture Hopperstad have been very shrewd in capitalizing on the good French researchers. SIMLab have even recruited some, like David Morin. What Norway has done well, is to take it all the way. We know a number of other places where they might have produced elegant solutions praised in papers but with no application," he says.
Hutchinson puts it in context:
"The US used to have expertise in ductile fracture funded by the nuclear industry. That came to a crashing halt in the late 70s. France went on."

The progress

The two readily agree that they would never have joined the SAB if it hadn't been for intellectual curiosity.
"Not at this point in life," as Embury puts it.
As it is, they have particularly enjoyed observing the evolution and progress of the programme.
"To start with, they basically did very little on polymers. Since then their polymer effort has come along very nicely. The other area that has evolved a lot is polycrystal plasticity. SIMLab wanted to predict behaviour and we asked why. They wanted to study fracture and we didn't see it going anywhere. In the end they have pushed it to a point where it does pay off."

Family

The two praise the atmosphere at the Centre:
"It's almost like a family. I know a few universities quite well and often neighbouring departments don't even speak to each other. There can be deep divisions. We don't see that here," Embury says. Hutchinson follows up:
"The people at SIMLab work effectively with a common purpose. I like the problems they work on, applying our field to specific engineering projects. David on the material side and me in structural engineering have a lot of overlap with the group. It's been a good match. We have enjoyed this so much we would happily do it all over again despite our advanced age!"

All Continents ON BOARD

Ignoring borders has been a core characteristic of SIMLab. Half of the industrial partners operate outside Norway – the home base. Contributions span all continents.

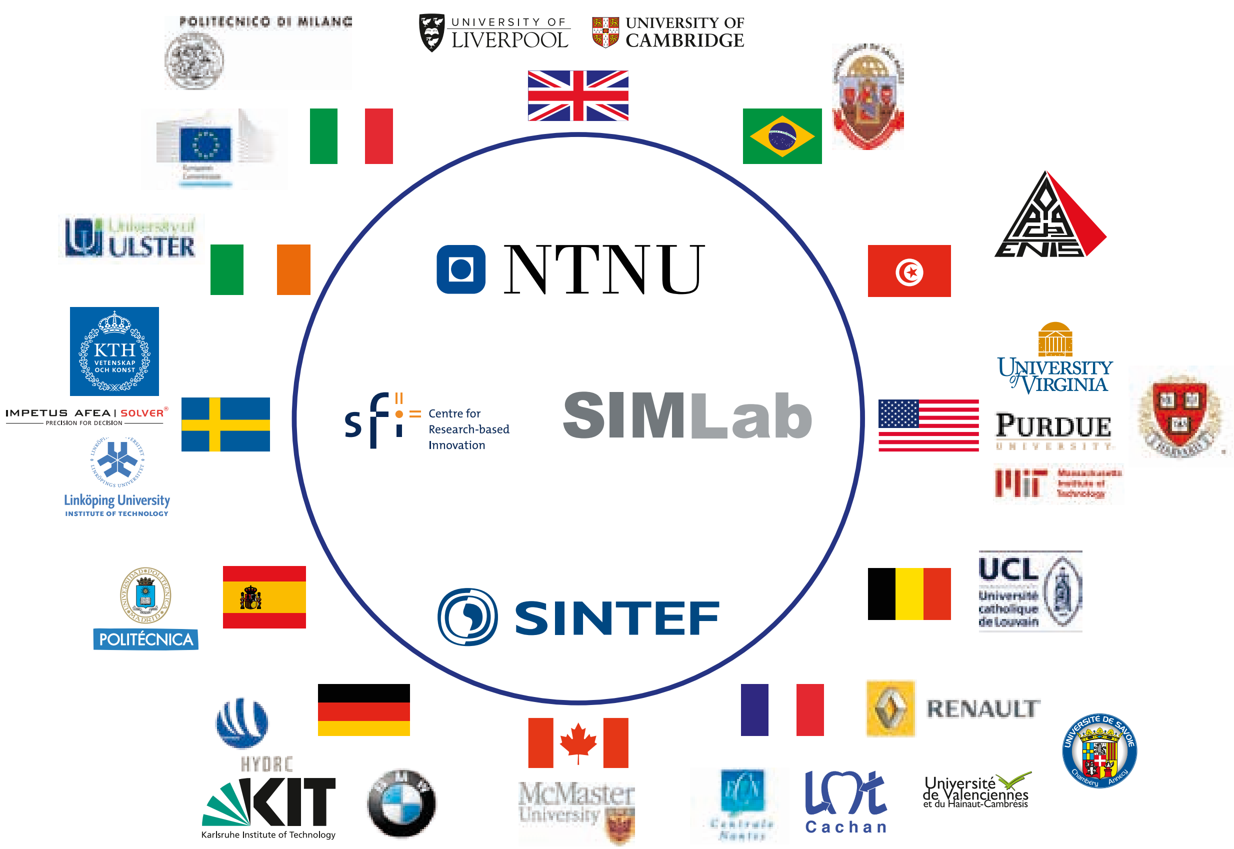
Reaching a world-leading status is impossible without making a presence on the international stage. Part of this visibility is about achieving sufficient scientific stature to catch the attention of the international research community. SIMLab has demonstrated this ability in a number of ways. Three of the professors are editors of international journals, the Centre has managed to attract world-leading capacities to its scientific advisory board, the exchange of researchers is extensive and cooperation is world-wide.

Global

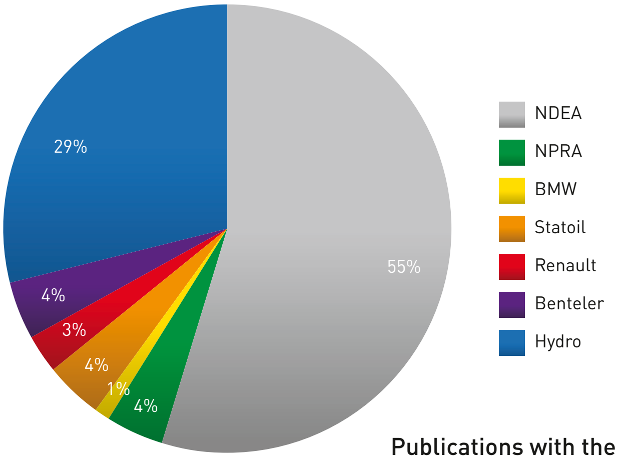
All continents are represented, although two of them are only marginal: a single student has visited from Australia, while Sana Koubaa from the Tunisia Polytechnic School contributed to the article "Finite-element analysis of errors on stress and strain measurements in dynamic tensile testing of low-ductile materials" in 2011. At the other end of the scale, we have the extensive cooperation with industrial partners like Audi, BMW, Renault, SSAB, Toyota and numerous scientific partners in the US and France. The latter has historical reasons.

French tradition

France has a strong research tradition in protective structures thanks partly to its heavy dependence on nuclear power in the production of electricity. This is evidenced on our international collaboration chart, where the logos of four French universities are present. It is also very well illustrated on the map presenting cooperation with publications in international peer-reviewed journals, where the French partners are present in more than a third. Professor Ahmed Benallal's post on our Scientific



International cooperation



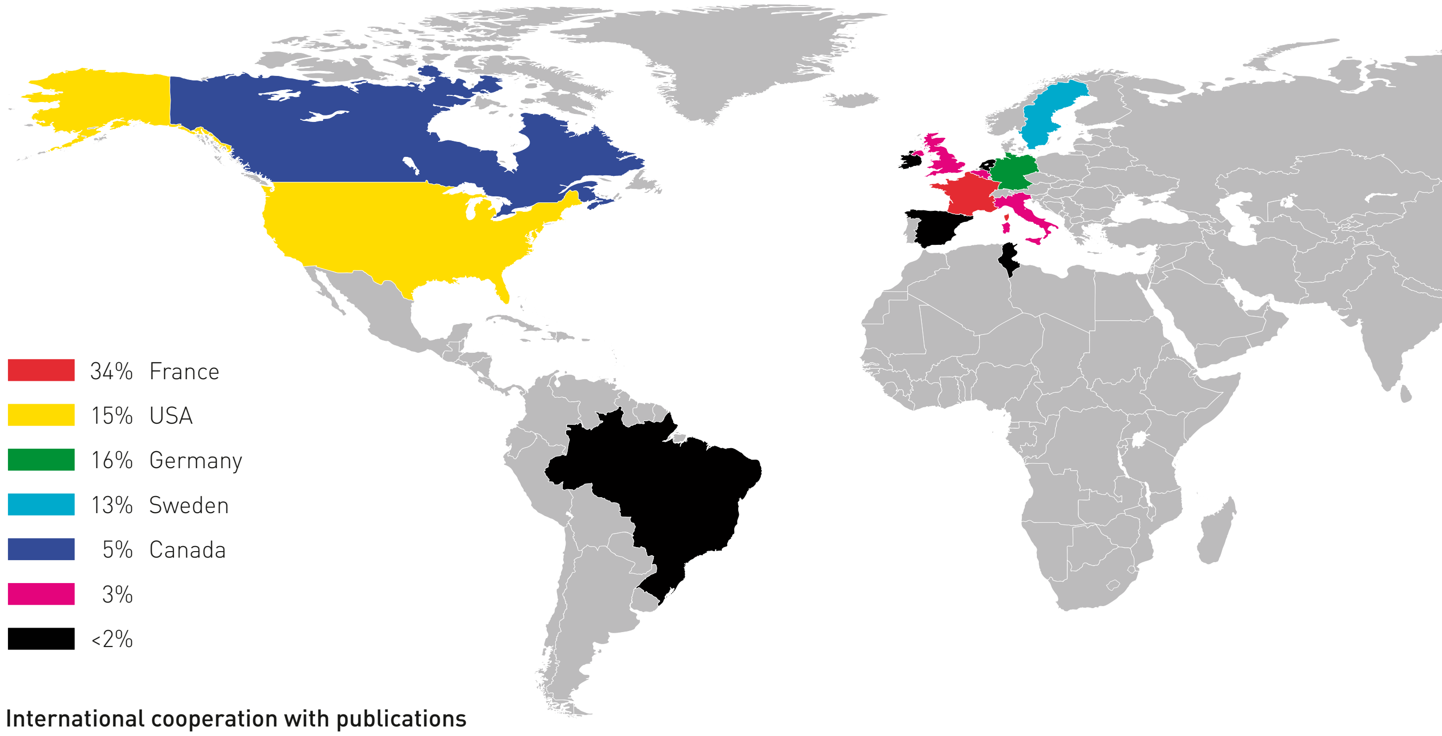
Publications with the user partners *73 publications in international peer-reviewed journals.*

Advisory Board is a logical part of this larger picture. So is cotutelle; an agreement on joint supervision at doctoral degree level. The programme originated in France, hence the term cotutelle (as in co-tutoring).

Cars and stars and stripes

Apart from the global character of the research co-operation, two traits stand out: the industrial links to the automotive industry and the links to some of the world's most prestigious universities, such as Harvard and MIT.

At the same time, the Norwegian contribution to the 73 publications with the user partners is noteworthy: More than half of them have the Norwegian Defence Estate Agency as partner; Hydro took part in another 29 per cent.



International cooperation with publications
67 publications in international per-reviewed journals

WAY OFF Target

We hope it's a good sign: statistics reveal that the SIMLab crowd is full of overachievers.

When SIMLab set out, the quantitative academic goals were to graduate ten PhD candidates where at least three were female, to graduate at least ten MSc students annually, to attract five international professors/scientists, to publish on average eight papers in international peer-reviewed journals annually and to organize two international conferences.

Twice as good

After eight years, the results deviate massively from the goals. Most are twice as good. Where the aim was ten PhDs, the result is 22, including four females. 80 MSc graduates became 159, 80 journal publications became 157. SIMLab delivered 30 keynote and invited lectures and another 176 conference contributions.

The Centre attracted 51 international researchers and 33 visiting students and it has organized one international conference.

France again

As the map shows, one third of the visiting students come from France. Again this illustrates the prominent scientific position and traditions of several French universities in this field. Four of them have also sent visiting researchers to Trondheim.

At the same time it is noteworthy that the Centre has 100 per cent Norwegian PhD candidates in its final stage. Recruiting Norwegian master's students to a PhD has proven a challenge in other disciplines.

Female input wanted

There is one point where SIMLab hasn't quite lived up to its ambitions: gender equality. Four female PhDs is one above target, but this is not satisfactory when the total number of 22 PhDs is more than double what we had aimed for. The main explanation for the inequality is

Visiting researchers

PhD students

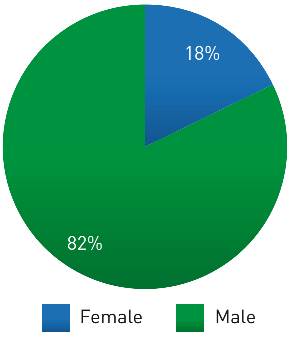
26 PhD students

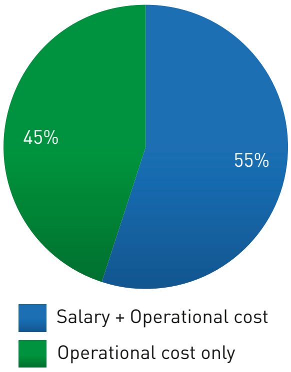
22 SFI

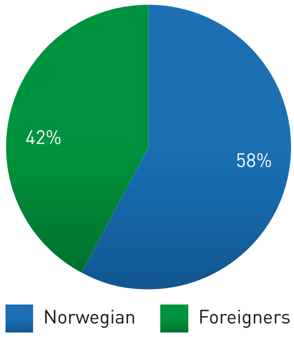
Originating from:
- Norway
- Denmark
- Germany
- France
- Russia
- Vietnam
- Malaysia

4 Affiliated

Originating from:
- Norway
- Germany

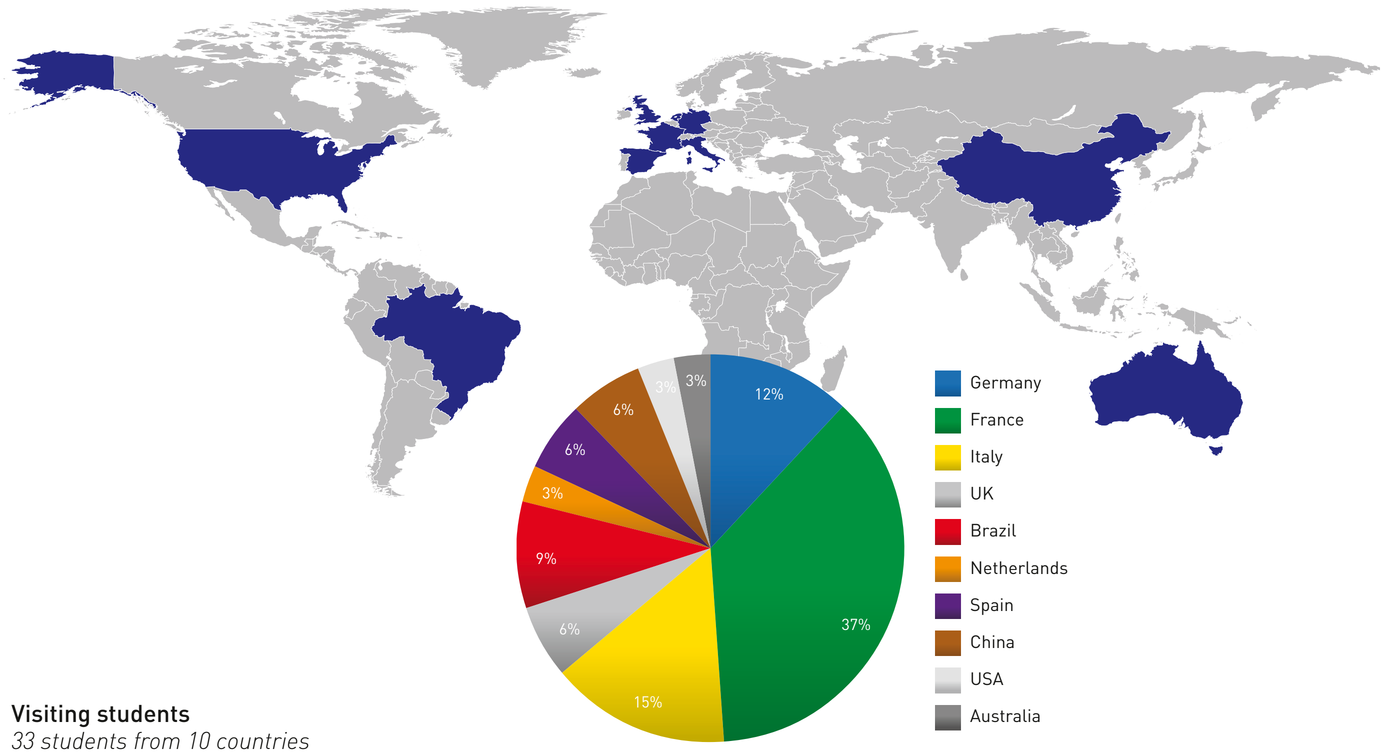






the recruitment base. Both our faculty and department have solid male dominance. Trends in other parts of engineering indicate greater female participation and our ambition to recruit more females has been strengthened in the new SFI CASA.

The comforting part of the female participation at SIMLab is that three of the four female PhDs strengthened international relations: Anizahyati Alisibramulisi was from Malaysia, Marion Fourmeau from France and Ida Westermann was from Denmark.



Visiting students

33 students from 10 countries

Photo: Ole Morten Melgård

THE WINNER

In the battle to reduce CO_2 emissions, some win and some lose.
Hydro's head of technology Hans Erik Vatne is ever so happy to be on the winning side and just as content to be a SIMLab partner.

"The shift towards aluminium in car production is stunning. Some automotive manufacturers have surprised us with the speed of their substitution actions, much of it due to eco-friendly regulations and the following race to reduce weight," Vatne says.

SIMLab is part

"SIMLab is very much a part of this process. The automotive industry is extraordinarily demanding. They want to know exactly how a component changes behaviour, not only when it crashes, but even in the 200 centigrade curing process after being painted. A supplier who can't tell them that, isn't considered serious. SIMLab's precise numerical models take care of such challenges.
This doesn't affect Hydro directly, since we have sold our bumper division to Benteler Automotive Systems, another SIMLab partner, and have transferred our extrusion products to Sapa. However, the more parts Benteler and Sapa produce, the more aluminium we sell," Vatne states.

Spot on

Hydro's head of technology is clear about the potential:
"SIMLab is in the forefront of numerical simulations. Their research on combining the micro level of materials with macro level simulations has given us much more precise information about the properties and behaviour of our product. This makes it easier to approach new markets. The micro- and macro-structures of metals used to be worlds apart. SIMLab's contributions in bringing them together are impressive.
The oil and gas industry is an obvious target. A few years ago it wasn't given that weight would be an issue for subsea installations. Today, no-one can ignore the considerable cost of lowering something extremely heavy. What was formerly a somewhat conservative industry is forced to think again. In turn, this opens new business opportunities. It is spot on with our strategy," Vatne observes.

Important test facilities

"In oil and gas many operators haven't imagined the possibility of using aluminium. The partnership with SIMLab has brought us in contact with programmes like "Arctic Materials" which wouldn't have happened otherwise.
In this context, the importance of SIMLab's test facilities comes through. The possibility to test materials at high and low temperatures is crucial. The tests help prove the true value of the modelling tools. As a consequence, it is easier to convince potential customers."

Direct approach

One of Vatne's pleasant surprises at SIMLab has been the approaches from car manufacturers as a direct result of their common partnership.
"One of the strengths of the SFI's is the intention that research is supposed to lead to something applicable for industry. SIMLab has led to concrete, commercial results for its partners. Still, in an environment that is first and foremost academic we didn't expect to be approached so directly by other SIMLab partners with concrete invitations for commercial cooperation. As it is, our partnership has opened new business relationships. An extra benefit has been the constant chase for better results in the automotive industry. It really has motivated and strengthened us to work this close with such a demanding business," Vatne says.

Recruitment base

For Hydro, the mere production of 22 PhD and 159 master's degree students with a lot of knowledge about metals is a plus in itself. They are both potential employees and potential buyers. One of Hydro's own researchers is an adjunct professor working in the SIMLab environment at NTNU and the academic interchange is constant. It is an obvious advantage for Hydro to have strong metal expertise in Norway's leading technological university.

The oil rig app

The financial crisis in 2007 hit the aluminium industry hard. Only recently have things started to change with the new quest for lightweight structures.
Hans Erik Vatne doesn't look back. It almost goes without saying that Hydro is one of the many partners behind SIMLab's next SFI, CASA (Centre For Advanced Structural Analysis).
"What SIMLab has produced, is an excellent base for further advances. On the horizon we see the potential for simulating whole oil rigs," he says.
However, he has some challenges:
"One of them is the implementation of the results we get from SIMLab in our own company. It has proved to be more challenging than we expected. In our partnership with CASA we have decided to establish a system for implementation, involving our own researchers from day one."

“IMPOSSIBLE without”

“Eleven million cars are produced in Europe every year. We provide five million parts. That would have been impossible without the technology from SIMLab.”

The words belong to Svein Terje Strandlie, general manager at Benteler Aluminium Systems. The statement was given to Norwegian daily Aftenposten towards the end of 2013, a year that marked record sales and profits for Benteler. Every week 100 000 bumpers left the plant at Raufoss. The expansion continued in 2014 with the introduction of new products.

Internal competition

Benteler decided to continue the partnership with SIMLab when Norwegian aluminium producer Hydro sold their bumper division to new, Austrian owners. As part of a company present in 38 countries around the world, Strandlie gives internal competition as one of the reasons for staying on board:
“We want to position ourselves as technological leaders. We are constantly benchmarked against other parts of the company. Critical questions are routine. In this context SIMLab’s expertise and the contact with the other partners is invaluable. Having a joint meeting of all SIMLab partners at BMW in Munich would have been unthinkable without an instrument like the SFI,” Strandlie says.
Benteler also profits from the steady production of new expertise in the sense that new researchers are recruited from SIMLab.

Active users

The car makers think much in the same way. Audi’s Dominic Seibert has been very keen on the scientific side of the partnership all along. He has had two PhD candidates working on the programme. First Andreas Koukal, now Holger Staack. They both use the Tool Box in their work.
Seibert is in charge of pedestrian safety at Audi. Colleague Thomas Hambrecht is head of functional design, including crash simulations and ride comfort. In an interview for one of SIMLab’s annual reports, they stated:
“The people at SIMLab aren’t just a group of top rank scientists. They’re extremely dynamic. A project we’ve done there recently ended up in the Audi Validation Programme. This had nothing to do with where we started. SIMLab happily changed focus and defined new topics on the way. That is the outstanding point.”

Canny Renault

Department manager for analysis and material behaviour at Renault, Eric Vaillant, has a canny observation of SIMLab’s usefulness:
“There’s no denying that it’s complicated to share projects and results with our fiercest competitors, but this is also one of the major strengths of the SFI. We are several partners with the same need and we have frequent contact meetings organized by SIMLab.
The exchange gives robustness to the results and teaches us a lot. If we see extensive synergy between our findings and those of our competitors, we have an indication that our strategy is right. If there are significant differences, we are forced to consider if we are on the right path.”

Joint thesis

Since joining the Centre in 2011 Toyota Motor Europe has become a very active partner. They are eager to use the material model in the Tool Box, with special attention on the polymer programme.
Yann Claude Ngueveu has been visiting SIMLab from Toyota, while master’s student Heine Røstum visited Toyota for the validation of the Tool Box on anisotropic elasticity in fibre-reinforced polymers. This joint master’s thesis served to enhance the application of the Tool Box and seems to be an adequate way of implementing technology at the user partners.

Implementation challenges

In the Midway Evaluation from the Research Council of Norway, some challenges were mentioned regarding mechanisms for transfer of research results to the partners. The evaluation stated that direct involvement of partners in research projects and mobility of researchers are very effective ways of transferring results. The evaluators concluded that these mechanisms appear to function unusually well in SIMLab.
However, they voiced some concern given at the evaluation meeting that industry had problems implementing the findings of the Centre due to the lack of understanding about how they should be used.

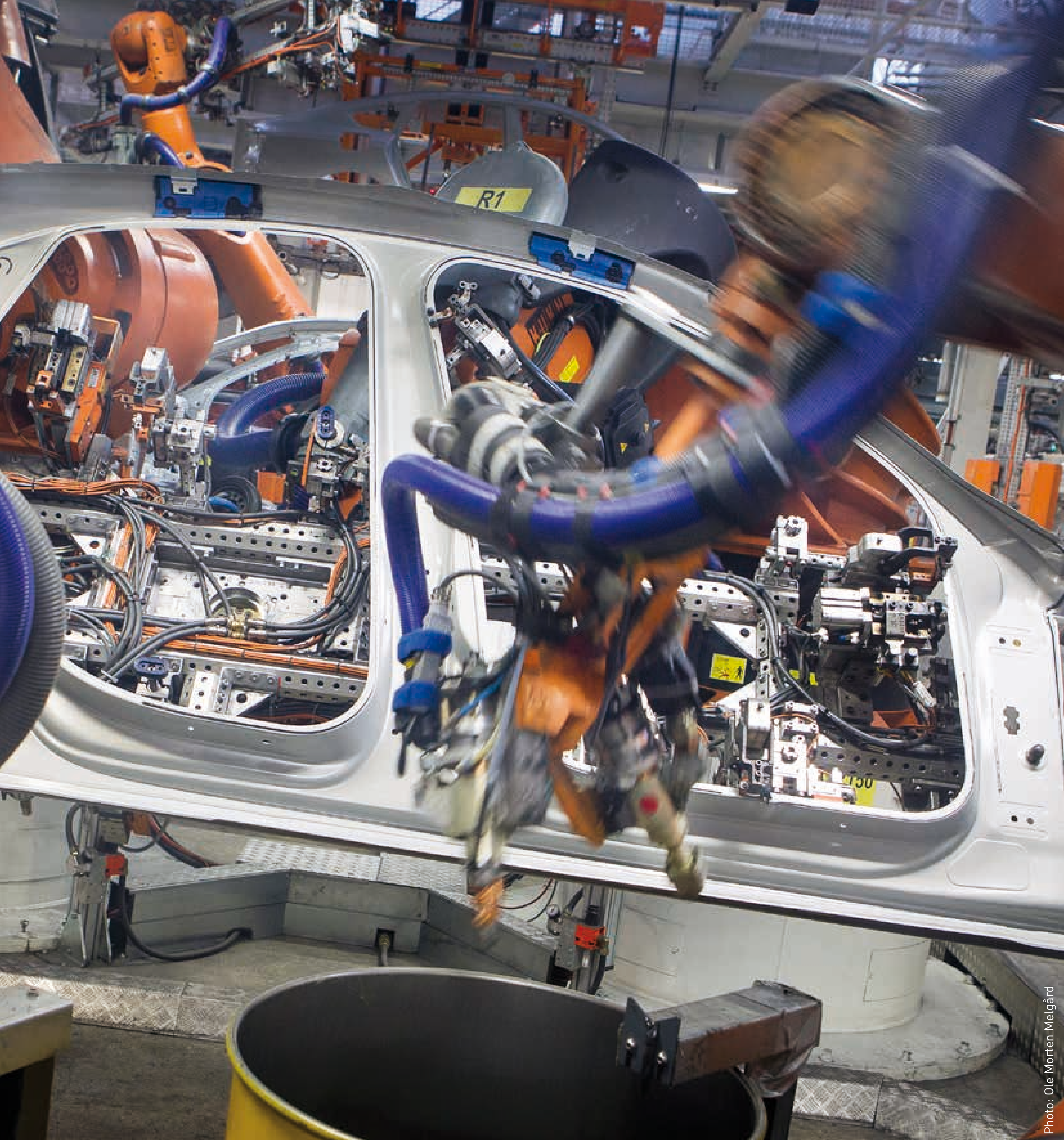


Photo: Ole Morten Melgård

While some partners confirm the challenges regarding implementation elsewhere in this report, the examples above clearly show that the Tool Box has brought this process forward significantly and will continue to do so.

Huge potential

To develop a car model costs between one and two billion euro. Simulating instead of testing can save enormous sums. Obviously, the business partners won't go into detail about the innovative results they obtain on the basis of the SIMLab partnership. What is crystal clear is that they see the huge potential. The fact that the new SFI CASA has four car manufacturers on board speaks for itself.

A Video in CHINESE

There's a video on YouTube that shows the planned crossing of the Sognefjord in Norway. One version is in Chinese. The reason is simple: this is spectacular stuff, attracting world-wide attention.

To cross the Sognefjord without a ferry will take some ground-breaking engineering.

Here are the facts: the world's longest suspension bridge to date has a main span of two kilometres. A similar bridge across the Sognefjord would need a 3.7 kilometre span. The fjord is 1.3 kilometres deep. Building a tunnel under it is out of the question. Obviously, the road builders need help. Who have they asked? SIMLab, for one.

Direct on to post doc

The reason is obvious. It's unthinkable to build such a crossing without preparing for a structural impact. A floating tunnel or bridge may be hit by a ship. A tanker truck may explode inside a floating tunnel; by accident or terrorist action.

So, after defending his PhD thesis on oil pipelines on the seabed, SIMLab's Martin Kristoffersen has dived into a three-year post doc programme to study implications and solutions in the Sognefjord.

SIMLab's expertise is needed because of their world-leading capacity to model and simulate structural impact. An enormous and steadily increasing library, the Tool Box, helps measure and predict countless possibilities.

Parliamentary decision

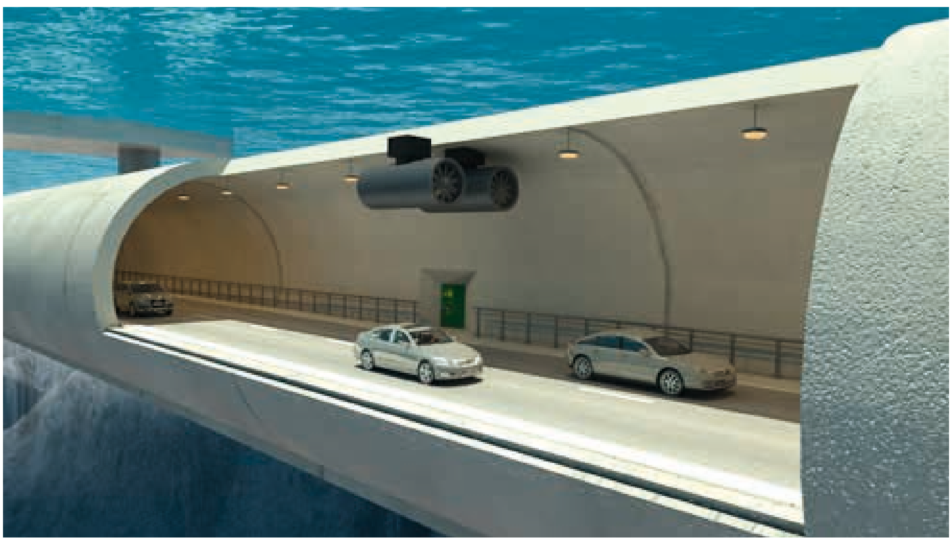
Martin Kristoffersen's work is part of a much larger picture. The Norwegian Public Roads Administration, NPRA, has signed an agreement with NTNU including 20 PhDs dealing with the new E39 highway alone.

This is a consequence of the 2013 decision by the Norwegian Parliament to make the E39 stretch from Kristiansand in the south to Trondheim in central Norway ferry-free. That takes eight new fjord crossings and creates countless other engineering challenges.

Part of strategy

SIMLab has had two public authority partners from the start. NPRA is one and the Norwegian Defence Estates Agency, NDEA, the other. In fact, NDEA was the very first to sign the partnership and it didn't happen by accident. The cooperation is decades old.

As it is, Helge Langberg at NDEA has his own man at SIMLab. It pays off. Of the 73 papers published in peer-reviewed journals in cooperation with the user partners, Professor Tore Børvik is involved in half. Professor Børvik was recruited from NDEA in the first place and is still a part-time NDEA advisor."SIMLab is part of our research strategy. Their combination of tests, numerical models and simulation is very good. We leave much of the basic research to them. They develop the models; we use the findings in our own research and innovation work," Langberg says.



Specialized in buildings

Helge Langberg used to head the R&D Department at NDEA. As a consequence of the 22 July terrorist attack, the Norwegian government decided to establish a specialized body for the protection of buildings. The result is that Helge Langberg now heads the newly established

National Centre for Protection of Buildings, organized under NDEA. This Centre gives advice on building protection and security to the whole public sector in Norway.

The test facilities at SIMLab have been very important for NDEA and will continue to be so in the next SFI, CASA. The recently installed shock tube will be a good complement to the much larger one NDEA is planning to build. The behaviour of glass subjected to shock waves is one of the topics that will be facilitated by these tubes.

Crucial for recruitment

"To us, SIMLab is also extremely important for recruitment. We need people who understand structural impact. We are looking for students who leave SIMLab constantly, with PhD's or master's degrees.

Society needs people with expertise in structural impact. This doesn't only go for us. Also consultants in security must know what happens when a building is exposed to an explosion. They need to know how shock waves work," Langberg says. He is impressed with SIMLab's performance. "They have developed into an international player to reckon with in their field," he concludes.

Strong new partners

Few indications could serve better to illustrate SIMLab's relevance for the partners and society as such than the portfolio they muster for their next SFI: Statoil Petroleum, DNV-GL, Aker Solutions, Hydro Aluminium, Sapa, The Ministry of Local Government and Modernization, Gassco, Benteler Aluminium Systems Norway, SSAB, the Norwegian National Security Authority, the Norwegian Public Roads Administration, the Norwegian Defence Estates Agency, Audi, BMW, Honda R&D Americas, and Toyota Motor Europe.

Only one SIMLab partner has left, seven new partners have joined. The strong, new representation from Norwegian public authorities dealing with public safety clearly shows an increased understanding that society needs this kind of expertise to protect its citizens.

The video

What about the video in Chinese?
Just Google "Sognefjord Crossing Chinese".

EXCELLENCE Sells the Faculty

Competition doesn't only exist in the business world. It's omnipresent. That's one of the reasons NTNU is very happy about SIMLab.

"Excellence is fundamental. When SIMLab gets top ratings at home and abroad, NTNU fulfils its obligations towards society in at least two ways: we produce unique expertise and we produce PhD and master's candidates who will benefit society for the next 40 years." Says Ingvald Strømmen. He is Dean of the Faculty of Engineering Science and Technology at NTNU, SIMLab's host institution.

"This excellence in turn makes us more attractive and helps us recruit the best students next time around," he adds.

Eight times up

Professor Strømmen gives SIMLab considerable credit for a number of effects on his faculty:
"Publications are eight times higher than they were in 2005. SIMLab has contributed to this on a massive scale. They have inspired others and helped turn around old cultures.
The research has built impressive CVs. I'm sure that one or more in the SIMLab team would be applicable for European Research Council grants if they tried. This fits perfectly with NTNU Research Excellence and its strategy in the Outstanding Academic Fellows."

Photo: Ole Morten Melgård

Positive spiral

SIMLab has been able to attract some of the most prestigious manufacturers in the automotive industry which is a feat in itself. It demonstrates that the research is noticed world-wide and that results rub off on the user partners. Industry understands this. At the same time they demand user-friendliness. The SIMLab Tool Box is a direct result. The partners praise the SIMLab researchers for their dynamic approach to this part of the cooperation.

Ingvald Strømmen is confident that this interaction builds relations of great importance for the future:
"It's a positive spiral. It attracts associated research like we witnessed with Honda joining our efforts without being a SIMLab member. Now Honda is part of our new Centre for Research-based Innovation (SFI)."

9 out of 17

SIMLab was an SFI and reached that status in fierce competition. Now the same people have been successful again and have obtained SFI status for their next centre, CASA. Professor Strømmen has every reason to be proud – his faculty will take part in 9 out of 17 new SFIs granted by the Research Council of Norway.

"SFI status is sound recognition of excellence in itself. In addition it carries the benefits of substantial additional funding from the government. The eight-year duration provides a long-time perspective. The Research Council of Norway deserves credit for introducing the SFI programme and sticking to it. The competition to get in is intense and that's exactly how it should be."

On STRUCTURING Knowledge

"Our belief in structuring knowledge has increased as a result of SIMLab. This has rubbed off on other parts of our activities and made us more efficient."

So says Rudie Spooren, Vice President Research at SINTEF Materials and Chemistry.

Photo: Ole Morten Melgård

Step change

"In recent years, we have increased our awareness related to "knowledge management" and in particular learned how to structure knowledge into software frameworks. Such frameworks improve the quality of our own research and the exploitation value of its results for our customers," Spooren goes on.

Joint ownership

The software platform developed in SIMLab is one of the most prominent examples of this method of work. Life before the SIMLab Tool Box was rather time-consuming for certain operations. The processing of test results and the set-up of computational models was labour-intensive and vulnerable to error when carried out by less experienced personnel. Now the process is automatized to the degree where it can be performed by engineers and technicians.

SIMLab has come to an end, but the Tool Box will live on as a very helpful instrument for the partners. NTNU and SINTEF jointly own the tool box and take responsibility together in its maintenance and further development.

Strategic effort

"The need for professional knowledge management through a software framework gradually developed during the work in SIMLab, and the long-term, strategic perspective of the centre was crucial to bring this work to a successful end. Partly inspired by the work in SIMLab, SINTEF concurrently developed a generic strategy for software development, led by Dr Josip Zoric," Spooren says.

Scientific recognition

"Another important asset of SIMLab is the thorough scientific basis on which the modelling tools are developed. This has been important to build confidence amongst potential users of the tools. The contribution of the Scientific Advisory Board has also been a substantial asset in the same direction," says Spooren.

From SINTEF's position the importance of the international recognition already in place through SIMLab will increase further when the next SFI, CASA, starts to work, and puts NTNU and SINTEF in a good position to collaborate in future EU projects.

Basis for recruitment

As Scandinavia's largest independent research organization, SINTEF depends on constant influx of highly qualified personnel. SIMLab has contributed significantly to the education of qualified scientists, and so far SINTEF has employed 4 PhD candidates and 2 Post Docs that were part of the Centre.

The Importance OF BEING NOTICED

Throughout its existence, SIMLab has enjoyed a privilege compared to many other research centres: images of crashes, explosions and penetrating bullets are visually exciting.

It may seem obvious, but is still forgotten far too often: producing high quality research is almost pointless if no-one gets to know about it. The results need to be made available to other scientists, to potential users and to the general public. Visibility may also help funding.

Two legs

SIMLab has taken all this seriously, partly by being very active on the international scientific scene. Three of the professors are editors of international journals. Throughout its existence the Centre has been in touch with all continents via journal publications, conference contributions, visiting researchers and students.
The other fundamental part of disseminating knowledge and interest is obviously by getting media coverage. The following four pages show a fraction of the results.

The French Connection

Logically, media coverage has accumulated. A pleasant climax was the inauguration ceremony for the Shock Tube on 20 October 2014. The event was covered by two French online news channels, Norway's largest radio channel NRK P1, national TV channel TV2 Nyhetskanalen, Norway's largest newspaper VG, the regional newspaper Adresseavisen, Norway's foremost technical journal Teknisk Ukeblad, online building industry magazines Bygg Fakta and Byggeindustrien, online research magazine Gemini.no and NTNU's online university news website Universitetsavisa.


Her tester NTNU effekten av terrorbomber

NTNU har bygd et laboratorium for å studere effekten av bomber på konstruksjoner og materialer.

Adressa.no 21.10.2014

Twice on Discovery

Discovery Channel is available in 400 million homes around the world. Having them visit in 2010 and again in 2014 is both an achievement and a recognition of SIMLab's activities. The first visit filmed two experiments: First, SIMLab's kicking machine demonstrated how a bumper reacts in a crash and second, a test where a bullet was fired into an aluminium construction filled with sand. This programme was shown in 45 countries.


NTNU på Discovery Channel

Adressa 16.10.2010


UA

Knuste «isfjell» for Discovery channel

In 2014, Discovery filmed what happens when ice meets metal as it will do increasingly in Arctic waters as ships and oil exploration move north.
This kind of coverage in turn spurs regional and local coverage of the international media attention.

Universitetsavisa 04.06.2014

NATIONAL media

National media interest started early. Norway's **largest newspaper VG** had its first story on SIMLab on 24 February 2009. It dealt with PhD candidate Henning Fransplass, who crashed virtual auto safety barriers every single day. He explained how the ideal barrier should behave like a hammock, a fact that is perfectly illustrated in the example on page 3 of this report.

Facsimile VG 24.02.2009

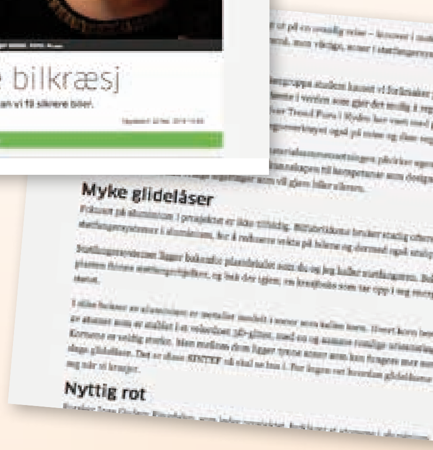
One thing is getting media coverage through visiting journalists. Another is contributing oneself. A good example of the latter is Anne Serine Ognedal's article published in Norway's leading business daily **Dagens Næringsliv** on 1 June 2012. Anne was then a PhD candidate and her research was focused on SIMLab's work on polymers and the collaboration with Audi, BMW, Renault and Toyota to make safer and more eco-friendly cars.

Facsimile of DN article 01.06.2012

Mandatory anti-terror

The technical journal **Teknisk Ukeblad** has had six articles about SIMLab, starting in 2012. These have included the more politically inclined sides of research, like where do we get money from next and a bold statement from the Norwegian Defence Estate Agency that anti-terror measures should be mandatory for all engineering students.

TU 30.10.2014



An interesting observation is how articles from NTNU and SINTEF's own website Gemini and the Norwegian universities' joint website **forskning.no** spill off to the rest of the media.

A typical example is an article on how aluminium atoms can soften car crashes. Articles on the topic were published on Gemini and Norway's largest morning daily **Aftenposten** on the same day.

Aftenposten.no 22.02.2014

The REGIONAL media

The regional newspaper Adresseavisen has had a dozen articles about SIMLab over the years, but it was its tiny rival **Byavisa** that had the first story ever about the new SFI as early as May 2007. The article covered the collaboration with the automotive industry.

Byavisa article 22.05.2007

byavisa.no

Gull verdt for bilindustrien

FORSKNING. Forskningsmiljøer i Trondheim leverer resultater som er av stor interesse for europeisk bilindustri. Både Audi, BMW, Renault og Volvo er på banen.

Adresseavisen | Lørdag 26. februar 2011

Nyheter | 5

Bilgigant kjøper seg inn i krasjlaboratoriet

Verdens største bilfabrikant kjøper seg inn i krasjlaboratoriet i Trondheim. – Dette åpner spennende perspektiver, sier senterleder Magnus Langseth.

Krasj-sjef: Magnus Langseth synes det er spennende at Toyota er kommet med som partner i krasjlaboratoriet ved NTNU. Foto: SVEIN INGE MELAND

Among **Adresseavisen**'s articles was the one from February 2011 where they announced that Toyota Motor Europe had decided to become a SIMLab partner.

Adresseavisen
26 February 2011

Lokket av kjærlighet og livsstil

In April 2011 they carried a story on the destiny of the PhD candidates. 40% of the international candidates at NTNU are employed by Norwegian industry. SIMLab's Virgile Delhaye was used as an example.

Adresseavisen
13 April 2011

NTNU får 10 millioner til terrorforskning

Hvis terroren rammer igjen og en bombe går av ved en bygning, skal forskning fra NTNU sørge for at bygget er sikkert.

December 2013 when the Norwegian National Security Authority announced that they intended to support SIMLab with NOK 10 million over a period of eight years.

Adresseavisen.no
23.12.2013

Opinions and smiles

SIMLab has also made itself noticed in various opinionated articles. One example is Professor Langseth's article in the **Research Council of Norway**'s magazine, with the title *"Hvor åpne skal vi være?"* – How open should we be? – dealing with the balance between openness and protection in the wake of the 22 July terror.


Hvor åpne skal vi være?

Forskning.no article 1.2012


Photo: Ole Kaland, NRK

Norwegian comedians Øystein Bache and Rune Gokstad visited SIMLab's laboratoratories as a part of their annual Easter quiz, **Påskenøttene**, *for the national TV station NRK.*

SIMLab also had input to TV entertainment. **NRK1**, Norway's largest TV channel, visited us when comedians Rune Gokstad and Øystein Bache prepared for their annual Easter TV quiz show, **Påskenøttene** on 29 March 2013.

PARTNERS' publications

Several of SIMLab's partners have published articles in their own magazines. **aktuelt@møller.no** explained about the cooperation between Audi and SIMLab in testing aluminium structures to produce more crashworthy bumpers.


Krasjer for Audi i Trondheim

I Trondheim vet et forskningsmiljø mye om hvordan man tåler en trøkk. Her blir aluminiumsranger til sammenklemte karosserk.


FORUTSER MATERIALENES OPPFØRSEL

På SIMLab i Trondheim finner vi et av verdens fremste forskningsmiljø på materialteknologi og beskyttelse, og det er her Forsvarsbygg futurus egen professor og ph.d.-kandidat holder hus.

Vi kan ikke sprenge et bygg for å vise at en løsning vi har kommet fram til er korrekt.

Professor Tore Børvik

An article for the magazine of the **Norwegian Defence Estates Agency**, **Innsikt**, in 2012 states the obvious advantage of research: "We cannot blow up a building to show that a solution we have arrived at is correct."

HOME, Sweet Home

How sweet it is to come home after travelling the world for eight years.

21 November 2014 will always have good memories for the people at SIMLab. That was the day they were granted a new Centre for Research-based Innovation, SFI. Eight new years of meaningful work is waiting to be done.
The timing was perfect. The announcement came only four days ahead of SIMLab's final workshop with partners, advisors and researchers present from around the world.

The home is new

It is a characteristic of the SFI system that no-one is granted another eight years continuing exactly the same work. Still, SIMLab is coming home since the name of the new centre is CASA. Casa, of course, means house or home in Spanish. Here it is also an abbreviation. The full name is Centre for Advanced Structural Analysis.
In this case, home is also the future. The Centre will deal with research on multi-scale testing, modelling and simulation of materials and structures as a basis for industrial applications. This includes transportation, oil and gas as well as industry and public enterprises working with physical security.

Same team, new wrapping

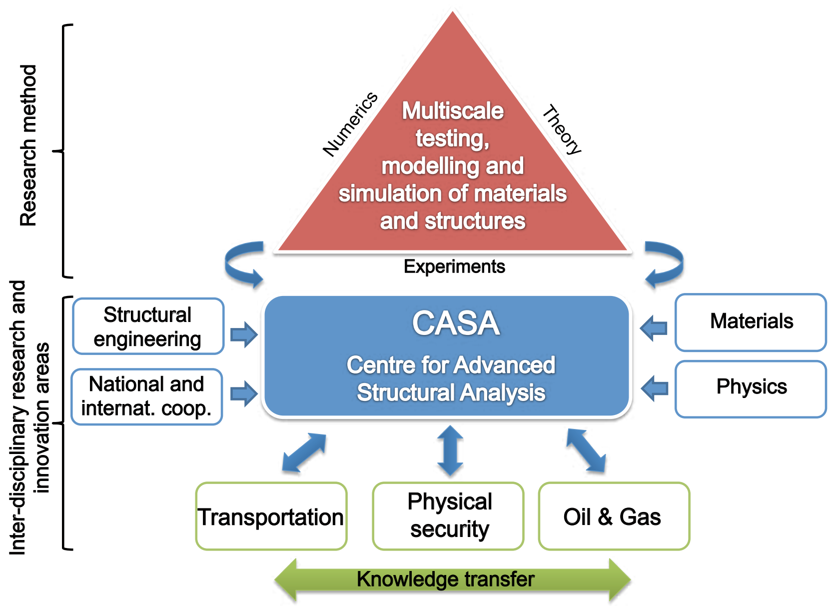
Yes, the saying goes "same shit, new wrapping". In this case, however, there's no shit. Rather the opposite: the same core team that has reached recognition as world leaders through SIMLab now takes up the task of the new Centre. The only new person on board is Professor Randi Holmestad from NTNU's Department of Physics, answering our stated ambition to meet the gender challenge.

Strong family

The research partner SINTEF is still on board, as are nearly all the SIMLab partners. Only one has decided to leave. This means Audi, BMW, Toyota Motor Europe, SSAB, Statoil Petroleum AS, Hydro Aluminium AS, Benteler Aluminium Systems Norway AS, the Norwegian Public Roads Administration and the Norwegian Defence Estates Agency all have found the way to CASA. They are joined by new family members Honda R&D Americas, DNV-GL, Aker Solutions, Sapa, the Ministry of Local Government and Modernization, Gassco and the Norwegian National Security Authority.

SIMLab is history

SIMLab is history, but not all books are closed.
Ten PhD projects will continue until disputation in 2015, 2016 and 2017.
The Tool Box will still be available for the partners and a myriad of spinoffs will continue to grow.



THE DRIVE to Beat the State of the Art

Norway has a tradition for experience-based innovation. The message from international industry is clear: innovation depends on top quality research.

"This is one SIMLab effect: I think our Norwegian partners have been inspired by observing how our partners in the automotive industry use research to drive innovation. State of the art is not good enough. There has to be a scientific lift. That's great news for the quality we have to put into our research," says director Magnus Langseth, summing up eight years of SIMLab.

Mutual benefit

Professor Langseth sees this mutual benefit as part of the positive experience of doing things the SFI way:
"We have to lift ourselves and make our results available and user-friendly as in the SIMLab Tool Box. At the same time our partners have come to understand the upsides of our generic and pre-competitive nature. They have learned to accept and appreciate that we research and publish as we go, in a manner that doesn't benefit one partner at the others' cost. This environment has made it possible for our partners to participate openly and without fear of revealing business secrets. The next phase, creating innovative products based on the knowledge we have produced, is up to each partner. I think the SFIs should stick to this approach," he says.

Open channels

"The SFI status is a reward in itself. It means we are better than 75 per cent of the other applicants. Once there, the status provides an eight-year perspective with continuous external funding.
The SFI status has helped us build a strong international network. We have become visible to Norwegian and international industry and research institutions.
The personal relations have built up an extremely valuable level of confidence. Channels have been open in both directions to air and solve challenges as they arose. In this way, significant disagreements never have had the chance to establish themselves," adds Langseth.

Same floor

The work in SIMLab was carried out according to the original application and in close cooperation with the partners. The work has been organized in work packages, but with programme heads operating across the boundaries, interchanging competence and findings and with everyone situated on the same floor in the same building. This has helped build centre identity. This way of organizing the work profits from having leadership with the know-how to get the work done and from highly qualified researchers.

Unusually well

In its Midway Evaluation, the Research Council of Norway's panel of experts said the following:
"SIMLab is characterized by excellent research conducted under dynamic leadership by a group of students and senior scientists that seem to cooperate well both internally and with user partners, from which they receive strong support."
It is SIMLab's firm belief that this still rings true.

Photo: Ole Morten Melgård

ALL THE SIMLabs

SIMLab's final conference in Trondheim in November 2014 was a truly international gathering of scientific and industrial partners, scientific advisors, the core family and PhD candidates.

Photo: Ole Morten Melgård

FUNDAMENTAL Facilities

The test facilities form a crucial part of SIMLab's success. Scientific Advisory Board member John Hutchinson put it like this in the 2013 Annual Report: "...they deal with basic mechanics, fundamental tests, development of models, implementation of simulation models and validation tests, and they are at the forefront of incorporating failure in simulating tools; they do it all, that's what so unusual. They really stand out."

Worries

This position has not been obtained without a fight. At times there have been worries that the "funding fathers" in government and elsewhere didn't sufficiently understand that a SIMLab without one of its key qualities would quickly have lost its leading position.
As it is, the inauguration of the shock tube in October 2014 represents a splendid confirmation that this understanding is now in place.

Some of the facilities are applied to material characterization at elevated rates of strain and different stress states. Other test rigs are used for quasi-static or impact testing of components and structures for the validation of numerical models. The following is a very brief presentation.

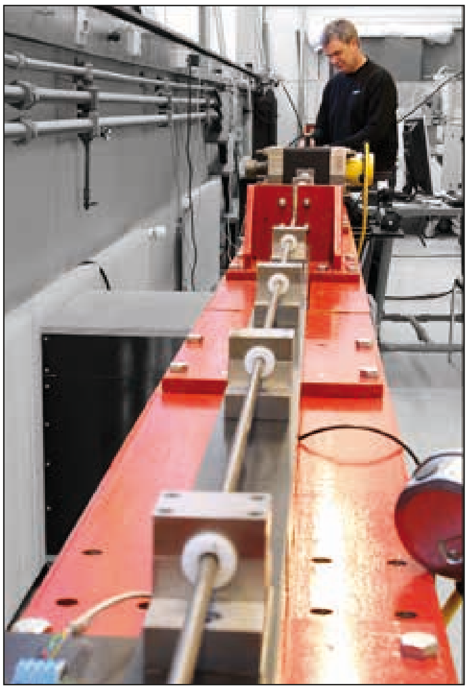


Photo: Melinda Gaal

Material testing at elevated rates of strain

The split-Hopkinson tension bar tests materials at strain rates in the range between 100 and 1500 s–1. The rig has been used for strain-rate characterization of different steel, aluminium and magnesium alloys. High and low temperature tests have been carried out for steel and aluminium.
This part of the lab is also equipped with a split-Hopkinson pressure bar and a hydro-pneumatic machine. The latter operates in the strain–rate range between 1-100 s^{-1}.

Component and structural testing

The pendulum accelerator, or kicking machine, is a device for impact testing of components and structures. The test rig accelerates a trolley on rails towards a test specimen fixed to a reaction wall. The deformations of the specimen can be recorded by high-speed cameras.

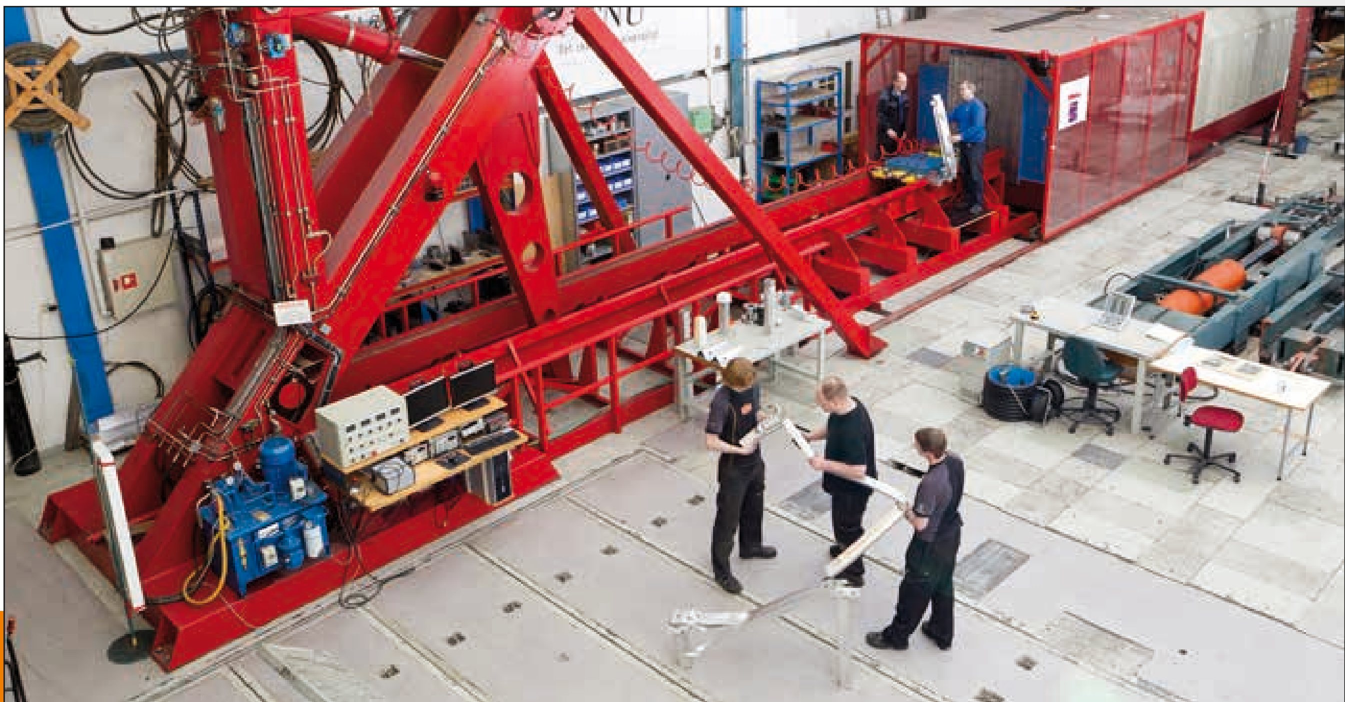


Photo: Ole Morten Melgård

Joining machine

In this machine, self-piercing riveting can be carried out of sheets under industrial conditions.

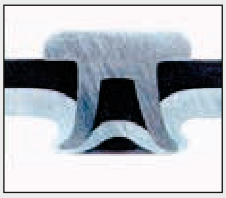


Photo: Melinda Gaal

Cameras

DIC (Digital Image Correlation) allows determining the displacement field on material/structural tests based on digital images. The SIMLab DIC software is able to handle 2D as well as 3D measurements using what is termed a Q4 formulation. Unique features to deal with crack propagation are implemented, like element erosion and node splitting techniques. The computational part of the DIC software is heavily parallelized to get very efficient computation times. The comprehensive Graphical User Interface runs on Windows platforms.
The lab also includes various infrared and high-speed cameras.

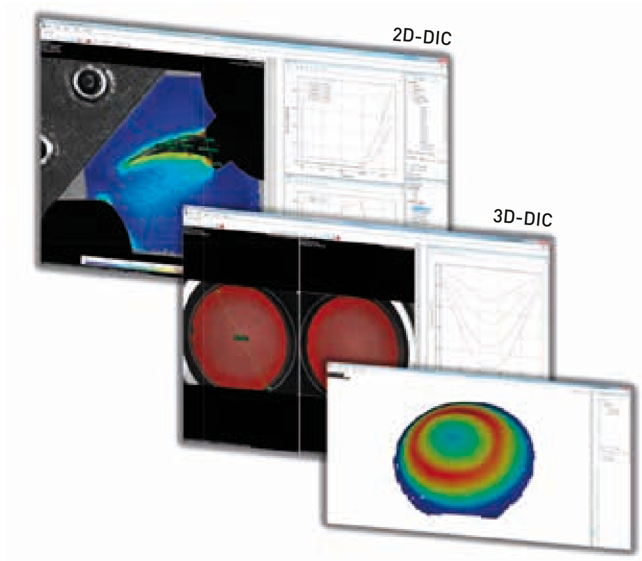


Photo: Melinda Gaal

This part of the lab also includes a sheet metal testing machine, a pneumatic accelerator, a stretch-bending rig, a drop-tower impact system and a compressed gas gun. The gas gun comprises a 200 bar pressure tank, a purpose-built firing unit, a barrel and a closed 16 m^3 impact chamber. Due to the size of the impact chamber, large structural components can be tested full scale. If the projectile perforates the target, residual velocities are measured before it enters into a rag-box.

FINANCING and Results, Key Figures

Summary sheet for the main categories of partners (MNOK)

Contributor	Cash	In-kind	Total
Host	8	35	43
Research partners		9	9
Companies	34	33	67
Public partners	10	17	27
RCN	80	0	80
Sum	124	94	226

Distribution of resources (KNOK)

Type of activity	MNOK
Research projects	175
Research equipment	16
Common centre activities	3
Administration	32
Total	226

Results - Key figures

	2007	2008	2009	2010	2011	2012	2013	2014	Total
Scientific/scholary publications (peer reviewed)	15	19	31	26	18	14	16	18	**157**
Dissemination measures for users	1	3	2	4	3	9	6	4	**32**
Dissemination measures for the general public	2	3	2	6	4	7	8	26	**58**
Number of new/improved methods/models/prototypes finalized									**1****
Number of new/improved products/processes/services finalized									**0**
PhD degrees completed*				1	2	3	2	4	**12**
Master's degrees	10	13	17	20	26	26	19	28	**159**

* 10 PhDs involved in SFI SIMLab will be completed after 2014
** SIMLab Tool Box

Emplyment of PhD candidates (2015)

Employment of PhD candidates (number)							
By Centre company	By other companies	By public organizations	By university	By research institute	Outside Norway	Other	Total
1	3	2	5	2	1		14

Appendix 1.

Funding

Activity/Item	RCN	Host NTNU	SINTEF	Audi	Benteler	BMW	Hydro	Plastal	Renault	SSAB	Statoil	Toyota	NDEA - Forsvarsbygg	NPRA - Statens vegvesen	Total
Program 1 - Connectors & Joints	12319	2420	0	1800	0	500	1065	0	0	0	0	0	100	5370	23574
Program 2 - Fracture & Crack propagation	16327	9830	0	2200	0	100	2939	0	0	250	135	0	1500	0	33281
Program 3 - M4	8610	5902	8800	0	0	0	19416	0	0	450	50	0	0	0	43228
Program 4 - OptiPro	9193	4448	0	50	0	151	0	0	0	1930	820	0	13070	1865	31527
Program 5 - Polymers	11241	9932	0	400	0	0	50	150	4760	200	350	650	0	100	27833
Program 6 - Demonstrators	963	2874	0	1358	1208	1508	3203	0	1008	1008	408	408	483	433	14862
Equipment	10806	420	0	412	376	491	1347	0	526	562	252	252	537	212	16193
Management	10541	6980	0	1780	416	1250	4780	0	1706	1200	2535	740	1910	980	34818
Sum	80000	42806	8800	8000	2000	4000	32800	150	8000	5600	4550	2050	17600	8960	225316

Cost

Activity/Item	Host NTNU	SINTEF	Audi	Benteler	BMW	Hydro	Plastal	Renault	SSAB	Statoil	Toyota	NDEA - Forsvarsbygg	NPRA - Statens vegvesen	Total
Program 1 - Connectors & Joints	12829	4325	1000	0	0	200	0	0	0	0	0	0	5220	23574
Program 2 - Fracture & Crack propagation	19064	10217	2200	0	0	400	0	0	0	0	0	1400	0	33281
Program 3 - M4	12278	11683	0	0	0	18867	0	0	400	0	0	0	0	43228
Program 4 - OptiPro	15677	4810	0	0	0	0	0	0	1100	0	0	8200	1740	31527
Program 5 - Polymers	17893	6340	200	0	0	0	0	3400	0	0	0	0	0	27833
Program 6 - Demonstrators	3435	5745	600	800	1000	2082	0	600	600	0	0	0	0	14862
Equipment	16020	173	0	0	0	0	0	0	0	0	0	0	0	16193
Management	23493	11325	0	0	0	0	0	0	0	0	0	0	0	34818
Sum	120689	54618	4000	800	1000	21549	0	4000	2100	0	0	9600	6960	225316

Appendix 2.
Post Docs and Students

Postdoctoral researchers with financial support from the Centre's budget

Name	M/F	Nationality	Scientific area	Years/period in the centre	Scientific topic	Main contact
Alexandre Kane	M	France	Structural engineering	2007-2008	Fracture & Crack Propagation	Hopperstad
Venkatapathi Tarigopula	M	India	Structural engineering	2007-2009	Fracture & Crack Propagation	Langseth
Afaf Saai	F	Syria	Structural engineering	2009-2011	Multiscale Modelling of Metallic Materials	Hopperstad
David Morin	M	France	Structural engineering	2010-2014	Connectors & Joints	Langseth
Egil Fagerholt	M	Norway	Structural engineering	2012-2015	Fracture & Crack Propagation	Hopperstad
Anne Serine Ognedal	F	Norway	Structural engineering	2012-2014	Polymers	Clausen

PhD candidates who have completed with financial support from the Centre's budget

Name	M/F	Nationality	Scientific area	Years/period in the centre	Scientific topic	Main contact
Virgile Delhaye*	M	France	Structural engineering	2007-2010	Behaviour and modelling of polymers for crash applications	Clausen
Ida Westermann*	F	Denmark	Structural engineering	2007-2011	Work-hardening behaviour in age-hardenable Al-Zn-Mg(-Cu) alloys	Hopperstad
Nguyen-Hieu Hoang*	M	Vietnam	Structural engineering	2007-2011	Behaviour and modelling of self-piercing riveted connections using aluminium rivets	Langseth
Egil Fagerholt*	M	Norway	Structural engineering	2008-2012	Field Measurements in Mechanical Testing Using Close-Range Photogrammetry and Digital Image Analysis	Børvik
Gaute Gruben*	M	Norway	Structural engineering	2008-2012	Ductile Fracture in Dual-Phase Steel. Theoretical, Experimental and Numerical Study	Hopperstad
Anne Serine Ognedal*	F	Norway	Structural engineering	2008-2012	Large-Deformation Behaviour of Thermiplastics at Various Stress Rates – An Experimental and Numerical Study	Clausen
Anizahyati Alisibramulisi**	F	Malaysia	Structural engineering	2007-2013	Through Process Modelling of Welded Aluminium Structures	Lademo
Knut Gaarder Rakvåg**	M	Norway	Structural engineering	2009-2013	Combined Blast and Fragment Loading on Steel Plates	Børvik
Marion Fourmeau**	F	France	Structural engineering	2009-2014	Characterization of the anisotropic behavior of high-strength aluminium alloy	Hopperstad
Henning Fransplass*	M	Norway	Structural engineering	2007-2014	Behaviour of threaded steel fasteners at elevated deformation rates	Langseth
Martin Kristoffersen*	M	Norway	Structural engineering	2010-2014	Impact on X65 Offshore Pipelines	Børvik
Dmitry Vysochinskiy**	M	Russia	Structural engineering	2010-2014	Formability of aluminium alloy subjected to prestrain by rolling	Reyes

* = Salary and operational costs from the Centre
** = Operational costs from the Centre, salary from other sources

PhD candidates with financial support from the Centre's budget who still are in the process of finishing studies

Name	M/F	Nationality	Scientific area	Years/period in the centre	Scientific topic	Main thesis advisor
Octavian Knoll*	M	Germany	Structural engineering	2009-2015	Probabilistic Failure Modelling of High Pressure Die-Castings	Langseth
Mikhail Khadyko**	M	Russia	Structural engineering	2010-2015	Experimental and numerical study of yielding, work-hardening and anisotropy in textured AA6xxx alloys using crystal plasticity models	Hopperstad
Vincent Vilamosa*	M	France	Structural engineering	2011-2015	Behaviour and modelling of aluminium alloys at different rates and temperatures	Clausen
Espen Myklebust**	M	Norway	Structural engineering	2009-2015	A large-deformation homogenization model for high contrast dual-phase metals	Langseth
Marius Andersen*	M	Norway	Structural engineering	2011-2015	Constitutive modelling of polymers for automotive applications	Clausen
Vegard Aune**	M	Norway	Structural engineering	2012-2016	Behaviour and modelling of structures subjected to blast loading	Børvik
Lars Edvard Bryhni Dæhli*	M	Norway	Structural engineering	2013-2017	Modelling of damage and fracture in aluminium alloy structures	Hopperstad
Erik Løhre Grimsmo**	M	Norway	Structural engineering	2013-2017	Bolted connections subjected to dynamic loading	Clausen
Jens Kristian Holmen**	M	Norway	Structural engineering	2013-2016	Computer-aided design of lightweight protective structures	Børvik
Petter Henrik Holmstrøm**	M	Norway	Structural engineering	2013-2017	Modelling of the mechanical behaviour of fibre-reinforced polymers	Clausen

* = Salary and operational costs from the Centre
** = Operational costs from the Centre, salary from other sources

MSc candidates with thesis related to the Centre's research agenda and an advisor from the Centre staff

Name	M/F	Nationality	Scientific area	Year in the centre	Thesis title	Main thesis advisor
HO. Bakken / H. Iversen	M	Norway	Structural engineering	2007	Road restraint systems	Lademo
H.A. Wathne / J. Wiggen	M	Norway	Structural engineering	2007	Trawl gear impact	Langseth
V A. Ulstein / A.M. Nøstvold	M	Norway	Structural engineering	2007	Plated structures subjected to explosion	Clausen
A.L. Lunde	M	Norway	Structural engineering	2007	Pipeline joining	Clausen
I. Westermann	F	Norway	Structural engineering	2007	Development of microstructure in aluminium during cold forming	Nes
K.H. Johansen / Ø. Gundersen	M	Norway	Structural engineering	2007	Bolted connections in aluminium	Larsen
A. Amundsen	M	Norway	Structural engineering	2008	Behaviour and modelling of self-piercing rivet connections in aluminium	Langseth
H. Aunehaugen	F	Norway	Structural engineering	2008	The behaviour of a high-strength aluminium alloy during impact	Børvik
K.H. Børøsund	M	Norway	Structural engineering	2008	Compression test on rings made of PEHD	Clausen
A. K. Drømtorp	F	Norway	Structural engineering	2008	Finite element analyses of welded aluminium connections	Hopperstad
K. C. Gallaher	M	Norway	Structural engineering	2008	Behaviour of beam connection – coped beam	Aalberg
G. Gruben	M	Norway	Structural engineering	2008	Finite element analyses of aluminium crash components	Hopperstad
H. Gundersen	F	Norway	Structural engineering	2008	Capacity simulations of beam-end connections and welded plates	Aalberg
E. Guriby / M. Mathiesen	M	Norway	Structural engineering	2008	Stiffness calculations for bearing type steel joints	Aalberg
J. I. Kristiansen	M	Norway	Structural engineering	2008	Development of damage on impacted pipelines	Langseth
E. Kristoffersen	M	Norway	Structural engineering	2008	Fracture modelling in quasi-ductile metals during impact	Børvik
E. R. Larsen	M	Norway	Structural engineering	2008	Use of aluminium foam to simulate blast loading	Børvik
T. Svanstrøm	M	Norway	Structural engineering	2008	Numerical simulation of fracture in bumper beam systems	Hopperstad
C. Berg	M	Norway	Structural engineering	2009	Computer implementation of the element method for crack growth problems	Mathisen
A. T. Bøksle	M	Norway	Structural engineering	2009	Deformation of polymers: Tests and numerical simulation	Clausen
A. K. Forseth	M	Norway	Structural engineering	2009	Investigation of cylindrical steel pipes with standardized pile ends	Aalberg
G. W. Granum	M	Norway	Structural engineering	2009	Nonlinear analyses of rectangular hollow section joints	Aalberg
M. Hovde	M	Norway	Structural engineering	2009	Plate girders with large web openings	Larsen
T. K. Johansen	M	Norway	Structural engineering	2009	Fracture of ductile materials: Experiments and simulations	Hopperstad
A. Ø. Kolstrøm	M	Norway	Structural engineering	2009	Beam to column joints	Aalberg
E. C. Langmoen	M	Norway	Structural engineering	2009	Behaviour of long aluminium extrusions subjected to axial loading	Langseth
A. Lervik / O. J. Lyng	M	Norway	Structural engineering	2009	Beam to column joints	Aalberg
E. Myklebust	M	Norway	Structural engineering	2009	Crash systems in trucks	Langseth
P. D. Nonstad	M	Norway	Structural engineering	2009	Imperfections in steel girders with web openings	Aalberg

M. R. Nøttveit	M	Norway	Structural engineering	2009	Low velocity perforation of steel plates	Børvik
K. G. Rakvåg	M	Norway	Structural engineering	2009	Combined blast and fragment loading of plates	Børvik
C. Revå	M	Norway	Structural engineering	2009	Computer implementation of the element method for crack growth problems	Mathisen
A. T. Sandven	M	Norway	Structural engineering	2009	Blast loaded window glasses	Børvik
L. Worren	M	Norway	Structural engineering	2009	Capacity of beam girders loaded in shear	Aalberg

M. B. Austnes / O. Bjørklid	M	Norway	Structural engineering	2010	Impact on Duplex stainless steel pipes with and without precipi-tated sigma phase	Børvik/Hopperstad/ Langseth
H. Torseth	M	Norway	Structural engineering	2010	Optimization of steel for protective structures	Solberg
M. Haugen / M. T. Hovden	M	Norway	Structural engineering	2010	Tests and Numerical Simulations of Polymer Components	Clausen/Hopperstad
E. Høyland / M. Kristoffersen	M	Norway	Structural engineering	2010	Fragmentation of metallic materials during impact	Børvik/Rakvåg/ Hopperstad
C. Kaurin / M. O. Varslot	M	Norway	Structural engineering	2010	Blast loading on square steel plates: A comparative study on numerical methods	Børvik/Rakvåg/ Hopperstad
M. Khadyko	M	Norway	Structural engineering	2010	Numerical modelling of the effects of crystallographic texture and grain structure on the macroscopic behaviour of metals	Saai/Dumoulin/ Hopperstad
Ø. Torgersrud / Ø. Nørstebø	M	Norway	Structural engineering	2010	Ductility of aluminium alloy 6016	Reyes
H. L. Nossen	M	Norway	Structural engineering	2010	Behaviour of aluminium at elevated strain rates and temperatures	Clausen/Børvik/ Hopperstad
A. Ørmen / K. Slåttedalen	M	Norway	Structural engineering	2010	Impact against offshore pipelines	Børvik/Hopperstad/ Langseth
G. Olsen	M	Norway	Structural engineering	2010	Design of an aluminium test cart	Aalberg/Langseth
S. Oven	M	Norway	Structural engineering	2010	Design of lightweight protective structures	Børvik/Hopperstad/ Langseth
A. Rybakken	M	Norway	Structural engineering	2010	Evaluation of Material Models for Thermoplastics	Clausen
S. J. Tveito	M	Norway	Structural engineering	2010	Driving of hollow steel piles with rock shoes into rock	Aalberg/Langseth
Ø. Vagnildhaug	M	Norway	Structural engineering	2010	Pipelines response to trawl pull-over	Hopperstad

L. Aune	M	Norway	Structural engineering	2011	Wave slamming forces on jacket in shallow water	Aalberg
I. Birkeland	M	Norway	Structural engineering	2011	Joints in buildings	Aalberg
E. B. Bjerknes	M	Norway	Structural engineering	2011	Time-dependent response of thermoplastics	Clausen
A. Dahlen	F	Norway	Structural engineering	2011	Plastic deformation and fracture of polymer materials	Clausen
J. G. Fornes / S. Gabrielsen	M	Norway	Structural engineering	2011	Impact against offshore pipelines	Børvik
G. Gjessing	M	Norway	Structural engineering	2011	Cyclic response of thermoplastics	Clausen
S. Hallset / J. S. Haagenrud	M	Norway	Structural engineering	2011	Combined fragment and blast loading on plates	Børvik
G. Haug	M	Norway	Structural engineering	2011	Running fractures in a H2 pressurized pipeline: from small scale material testing to full scale experiments and simulations	Hopperstad
Ø. J. Hjort / M. E. H. Andersen	M	Norway	Structural engineering	2011	Modelling procedures for non-linear analysis of metallic structural components	Hopperstad
E. Hofseth / Ø. Sæveland	M	Norway	Structural engineering	2011	Design of structural frame for tidal stream turbine	Aalberg
S. Kalstad / T.S. Nord	M	Norway	Structural engineering	2011	Fragmentation of metallic materials during impact	Børvik
F.T. Karlsen	M	Norway	Structural engineering	2011	Joints for elements of hollow sections	Aalberg
J. Karstensen / K. Frøysnes	M	Norway	Structural engineering	2011	Modelling procedures for non-linear analysis of metallic structures components	Hopperstad
I. M. Larsen	F	Norway	Structural engineering	2011	On the fracture locus of ductile materials	Børvik
A. H. Malvik	M	Norway	Structural engineering	2011	Void growth in calcium carbonate filled PVC	Clausen
B. Nesland	M	Norway	Structural engineering	2011	Perforation resistance of lightweight protective structures. An experimental and analytical study.	Børvik
V. R. Rørsand / M. M. Saltnes	M	Norway	Structural engineering	2011	Fibre-reinforced thermoplastics	Clausen
R. B. Stormoen	F	Norway	Structural engineering	2011	Experimental investigation and numerical modelling of sheet metal formability	Lademo
S. Valheim	M	Norway	Structural engineering	2011	Running fracture in a H2 pressurized pipeline: characterization and simulation of dynamic ductile fracture in two X65 pipeline steels	Hopperstad

V. Aune / M. S. Hovdelien	M	Norway	Structural engineering	2012	Impact Against Offshore Pipelines	Børvik
H. Bergsager / E. H. Bårgard	M	Norway	Structural engineering	2012	Buried Penstock in Steep Terrain	Aalberg
A. Bratlie	M	Norway	Structural engineering	2012	Impact on Duplex Steel Pipes with Precipitated Sigma-phase	Børvik
J. Ø. Gjernes / E. R. Klokk	M	Norway	Structural engineering	2012	Simulation of fracture and crack propagation using X-FEM	Hopperstad
M. K. Grindstad	M	Norway	Structural engineering	2012	Behaviour of End Plate Joints in Hollow Sections	Aalberg

S. Gunstad	M	Norway	Structural engineering	2012	Structural Frame for Tidal Stream Turbine	Aalberg
E. F. Haare	M	Norway	Structural engineering	2012	Penetration of Pile Shoes in Rock	Aalberg
N. K. Haga	F	Norway	Structural engineering	2012	Design of steel fasteners for use in concrete	Aalberg
T. Hegni	F	Norway	Structural engineering	2012	Validation of material model for polypropylen (HDPE)	Clausen
C. B. Hillestad	M	Norway	Structural engineering	2012	Impact on Duplex Steel Pipes with Precipitated Sigma-phase	Børvik
J. K. Holmen / J. Johnsen	M	Norway	Structural engineering	2012	Effects of Heat Treatment on the Ballistic Properties of AA6070 Aluminium Plates	Børvik
T. Karlsen / A. B. Kjølseth	M	Norway	Structural engineering	2012	Fragmentation of Metallic Materials During Impact	Børvik
V. Martinsen	M	Norway	Structural engineering	2012	Micromechanical Modelling of Strain Localization and Fracture in Aluminium	Hopperstad
O. Neset	M	Norway	Structural engineering	2012	Structural Frame for Tidal Stream Turbine	Aalberg
A. Ostad	M	Norway	Structural engineering	2012	Behaviour of End Plate Joints in Hollow Sections	Aalberg
L. J. Reiersølmoen	F	Norway	Structural engineering	2012	Design of steel fasteners for use in concrete	Aalberg
V. Schønberg / C. D. Øien	M	Norway	Structural engineering	2012	Simulations of impact using the modified Gurson model	Hopperstad
K. Sælen / K. Vange	F	Norway	Structural engineering	2012	Validation of material model for polypropylene (PP)	Clausen
T. Østen	M	Norway	Structural engineering	2012	Validation of Material Model for Polyvinyl Chloride (PVC)	Clausen
K. H. Andersen	M	Norway	Structural engineering	2013	Numerical Simulations of Docol 600 DL Steel Plates Subject to Blast Loading	Børvik
T. I. Asheim	M	Norway	Structural engineering	2013	Impact Against Offshore Pipelines	Børvik
B. E. Egeland	F	Norway	Structural engineering	2013	Stivhet til endeplateforbindelser i hulprofil	Aalberg
H. O. S. Eide	F	Norway	Structural engineering	2013	Blast Loaded Aluminium Plates	Børvik
K. C. Falao	M	Norway	Structural engineering	2013	Blokkutrivningsbrudd i aluminiumsplater	Aalberg
F. B. Hernandez	M	Norway	Structural engineering	2013	Numerical Simulations of Docol 600 DL Steel Plates Subject to Blast Loading	Børvik
P. H. Holmstrøm / J. K. Sønstabø	M	Norway	Structural engineering	2013	Behaviour and Modelling of Self-piercing Screw and Self-piercing Rivet Connections	Langseth
A. Ilseng	M	Norway	Structural engineering	2013	Mechanical behavior of laminated glass exposed to blast loading	Clausen
V. B. Kristensen	M	Norway	Structural engineering	2013	Visco-elastic response of thermoplastics	Clausen
K. Lauknes	M	Norway	Structural engineering	2013	Beregning av endeplate i høyfast stål	Aalberg
E. A. Melby	M	Norway	Structural engineering	2013	Blast Loaded Aluminium Plates	Børvik
I. Mogstad	M	Norway	Structural engineering	2013	Impact Against Offshore Pipelines	Børvik
E. Semb	M	Norway	Structural engineering	2013	Behavior of Aluminum at Elevated Strain Rates and Temperatures	Clausen
I-M. Torstvedt	F	Norway	Structural engineering	2013	Stivhet til endeplateforbindelser i hulprofil	Aalberg
H. Urseth	M	Norway	Structural engineering	2013	Design of Beam Ends with Copes	Aalberg
A. S. Vium	M	Norway	Structural engineering	2013	Oppførsel til platefelt med tverrstivere - Oseberg Sør dekker	Aalberg
R. Zahlquist	M	Norway	Structural engineering	2013	Knekklast for platefelt med aksiallast	Aalberg
H. Røstum	M	Norway	Structural engineering	2013	Behaviour and modelling of injection molded PP	Clausen
B. Siedziako	M	Poland	Structural engineering	2014	Analysis of beam ends with copes	Aalberg
B. Hofstad / K. Hofstad	M	Norway	Structural engineering	2014	Effekter av shear lag i stålbjelker	Aalberg
T-A. Knutsen / T. Oma	M	Norway	Structural engineering	2014	Forsøk og stivhetsberegninger for hulprofil-endeplateskjøt	Aalberg
A. M. Uhre	M	Norway	Structural engineering	2014	Hulprofil med endeplateforbindelse	Aalberg
S. T. Frølandshagen	M	Norway	Structural engineering	2014	Kapasitet av konsoll i stål	Aalberg
H. Aa. Nisja	F	Norway	Structural engineering	2014	Numerical Modelling of Brittle Failure in Ice Structures	Aalberg
B. G. Myrold / E. Skulstad	M	Norway	Structural engineering	2014	Stiverplater og konsollplater med trekantform, oppførsel og kapasitet	Aalberg
T. A. Hustad / A. L. Lindland	M	Norway	Structural engineering	2014	Aluminum structures exposed to blast loading	Børvik
E. Orthe / H. Thorsen	M	Norway	Structural engineering	2014	Ballistic Perforation of Surface Hardened Mild Steel Plates	Børvik
E. Digerud / K. Lofthaug	M	Norway	Structural engineering	2014	Bending of X65 Offshore Steel Pipes	Børvik
S. Heggelund	F	Norway	Structural engineering	2014	Docol 600 DL Steel Plates Subjected to Blast Loading	Børvik
S.M.W. Breivik / E.F. Thomsen	M	Norway	Structural engineering	2014	Perforation of Welded Aluminium Structures	Børvik
H. Frich	M	Norway	Structural engineering	2014	Beam - Column Connections Subjected to Static and Dynamic Loading	Clausen
A. H. Amundsen	F	Norway	Structural engineering	2014	Behaviour and Modelling of Fibre-Reinforced Polymers	Clausen
G. Båsen / T. Nordgård	M	Norway	Structural engineering	2014	Bjelke-søyle-forbindelser påkjent av statisk og dynamisk last	Clausen
S. Hegna	M	Norway	Structural engineering	2014	Mekanisk oppførsel av elastomere under trykkvariasjoner.	Clausen
B. M. Kolberg / E. T. Willand	M	Norway	Structural engineering	2014	Behaviour and Modelling of Bolted Connectors in Road Safety Barriers	Langseth
D. H. Amundsen / J. U. Gustad	M	Norway	Structural engineering	2014	Behaviour and Modelling of Flow-Drilling Screw Connections	Langseth

Appendix 3. Journal publications 2007-2014

2007

Aretz H., Hopperstad O.S., Lademo O-G.: *"Yield function calibration for orthotropic sheet metals based on uniaxial and plane strain tension tests"*. Journal of Materials Processing Technology 2007; 186(1-3);221-235.

Børvik T., Gjørv O.E., Langseth M.: "Ballistic perforation resistance of high-strength concrete slabs". Concrete International 2007; 29(6);45-50.

Dey S., Børvik T., Teng X., Wierzbicki T., Hopperstad O.S.: *"On the ballistic resistance of double-layered steel plates: An experimental and numerical investigation"*. International Journal of Solids and Structures 2007; 44:6701-6723.

Dørum C., Hopperstad O.S., Lademo O-G., Langseth M.: *"Energy absorption capacity of thin-walled AM60 castings using a shear bolt principle"*. Computers & Structures 2007; 85(1-2);89-101.

Dørum C., Hopperstad O.S., Lademo O-G., Langseth M.: *"Numerical modelling of the structural behaviour of thin-walled cast magnesium components using a through-process approach"*. Materials & Design 2007; 28(10).

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Hanssen A.G., Artelius A., Langseth M.: *"Validation of the simplified super folding element theory applied for axial crushing of complex aluminium extrusions"*. International Journal of Crashworthiness, IJCrash 2007 Vol. 12 No. 6;591-596.

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What is an SFI?

The Research Council of Norway (RCN) administers a number of funding schemes to promote excellence in research. One of them is the SFI (Centre for Research-based Innovation) scheme.

The main objective for the SFIs is to enhance the capability of the business sector to innovate by focusing on long-term research based on forging close alliances between research-intensive enterprises and prominent research groups. The SFI scheme will:

- Encourage enterprises to innovate by placing stronger emphasis on long-term research and by making it attractive for international companies to establish R&D activities in Norway.
- Facilitate active alliances between innovative enterprises and prominent research groups.
- Promote the development of industrially oriented research groups that are on the cutting edge of international research and are part of strong international networks.
- Stimulate researcher training in fields of importance to the business community and encourage the transfer of research-based knowledge and technology.

Host institution and partners

The host institution for a centre can be a university, a university college, a research institute or an enterprise with a strong research activity. The host institution should have a strong reputation within the disciplines or industrial areas the centre addresses. The host institution's administration must make a declaration of intent stating that it will undertake the obligations entailed by hosting, and explain how the SFI's research will fit into the host institution's research strategy.

The partners (enterprises, public organisations and other research institutions) must contribute to the centre in the form of funding, facilities, competence and their own efforts throughout the life cycle of the centre. User partners must point out the commercial potential they envisage resulting from the centre's activities. The life span of a centre is eight years.

Budget

Last November, RCN announced 17 new SFI centres, of which SIMLab's follow-up CASA is one. In the eight years to come, The Research Council will be allocating roughly NOK 1.6 billion to the new centres.

Each centre receives roughly 12 MNOK per year from RCN. The host institution and partners must contribute with at least the same amount.

sfi Centre for Research-based Innovation

FINAL REPORT SIMLab Centre for Research-based Innovation

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THE GOALS

The main objective of the Centre was to provide a technology platform for the development of safe and cost-effective structures.

The original quantitative goals were
1. Industrial: To implement the developed technology by exchange of personnel and arranging courses for the partners and to facilitate employment with them for MSc and PhD candidates.
2. Academic: To graduate 10 PhD and 80 MSc candidates, to attract five foreign professors/scientists, to publish 64 papers in international journals and organize two international conferences.

In most categories, final results are twice the original goals.
In other words: **Mission accomplished.**

CONTACT – RESPONSE

Professor Magnus Langseth
Dr. ing., Centre Director
Phone: +47 73 59 47 82, +47 930 37 002
Email: magnus.langseth@ntnu.no

Peter Karlsaune, Coordinator
Phone: +47 73 59 46 72, +47 450 02 177
Email: peter.karlsaune@ntnu.no

Albert H. Collett, Author of Report
Phone: +47 917 66 127
Email: albert.collett@ntnu.no

Postal address:
SIMLab, Department of Structural Engineering,
NTNU, NO-7491 Trondheim, Norway

Office location:
NTNU, Richard Birkelands vei 1a,
Trondheim, Norway