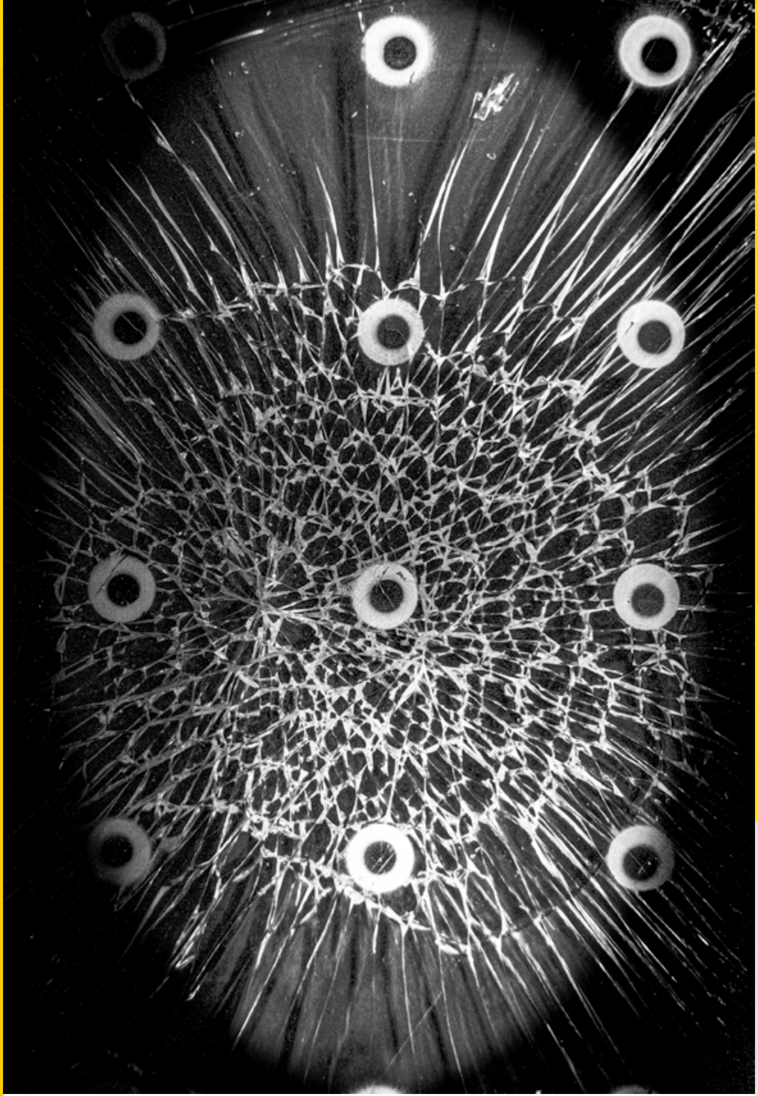

Final report
2015-2023

CASA
Centre for Advanced Structural Analysis

Norwegian Centre for Research-based Innovation

SINTEF

NTNU

NORWEGIAN NATIONAL SECURITY AUTHORITY

Norwegian Ministry of Local Government and Regional Development

Statens vegvesen

HONDA

BMW

Audi

BENTELER Automotive

RENAULT

equinor

FORSVARSBYGG

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Magnus Langseth: Lena Knutli

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Olav Bolland: Thor Nielsen

P13 Figures
RQ1: Vetle Espeseth
RQ2: John Fr. Berntsen
RQ3: Karoline Osnes

P 16-29:
Programme Heads: Lena Knutli
Anne-Sophie Sur: Dept. of Structural Engineering, NTNU
All other: Sølvi W. Normannsen

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Nicolas Neumann: Sølvi W. Normannsen
Eric DeHoff: Sølvi W. Normannsen

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Research for a Safer Society

Magnus Langseth, Centre director

It takes a massive amount of teamwork to run a functional SFI. This report aims to show how CASA has done so and how our efforts delivered an impact for those who invested in us

Destructive experiments have been SFI CASA's hallmark over the years. Violent crashes. Blast loadings and shock waves. Projectiles fired at glass, steel, and concrete. All the destruction has had a higher goal: improved safety for people and vital infrastructure. The experiments were used to develop and validate numerical models. Structural engineers and industrial designers use the models to simulate how materials, buildings, cars, and other structures behave under extreme loading.

THE BEAUTY OF THE GENERIC

The public and private partners who embarked on the journey with us more than eight years ago come from the transportation, energy, and physical security sector. Although for different applications, they all could benefit from our technology.
That is the beauty of generic research.
Computer crash tests can reduce the number of physical tests needed, leading to less waste and contributing to the green shift. The new virtual tools can drastically reduce the time – and money – spent on testing prototypes. Improved accuracy makes the models more reliable and safer to use.

BRIDGING THE TECHNOLOGY GAP

In addition to providing insight into the teamwork behind the Centre, this report is an opportunitiy for us to showcase the praiseful concluding remarks of our Scientific Advisory Board (SAB). The SAB comprises some of the world's foremost experts in our field. Their final report described the Centre using words such as «World-leading. Business sector relevant research of the highest international quality. A collaboration built on mutual trust between scientists and industrial partners». We must quickly look in the rearview mirror to understand how we progressed to this stage.

WIDER IN SCOPE AND DEEPER IN SCALE

Our vision was to establish a world-leading centre for multiscale testing, modelling and simulations of materials and structures for industrial applications. CASA surpassed our predecessor, SFI SIMLab (2007-2014), in breadth of scope and depth of scale.
Some of our first PhD candidates studied and modelled how the atoms in different aluminium alloys behave under large deformations. The models developed make it possible to optimise for superior material properties down to the nano level and adjust the chemical composition and treatment accordingly.

A VIRTUAL LAB AND GROUNDBREAKING RESEARCH

Hydro uses CASA technology to develop ideal aluminium alloys for different customers. Two of the most extensive simulation programs in the world, LS-DYNA and PAMCRASH, have included models generated by the Centre. Our glass model has become mainstream in leading car manufacturers' design and production processes.

In collaboration with the Norwegian Defence Estates Agency (NDEA), the Centre has developed material models that allow the NDEA to run simulations of projectiles penetrating concrete. CASA's research on optimal pipeline solutions has saved companies such as Equinor large sums of money.

The Scientific Advisory Board left no doubt that the Centre has facilitated effective bridgebuilding between science and industry. You can read more about our joint efforts and achievements on the following pages.

Interested in more details? Check out CASA's publications and our comprehensive collection of annual reports.

Magnus Langseth

A Great Success for NTNU

Olav Bolland, Chairman of The Board

The Centre for Research-based Innovation, CASA, is a great success for NTNU. CASA´s research is about understanding how materials and structures react to impact and other extreme loadings. The more we know, the safer industry can design cars, pipelines, and buildings. The research centre has been closely linked to the education of students.

CASA has used testing and research in laboratories to improve understanding of physical phenomena and material properties and has used this to improve mathematical simulation models.

CASA has worked in close collaboration with the international car industry, metal producers, the petroleum industry, and public agencies responsible for various infrastructure. It has been important for CASA to both be academically outstanding internationally, and at the same time contributed with innovations and value for its partners.

I am very satisfied with the development of a strong professional environment, the research results, all the PhD and master's candidates who have been trained, and the contribution NTNU has made to its partners.

Olav Bolland

Dean of the Faculty of Engineering and chairman of CASA's board.

Concrete specimens after compression tests.
Photo: Sølvi W. Normannsen

Verktøy for innovasjon

Stipendiat Øystein Eirik Kvist Jacobsen sammenligner karbonfotavtrykket og sikkerheten til standard betong og betong produsert med lavere karbonutslipp. Her studerer han og veilederne hans, professor Tore Børvik (til venstre) og Dr. Sumita Dey fra Forsvarsbygg, en video der et prosjektil skytes gjennom en betongplate. I bakgrunnen: senioringeniør Trond Auestad ved SFI CASA. (Foto: Sølvi W. Normannsen)

Da CASA startet opp i 2015, satte vi oss noen overordnede mål. Vi skulle være et attraktivt vitenskapelig arbeidsmiljø. Grunnleggende kunnskap skulle utvikles gjennom tverr-faglig teoretisk, numerisk og eksperimentell forskning i ulike skalaer. Kunnskap og teknologi skulle overføres til tre sentrale sektorer: olje og gass, fysisk sikkerhet og transport.
Vi skulle tilby partnerne våre en forsknings- og teknologiplattform. Ut fra denne skulle vi legge til rette for å skape og utvikle smarte, kostnadseffektive, sikre og miljøvennlige konstruksjoner og produkter. Nøkkelen til alt dette var flerskala testing, modellering og simulering.
I dag, åtte år etterpå, er vi stolte over å kunne si at vi holdt fast i målene vi satte oss, og at vi har oppnådd dem.

VERKTØY FOR INNOVASJON
CASA har utviklet og validert beregningsverktøy for innovasjon sammen med, og for partnerne våre. Mens Equinor og DNV kommer fra olje- og gassindustrien, representeres transportindustrien ved Hydro, Benteler, Audi, BMW, Honda, Renault og Statens vegvesen. Kommunal- og distriktsdepartementet, Multiconsult, Nasjonal Sikkerhetsmyndighet og Forsvarsbygg er alle industrielle og offentlige virksomheter som arbeider med fysisk sikkerhet.

NTNU har vært vertsinstitusjon, mens forskningsgruppen SIMLab ved Institutt for konstruksjonsteknikk har ledet senteret. SINTEF Industri har vært forskningspartner. Senterets øvrige samarbeidspartnere har vært Institutt for fysikk og Institutt for materialteknologi.

VITENSKAPELIGE RESULTATER
Diskusjoner med partnerne viste oss tidlig at mer omfattende bruk av avanserte numeriske simuleringer er viktig for å forbedre konkurranseevnen deres. Vi konsentrerte arbeidet om fem grunnleggende forskningsområder:
Oppførsel og modellering av konstruksjoner, forbindelser/skjøter mellom konstruksjoner, metalliske materialer, polymere materialer og materialer på lavere skala. Hovedmålet er alltid den ferdige konstruksjonen eller produktet.

Forskningen i senteret har så langt resultert i 165 publikasjoner i fagfellevurderte tidsskrifter, 150 konferansebidrag og 25 inviterte/keynote-foredrag.

MERITTLISTEN VÅR:
- Virtuelt laboratorium for design av metalliske konstruksjoner
- Flerskala modelleringsrammeverk for konstruksjonsmessige forbindelser.
- Probabilistisk styrkeprediksjonsmodell for float- og laminert glass
- Regulariseringsskjema for skallelement med modellering av svikt i metaller
- Eksperimentelle teknikker for karakterisering av polymerer over et bredt spekter av temperaturer og tøyningshastigheter
- Enkel modell for fiberarmerte polymerer
- Dypere forståelse av mekanismer for korngrensedeformasjon på nanoskala.
- Eksperimentelle studier som viser at lavkarbon betong har like stor gjennomtrengningsmotstand som normalbetong.
- Etablering av spinoff-selskapet Enodo As i 2018

SLIK HAR FORSKNINGEN VIRKET
For å styrke implementeringen av teknologien utviklet i senteret hos brukerpartnerne, etablerte vi en industriell referansegruppe (IRG). Denne bestod av eksperter fra partnerne. IRG har hatt jevnlige møter. Mandatet har vært å legge fram en årlig rapport for SFI CASA-styret om hvordan teknologien utviklet i senteret brukes. I 2019 ga CASA rådgivningsfirmaet Impello Management i oppdrag å kartlegge innovasjoner og effekter hos partnerne som følge av deltakelsen i senteret. Rapporten viste, halvveis i prosjektperioden, et potensiale for besparelser på flere hundre millioner euro når industrien tar metoder og teknologi i bruk.

MANGE FLERE KAN TA VERKTØYENE I BRUK
Pålitelige numeriske simuleringer har også relevans og nytte for offentlig sektor, industri eller sivilsamfunn enten vi ser det i regionale, nasjonale eller globale sammenhenger. Norsk næringslivs motivasjon for å ta slike verktøy i bruk, vil være den samme som senterets brukerpartnere.

EKSEMPLER PÅ MULIGE ANDRE BRUKSOMRÅDER:
- fornybar energi (design av vindturbiner utsatt for vind og bølger)
- fiskeoppdrett/akvakultur (design av nye og innovative merder)
- forsvarsindustri, mekanisk/produksjonsindustri (stempling, smiing, sintring og sveising)
- elektronikk (støt- og støtdemping)
- konstruksjonsteknikk (senk- og flytebroer, jordskjelvsikkerhet, design av aluminium-, stål- og betongkonstruksjoner)
- sikker transport til sjøs (sammenstøt mellom skip og is, grunnstøting).

Muligheten til å optimalisere prosesser og produkter ved hjelp av troverdige numeriske simuleringer bedrer norsk industris konkurranseevne internasjonalt. Produkter av høyere kvalitet og merverdi kan kompensere for det høye norske kostnadsnivået og være med på å sikre og støtte det norske arbeidsmarkedet.

FORSKERUTDANNING OG MASTERUTDANNING
SFI CASA har utdannet 26 PhD-kandidater. Av disse har 16 fått dekket lønns- og driftskostnader av senteret. 10 kandidater har kun medført driftskostnader for senteret mens lønn er kommet fra andre kilder. En av disse var ansatt i BMW og tilbragte halvparten av tiden ved bilfabrikantens forskningssenter i München.
157 Masterstudenter har skrevet oppgaver med tema nært knyttet til forskningen i CASA. Forskerteamet har undervist kurs som er relevante for senteret på master- og ph.d.-nivå.

INTERNASJONALT SAMARBEID
Senteret har hatt fire internasjonale industripartnere. Forskningsgruppen har gjort seg sterkt synlig gjennom publikasjoner i kjente fagfellevurderte tidsskrifter, og høye h-indekser hos nøkkelpersonell. Professor Magnus Langseth er sjefredaktør i International Journal of Impact Engineering, mens professor Tore Børvik er assisterende redaktør i samme tidsskrift. Professor Odd Sture Hopperstad er assisterende redaktør i European Journal of Mechanics A/Solids. Senterets anerkjente internasjonale forskningsposisjon har tiltrukket seg flere gjesteforskere. I tillegg har ansatte, ph.d.-kandidater og post docs vært på utenlandsopphold av varierende lengde.

MERVERDI AV SENTER-ORGANISERING
Langsiktig finansiering kombinert med en sterk forskningsgruppe som samarbeider tett med industri har gjort det mulig å drive forskning på høyt internasjonalt nivå og samtidig legge til rette for innovasjon og verdiskaping. En slik stor, samlet fou-innsats kan bare oppnås innenfor rammen av et senter. Det omfattende internasjonale nettverket til NTNU er gunstig for å kunne invitere internasjonale eksperter til å bidra til forskningen ved senteret. Senteret har spilt en viktig rolle i å definere den fremtidige retningen for forskning og utdanning. De nære koblingene mellom akademia og industri har skapt entusiasme og kreativitet. Det har også bidratt til å utvikle et felles syn på hvordan vi på best mulig måte kan iverksette ny og innovativ forskning hos brukerpartnerne.

FREMTIDSPLANER
I 2022 kjørte SIMLab-gruppen en strategiprosess som resulterte i en plan for mulige fremtidige veivalg. Det har vært avholdt flere møter med partnerne i senteret. Alle har uttrykt vilje til å fortsette samarbeidet med forskningsgruppen. Planene så langt består av et senter for fysisk sikkerhet og et senter for e-mobilitet knyttet til elektrifisering av bilindustrien. I strategiprosessen ble det etablert tett kontakt med Norges forskningsråd.

Tools for Innovation

MSc students Ingrid Gisnås (left) and Ayesh Syed performing a test in the Shock Tube Test Facilities, assisted by Senior engineer Trond Auestad and Associate Professor Vegard Aune. (Photo: Sølvi W. Normannsen)

BRIEF DESCRIPTION OF OBJECTIVES/VISION
The Centre has been an attractive scientific work environment where fundamental knowledge was created through multidisciplinary theoretical, numerical and experimental research on different scales. Interdisciplinary research beyond the state-of-the-art has been coupled with the transfer of knowledge and technology to key business sectors: oil and gas, physical security and transportation.

THE CENTRE´S OVERALL OBJECTIVE WAS:
To provide a research and technology platform for the creation and development of smart, cost- effective,safe and environmentally friendly structures and products through multi-scale testing, modelling and simulation.

BRIEF DESCRIPTION
CASA has developed and validated computational tools for innovation together with and for partners in the oil and gas industry (Equinor and DNV), the transportation industry (Hydro, Benteler, Audi, BMW, Honda, Renault and Norwegian Public Roads Administration) and in industrial and public enterprises working with physical security (Ministry of Local Government and Regional Development, Multiconsult, Norwegian National Security Authority and the Norwegian Defence Estates Agency).

NTNU has been the host institution. SIMLab at the Department of Structural Engineering has been the leading research group. The Department of Physics and the Department of Materials Science and Engineering at NTNU, as well as SINTEF Industry have acted as cooperating units.

SCIENTIFIC RESULTS
Discussions with the partners revealed that more extensive use of advanced numerical simulations would improve their competiveness in making cost-effective, safe and environmentally friendly structures and products. These industrial needs formed the basis for five Basic research areas where multi- and interdisciplinary research on different physical scales was conducted. This research encompassed the behaviour and modelling of Structures, Structural Joints, Metallic Materials, Polymeric Materials and of materials at Lower Scale. The main goal of the research was always the final structure or product.

The research in the Centre has so far resulted in 165 publications in peer-reviewed journals, 150 conference contributions and 25 invited/keynote lectures.

EXAMPLES OF MAIN RESEARCH ACHIEVEMENTS:
Our main research achievements:
- Virtual laboratory for the design of metallic structures
- Multiscale modelling framework for structural joints
- Probabilistic strength prediction model for float and laminated glass
- Regularization scheme for shell element modelling of failure in metals
- Experimental technique for characterization of polymers over a wide range of temperatures and strain rates
- Simple model for fibre-reinforced polymers
- Deeper understanding of mechanisms for grain boundary deformation at the nanoscale.
- Experimental studies proving that low carbon concrete has the same perforation resistance as normal concrete
- Spin-off company Enodo, established in 2018

RESULTS AND IMPACT
We established an Industrial Reference Group (IRG) with experts from the partners to strengthen the implementation of the technology developed in the Centre. The IRG had regular meetings, and, according to the defined mandate, presented a report to the SFI CASA Board once a year. The report adressed how implementation was to be carried out and how research and commercial cooperation would be initiated between the industrial partners.
On mission from CASA, the strategic and financial advisory firm Impello Management mapped impact and innovations from the Centre. The report (2019) showed a realized economic impact of hundreds of millions of euro saved when industry implements CASA's technologies and methods.

MANY MORE CAN USE THE TOOLS
Credible numerical simulations have relevance and benefit for the public sector, industry or civil society viewed in regional, national or global contexts. The motivation for other segments of the Norwegian business sector using numerical simulations is the same as for the present user partners.

SOME EXAMPLES OTHER USE AREAS:
- renewable energy (design of wind turbines exposed to wind and waves)
- fish farming (design of new and innovative net structures in aquaculture)
- the defence industry, mechanical/manufacturing industry (stamping, forging, sintering, welding)
- electronics (impact and shock absorption)
- structural engineering (submerged and floating bridges, earthquake safety, design of aluminium, steel and concrete structures)
- safe transportation at sea (interaction between ship and ice, stranding)

The opportunity to optimize processes and products using credible numerical simulations improve industrial competitiveness internationally. Products of higher quality and excess value can compensate for the high Norwegian cost level and in turn secure and support the Norwegian labour market.

RESEARCHER TRAINING EDUCATION
26 PhD candidates were educated in the Centre. Of them 16 have had salary and operational costs covered by the Centre.10 candidates have had operational costs from the Centre only and salary from other sources. One of the students was financed and employed by BMW, and thus spent half of the time at the BMW research Centre in Munich. Renault financed one candidate, who spent 50 percent of her time at the manufacturers research centre in Guyancourt, France.
157 master's students have written their theses on topics closely related to the research in the Centre. With respect to teaching, the research team has taught courses relevant to the Centre at master's and PhD levels.

INTERNATIONAL COOPERATION
The centre had four international industrial partners. In addition, the international research cooperation has been attended through the research group's strong visibility in publications in well-known peer-reviewed journals, well noted h-indexes on key personnel. Professor Magnus Langseth is the editor-in-chief of the International Journal of Impact Engineering, whereas Professor Tore Børvik is an associate editor in the same journal. Professor Odd Sture Hopperstad is an associate editor of the European Journal of Mechanics A/Solids. The international research position of the Centre has attracted several visiting researchers. In addition, Centre staff members, PhD candidates and post docs had longer and shorter stays abroad.

ADDED VALUE OF ORGANISING
A centre with long-term funding coupled with a close cooperation between a strong research group and industry makes it possible to simultaneously carry out research at a high international level and facilitate innovation and value creation. This amounts to a major research and development effort that can only be achieved within the framework of a centre. The close links between academia and industry fostered by the centre generate enthusiasm and spurs creativity, and further enforces a common view on best practice for implementing new and innovative research for the user partners.

FUTURE PLANS FOR THE CENTRE
In 2022 the SIMLab group ran a strategy process which resulted in a strategy plan with advice for the future. Several meetings with the partners in the centre have been held in which each of them expressed willingness to continue cooperation with the research group. Plans so far consist of a centre on physical security and a centre on e-mobility linked to the electrification of the automotive industry. In the strategy process close contact with the Research Council of Norway has been established.

Main organisation of the centre

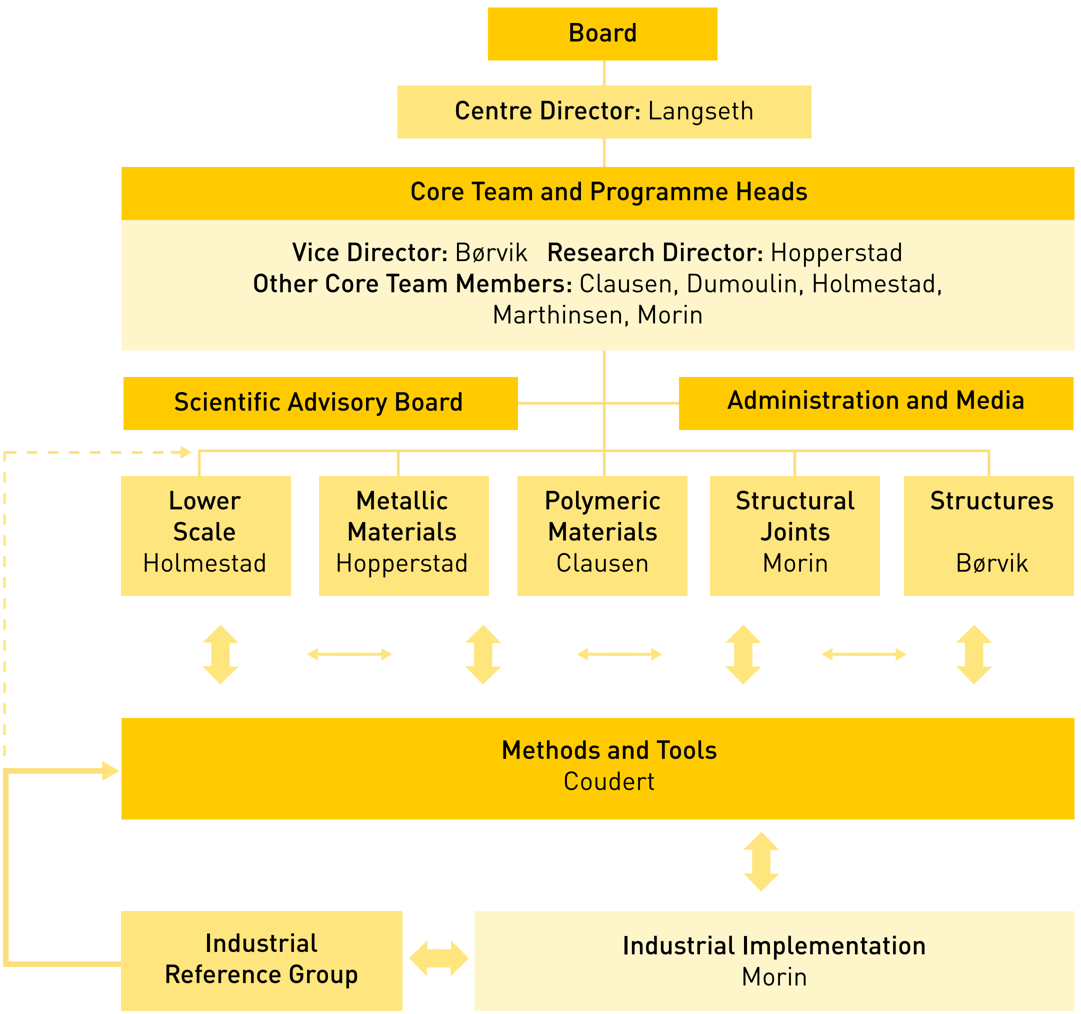
The Centre was managed by a Board whose mandate was to formulate the Centre's strategy, approve annual work plans, monitor the performance of the Centre according to the performance indicators described in the project description and annual targets, and propose corrective actions when needed. The Board is comprised of members from all consortium participants.

The daily operation of the Centre was managed by the Centre director, assisted by a core team of researchers. The research and innovation activities were organized in seven programmes of which five focused on fundamental research and two focused on industrial implementation and instruments to assist industrial utilization.

A Scientific Advisory Board of international experts was appointed to give scientific and strategic advice. They convened three times during CASAs eight years.

Finally, the implementation work in the Centre was assisted by an Industrial Reference group with one member from all consortium participants. This reference group formulated the partners' requirements and needs and was instrumental in the Centre's innovation work.

The overall management structure is illustrated below.



THE BOARD

All partners had one seat each on the Board.
The partners in SFI CASA were:

Host:
NTNU

Research partner:
SINTEF Industry

Public partners:
Gassco 2015-2017
Ministry of Local Government and Regional Development 2015-2023
Norwegian Defence Estates Agency 2015-2023
Norwegian National Security Authority 2015-2023
Norwegian Public Roads Administration 2015-2023

Company partners:
Aker Solutions 2015-2016
Audi AG 2015-2023
Benteler Automotive Raufoss AS 2015-2023
BMW Group 2015-2023
DNV AS 2015-2023
Equinor Energy AS 2015-2023
Honda R&D Americas, LLC 2015-2023
Hydro Aluminium AS 2015-2023
Multiconsult Norge AS 2018-2023
Renault 2017-2023
Sapa 2015-2018
SSAB 2015-2016
Toyota Motor Europe 2015-2020

Administration and Media:
Peter Karlsaune - Coordinator
Sølvi W. Normannsen - Communication Officer (2018-2023)
Albert H. Collett (2015-2018)

COOPERATION WITHIN THE CENTRE

CASA's research has been conducted according to annual work plans based on the project description in the SFI CASA application, previous work, and discussions with the industrial partners. The industrial partners´ involvement has been organized through the Centre's Industrial Reference Group (IRG). Each industrial partner has had one member in the IRG, whose mandate was to give advice on how implementation should be facilitated and to evaluate the implementation work at each partner. The research in the Centre was carried out by NTNU (PhD candidates, postdocs, scientists, and professors) and SINTEF (scientists) personnel. The main contribution from the partners has been to guide the direction of the research and to be active in the implementation of the technology. In addition, several industrial partners have funded Adjunct Professors and MSc projects to strengthen the link between business and academia. The Centre's research team has been located at NTNU in Trondheim, with most colleagues within a five-minute walking distance. Short distances and frequent meetings have helped the cooperation and contributed to a friendly working environment.

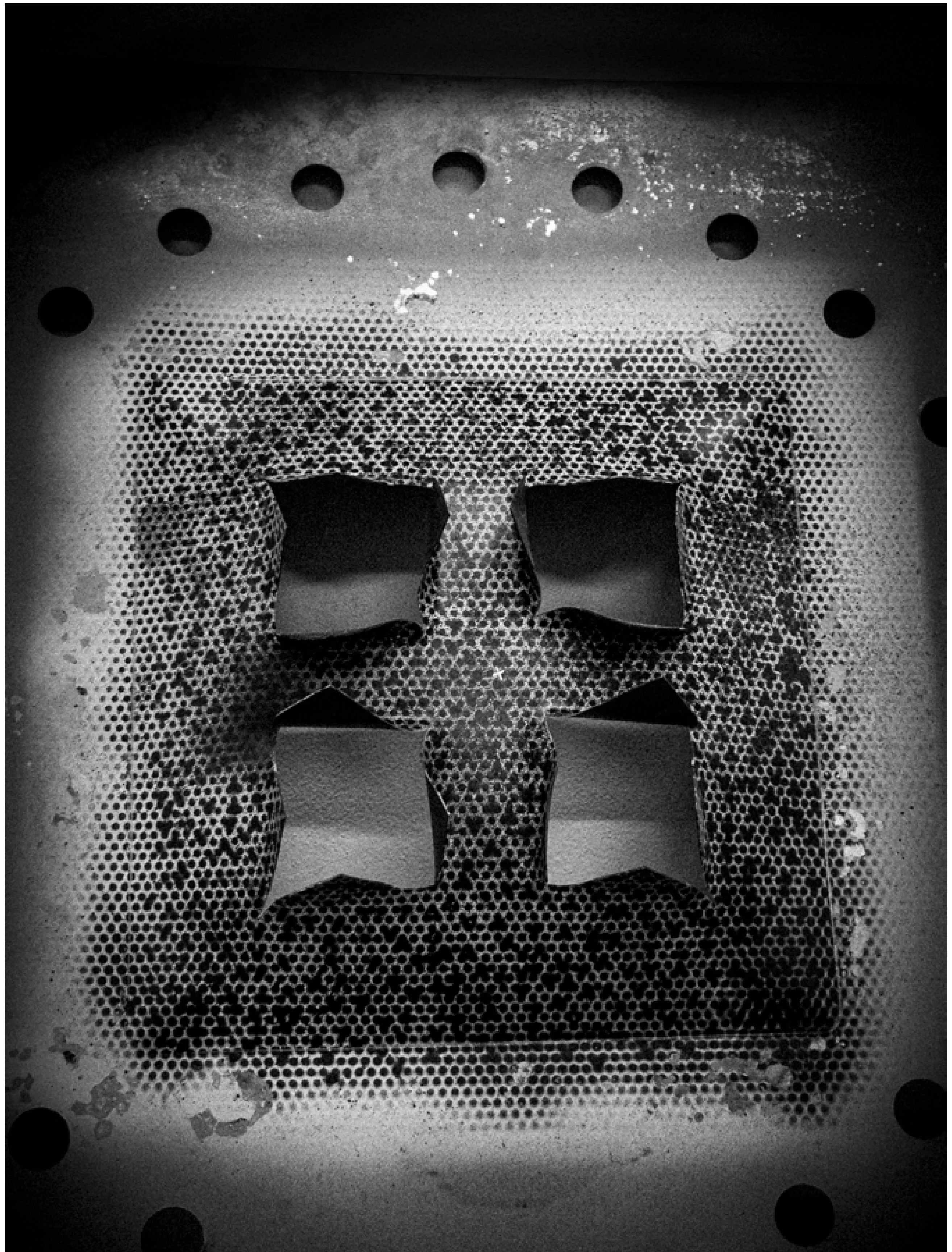
The covid-19 pandemic hindered face-to-face meetings for almost two years. However, this inspired an extensive series of online seminars on a variety of topics. As a result, social distancing in fact improved cooperation within the Centre.

THE SCIENTIFIC ADVISORY BOARD

Professor Ahmed Benallal	LMPS, Université Paris-Saclay, ENS Paris-Saclay, CNRS, France
Professor Em. David Embury	McMaster University, Canada
Professor Jonas Faleskog	Royal Institute of Technology, Sweden
Professor Norman Fleck	University of Cambridge, UK
Professor Stefan Hiermaier	Ernst Mach Institute, Germany
Professor John Hutchinson	Harvard University, USA
Professor Stefanie Reese	Aachen University, Germany
Professor Patricia Verleysen	Ghent University, Belgium

SENIOR RESEARCHERS

Magnus Langseth	Centre Director, Professor	Dept. of Structural Engineering, NTNU
Tore Børvik	Professor	Dept. of Structural Engineering, NTNU
Arild Holm Clausen	Professor	Dept. of Structural Engineering, NTNU
Terence Coudert	Research Scientist	SINTEF Industry
Stephane Dumoulin	Research Scientist	SINTEF Industry
Randi Holmestad	Professor	Dept. of Physics, NTNU
Odd Sture Hopperstad	Professor	Dept. of Structural Engineering, NTNU
Knut Marthinsen	Professor	Dept. of Materials Science and Engineering, NTNU
David Morin	Associate Professor	Dept. of Structural Engineering, NTNU



Steel plate subjected to blast loading. (Photo: Sølvi W. Normannsen)

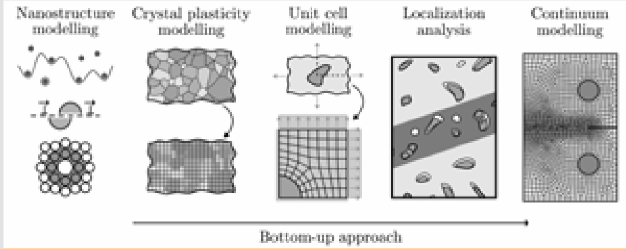
Improving Competitiveness with Numerical Simulations

The Centre selected three key business sectors: oil and gas, physical security, and transportation. All the partners shared a common objective to improve their competiveness with advanced numerical simulations. This industrial need defined three research questions as the point-of-departure for our basic research activities:

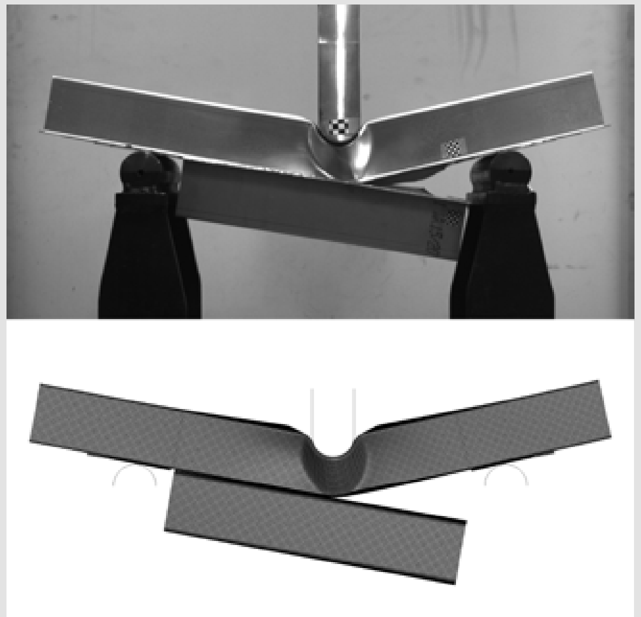
RQ1: How can we establish accurate, efficient, and robust constitutive models based on the chemical composition, microstructure, and thermo-mechanical processing of a material?

RQ2: How can we apply knowledge of material, geometry and joining technology to obtain optimal behaviour of hybrid structures for given load situations?

RQ3: How can we describe the interaction between the load and the deformable structure under extreme loading scenarios?



RQ1: The multiscale modelling framework.



RQ2: Bonded component test versus simulation.

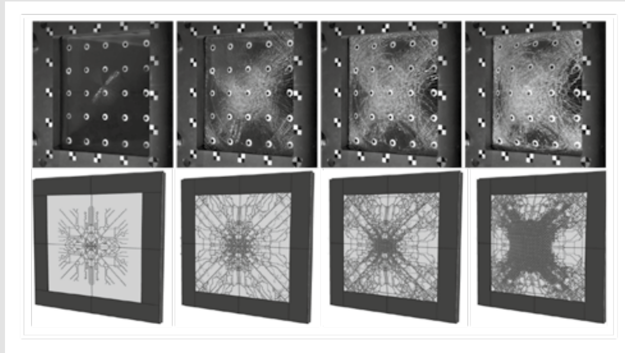
We concluded that expertise and technology should be transferred to the partners via five basic research areas of focus:
Structures, Structural Joints, Metallic Materials, Polymeric Materials, Materials at Lower scale.

All programmes were led by our key scientists.
The Metallic Materials programme, led by Professor Odd Sture Hopperstad was closely coupled to Hopperstad´s Toppforsk project "Microstructure-based Modelling of Ductile Fracture in Aluminium Alloys, FractAl (2016-2022).
In addition, we established the *Methods & Tools* and the *Industrial Implementation* programmes. Methods & Tools synthesised Basic research. Industrial Implementation linked Methods & Tools to the industrial use of the research and technology developed in CASA.

To strengthen the implementation of the technology we also established an Industrial Reference Group (IRG), that consisted of experts from the partners.

The majority of the research in the Centre was carried out by PhD candidates and post docs. All our candidates had the opportunity to have 3-4 months stay at a partner institution. The motivation was to expose the students to the need for reliable numerical simulations at the respective partner while enacting the implementation of their research.

The Midway evaluation (2019) concluded that SFI CASA «is an excellent competence centre with many examples of best practice in its research, research training, organisation, and industry support operations».
The evaluation committee´s only recommendation was that «The Centre ensure that its scientific advisory board (SAB) is gender balanced». CASA immediately followed up on the recommendation and appointed Professors Stefanie Reese (Aachen University) and Patricia Verleysen (Ghent University) to the SAB.



RQ3: Blast loading on laminated glass versus simulation.

Research that Makes a Difference

PhD student Debora Obkircher works on bolted connections in steel structures. (Photo: Sølvi W. Normannsen)

A collaboration built on mutual trust between scientists and industrial partners. Effective bridgebuilding over the technology gap.

These were some of the concluding remarks of SFI CASA's Scientific Advisory Board (SAB) in the final report on the Centre. Seven months before the doors close, the SAB observed strong indications that CASA´s industrial partners were satisfied.

The beauty of CASA's generic technology is that, although for different applications, all partners can reap the benefits. The new virtual tools drastically reduce the time – and money – spent on testing prototypes. Crash tests on a computer can reduce the number of physical tests needed, leading to less waste, and contributing to the green shift. Improved accuracy makes virtual tests more reliable and safer to use.

ONE THOUSANDTH THE WIDTH OF A STRAND OF HAIR

In many ways, the SAB report marks the close of SIMLab's SFI journey. To understand how the group progressed to this stage, praised by the world's foremost experts, we must take a quick look in the rearview mirror.

The vision for SFI CASA was to establish a world-leading centre for multi-scale testing, modelling and simulations of materials and structures for industrial applications. The predecessor, SFI SIMLab (2007-2015), was surpassed in breadth of scope and depth of scale in numerical models. Materials were studied at the scale of one thousandth the width of a strand of hair. This is the size of the smallest building blocks in aluminium and steel, the favourite construction materials of engineers and architects.

MODELS THAT SUPPLY COMMERCIAL SOLVERS

Several of the first CASA PhD students studied and modelled how the atoms in different aluminium alloys behave under large deformations.

Why?

Because the models make it possible to optimise for superior material properties all the way down to the nano level and adjust the chemical composition and treatment accordingly. Hydro uses the technology to develop ideal aluminium alloys for different customers.

Two of the largest simulation programs in the world, LS-DYNA and PAMCRASH, have included models generated by CASA. Among these, a through-thickness damage regularisation scheme for shell elements subjected to severe bending and membrane deformations. CASA's glass model has also become mainstream in the design and production processes of leading car manufacturers. The Centre has succeeded in improving the tools used by industry worldwide.

A VIRTUAL LAB AND GROUNDBREAKING RESEARCH

The Virtual Laboratory established for aluminium and steel enables the replacement of full-scale physical impact tests with simulations. CASA´s research on optimal pipeline solutions has saved companies such as Equinor large sums of money. In collaboration with the Norwegian Defence Estates Agency (NDEA), the Centre has developed material models that allow NDEA to run simulations of projectiles penetrating concrete. Ground-breaking work has transformed knowledge on glass, adhesive bonded connections, hybrid connections between aluminium and steel, and polymer foams used in car bumpers.

26 DOCTORS AND 155 MASTERS

In its eight-year programme, CASA will have produced 26 PhDs and 157 masters' degrees. These numbers include 4 PhD candidates with combined funding from CASA and FME NCCS, ALLDESIGN, BMW, and Renault respectively. In addition, 5 PhDs have been trained in the project FractAl, which has been closely connected with the activities in CASA.

The Ministry of Justice and Public Security has financed a professorship in civil infrastructure security. An external grant from Hydro sponsors a professorship in the design and modelling of aluminium structures at the Centre. The start-up company Enodo AS is a genuine and commercially viable spinoff from CASA.

RESEARCH-BASED INNOVATION – AT THE PARTNERS

The Scientific Advisory Board evaluated the Centre for the third and last time in November 2022. The members support the view that innovation is best effectuated by the industrial partners based on the research output of CASA. However, they leave no doubt that the Centre has worked profitably to bridge the gap between science and industry.

The SAB highlights that the Centre has:

- achieved its objectives in educating many researchers.
- conducted long-term, business sector relevant research of high international quality.
- conducted work well-aligned with the partners' interests.
- recruited PhD students of high quality.
- managed to attract national students.

PhD student Victor Andrés was working on modelling of multilayered joints. In the background Senior engineer Trond Auestad. (Photo: Sølvi W. Normannsen)

LOWER SCALE

Programme Head:
Professor Randi Holmestad

This programme concentrated on the lower length scales of materials, from atomic to microscale, and provided the lower scale experimental and modelling input to the multiscale framework.

THE ANSWERS LIE AT THE NANOSCALE
EMIL CHRISTIANSEN (2015-2019)

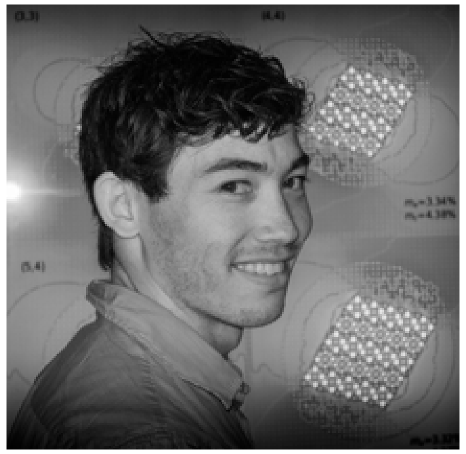
Thesis: Nanoscale Characterisation of Deformed Aluminium Alloys

«You must go down in scale to see what really happens. It is like a reality-check on the theories. In a way, the answer book lies at the nanoscale», says Emil Christiansen.
He knows more than most of what happens deep inside aluminium when the material is bent and pulled to fracture.
«We try to understand how the smallest building blocks behave, when we bend, stretch, and deform the material. Simply because with this knowledge we can achieve structural materials of higher quality».

SPUTTERING GOLD ON STEEL
CHRISTIAN OEN PAULSEN (2016-2019)

Thesis: Experimental Characterization of Two-Phase Steels

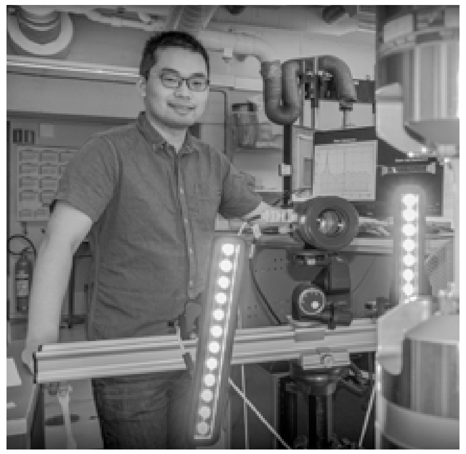
Christian Oen Paulsen went by way of gold to bring our understanding of steel one step further.
When you seek local strains in the microstructures of steel in a scanning electron microscope (SEM), contrast is essential. That is where the gold comes in. Simply, because if you sputter a layer of the precious metal on the surface of a steel specimen, contrast and resolution improve by one hundred times compared to spray paint. The experimental technique of gold sputtering plays a central role in Christian Oen Paulsen´s work on micromechanical modelling of steel.



DIGITAL DESIGN, TAILOR-MADE ALLOYS
JONAS FRAFJORD (2016-2020)

Thesis: Atomistic Scale Modelling of Defects in Aluminium Alloys

Aluminium is one of the most used materials in the global construction industry.
«Imagine bending an aluminium spoon», says Jonas Frafjord.
«The deformation that you observe is a combination of millions of small defects at the atomic level».
These defects are called dislocations, and they govern plastic deformation. The damage always begins in the microstructure. Frafjord has studied how crystals, grains, particles, atoms, and electrons move and interact with each other. He translates this behaviour into computer simulations, and thus paves the way for the digital design of tailor-made alloys.



INVESTIGATING THE PLC EFFECT
JIANBIN XU (2018-2021)

Thesis: An experimental and numerical study of the Portevin-Le Chatelier (PLC) effects in an Al-Mg alloy

The Portevin-Le Chatelier effect is related to a strengthening mechanism, but it has a catch: the additional alloying element causes the alloy to deform in an unstable manner. This can lead to poor ductility and premature failure. Xu has studied the mechanisms related to this phenomenon that have been well-known for almost 200 years.
«The PLC effect has been extensively studied. Ground-breaking research has not appeared for quite a long time. There is still a way to go to accurately predict the behaviour of a material. I have added some bricks to the wall that has already been built», says Xu.

STRUCTURAL JOINTS

Programme Head:
Associate Professor David Morin

The programme has aimed to provide validated computational models for multi-material joints applicable to large-scale finite element analyses. The scope is limited to the behaviour and modelling of structural joints made with, for example, screws, adhesive bonding, and self-piercing rivets – as well as possible combinations of these.

SAFER AND LIGHTER CAR BODIES
MATHIAS REIL (2015-2019)

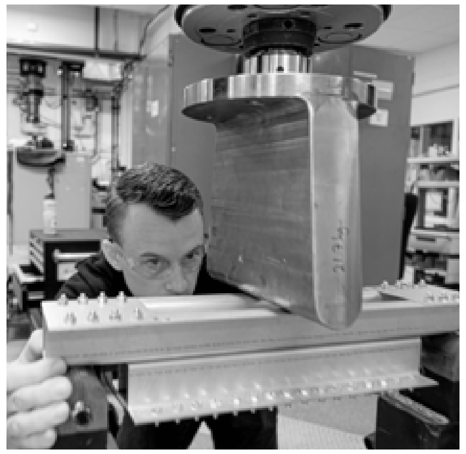
Thesis: Connections between steel and aluminium using adhesive bonding combined with self-piercing riveting: testing, modelling, and analysis.

The body of a modern car is like a gigantic 3D Puzzle, with a multitude of different materials, parts, and pieces. To join all those mixed parts is a crucial challenge in today´s design of car bodies. The industry is out on a never-ending hunt to reduce time, weight, and costs. At the same time, the complexity is increasing. «Virtual testing is one of the most important tools to solve this conflict of interest», states Matthias Reil. He is convinced that his research will contribute to safer and lighter car bodies. However, he underlines that it is «The sum of the work performed by all researchers and engineers is what makes the big difference».

THE IMPORTANCE OF ADHESIVES
JOHN FREDRICK BERNTSEN (2015-2020)

Thesis: Testing and modelling of multi-material joints

The strongest adhesive John Fredrick Berntsen has studied in his doctoral work could lift a 1500 kilo car with a bonded area of only 2x2 centimetres. «Rough estimates, and in ideal conditions, obviously. But these adhesives are not your standard glue from the kindergarten», Dr Berntsen, says. These superglues connect the range of fundamentally different materials found in modern car bodies as well as improve crash performance. Plus, they possess several other beneficial properties which explain why they are being used more and more in automotive industry.



NEURAL NETWORK MODELING TECHNIQUES
VICTOR ANDRÉ (2019-2023)

Thesis: Behaviour and modelling of multi-layered joints

Characterisation and modelling techniques are needed for the design of mixed material parts containing more than two sheets. Effects like partial joint failure must be captured in large-scale analyses to correctly predict the deformation of a crash relevant components in automotive structures. Victor André developed a virtual calibration framework and a modelling technique for self-piercing rivet joints with three aluminium sheets. Neural network modelling techniques working within the FE solver are presented to exploit the data generated from detailed joint models and increase the accuracy of future large-scale models.

THE CHALLENGE OF WELDED JOINTS
SIGURD AUNE (2021-2025)

Thesis: HAZ in Welded aluminium structures

HAZ, or heat-affected zones, occur during the welding of aluminium joints. They can reduce the strength of the metal, which in turn can lead to the failure and fatal collapse of structures.
Sigurd Aune aims to create simple and effective solutions to predict the exact behaviour of the zones when the welded joints are subjected to extreme loads. On one hand, the approach should be accurate and incorporate the interaction between various materials and joining techniques. On the other hand, the model must be easy to use and not too computationally demanding.
«So, basically, we look for a simple solution to a very complex problem», he says.

ADHESIVES AND THE TOPIC OF AGEING
FANNY DAMEME (2021-2024)

Thesis: Testing and modelling adhesives under impact loading.

Fanny Dameme works with the testing and modelling of adhesives under impact loading. Her Ph.D. thesis builds upon the work initiated by John Fredrick Berntsen and will extend the partial virtual laboratory to high-speed impacts and ageing of adhesives. The ageing topic is of high interest since, over time, adhesives can deteriorate and alter their behaviour. In a way, ageing is a critical factor in the durability of structures. In other words, a car should continue to be safe after ten years on the road. The overall idea is to shift the modelling strategy and research on adhesives developed within CASA to higher TRL levels. Partner Renault finances Dameme´s work.

THE LOAD-BEARING CAPACITY OF STEEL JOINTS
DEBORA OBKIRCHER (2022-2026)

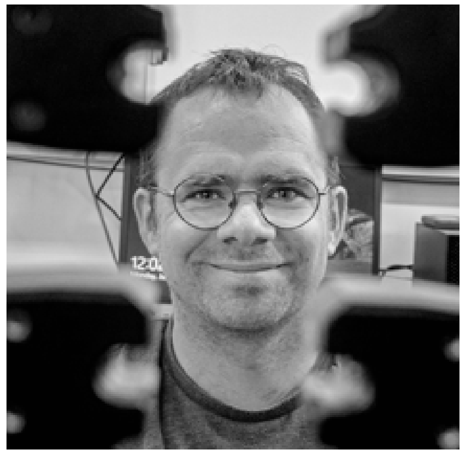
Thesis: Bearing capacity of fin-plate connection under quasi-static and dynamic loading.

Debora Obkircher is dealing with the load-bearing capacity of fin-plate connections, a type of simple steel joint. In Norway, these joints are used very commonly, partly because they are very easy to manufacture and erect. However, these joints are extremely pliant and exhibit only low energy absorption capacity, which can have a severe impact on the overall structural performance, especially when subjected to impulsive loads. Obkircher aims to obtain a more in-depth understanding of the load transfer of supporting and supported members for this type of connection.

POLYMERIC MATERIALS

Programme Head:
Professor Arild Holm Clausen

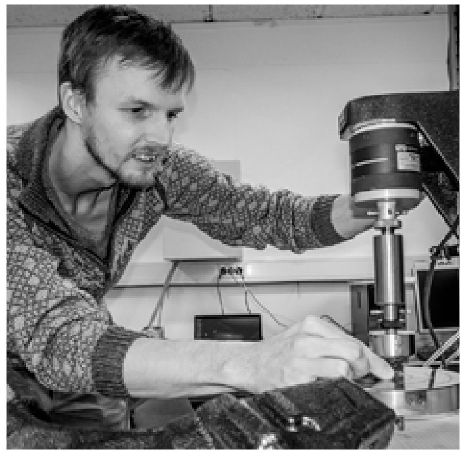
The polymeric programme aimed to develop and improve material models representing the thermo-mechanical response up to fracture for polymers, i.e., thermoplastics with or without fibre-reinforcement and elastomers. The models have been developed for application in an industrial context.



INTO THE DEEP INTERIOR OF POLYMERS
SINDRE NORDMARK OLUFSEN (2015-2020)

Thesis: Experimental and numerical study of dilation in mineral-filled PVC

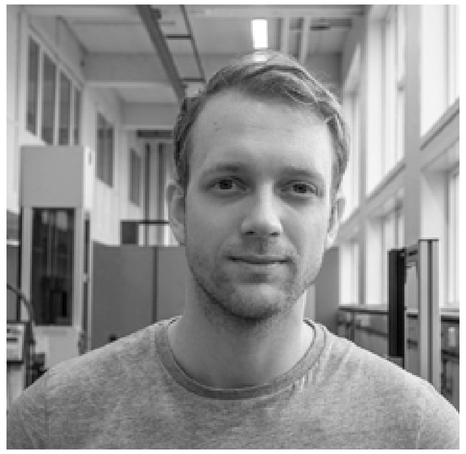
Sindre Nordmark Olufsen's efforts to understand the deep interior of polymers can improve the safety of everything from cars to planes, and perhaps even heart valves.
He has developed a novel method to measure how voids grow and spread inside a polymer during deformation.
«The novelty is that we can do such experiments using readily available equipment. Thus, we make this kind of measurement available to a broad audience and our industrial partners», he says. His work is referred to as original, creative, and ground-breaking.



MODELLING THE BEHAVIOUR OF FOAMS
DANIEL THOR MORTON (2016-2021)

Thesis: Characterization and modelling of the mechanical behaviour of polymer foam

They are ultra-light, excellent energy absorbers, and they may save your life. Daniel Thor Morton investigated foams used in the bumpers of modern cars. He worked on understanding and describing their response to impact under different loading rates and temperatures. The internal structures of the foams bear close resemblance to soapy foam. In his doctoral thesis, Morton presented a micromechanical model that resembles these structures and is used to model the behaviour of the foam.



SAFER POLYMER PRODUCTS
EINAR SCHWENKE (2018-2022)

Thesis: Behaviour and modelling of two semi-crystalline polymers over a wide range of rates and temperatures

Dr Einar Schwenke has fine-tuned the tools that give us safer polymer products. If the polymer components in our cars break down, it can be fatal. Therefore, designers and engineers must predict if the parts will effectively absorb an impact and protect us in a crash. To do so, they need accurate and reliable material models. Schwenke's PhD work had several objectives. The overall goal was to characterise the viscous response of polymers, which means how their behaviour varies when exposed to a wide range of strain rates and temperatures.

3D-PRINTED POLYMERS
RUBEN LØLAND SÆLEN (2019-2023)

Thesis: Mechanical behaviour and material modelling of an additively manufactured polymer.

Ruben Løland Sælen started on his PhD studies on 3D printed polymers in August 2019.
He says it is essential to develop knowledge about the strength and behaviour of such materials used in components that should withstand loads. Løland Sælen investigates their mechanical behaviour by performing material tests. After testing, he studies the data and try to describe the observed behaviour with mathematical material models. With accurate material models, the materials may be used in computer simulations of component tests. Simulating tests that are normally performed in the lab can save both time and money.

METALLIC MATERIALS

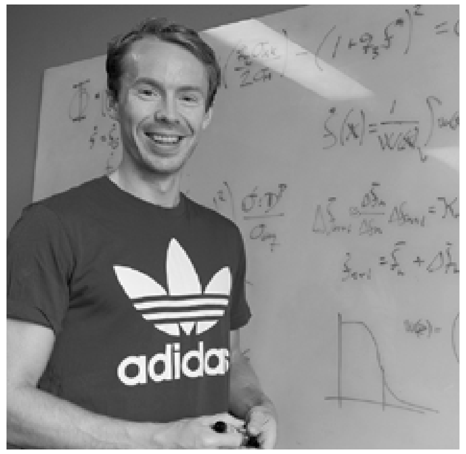
Programme Head:
Professor Odd Sture Hopperstad

This programme aimed to develop a physically based and experimentally validated multiscale framework providing constitutive models for crystal plasticity, continuum plasticity, damage, and fracture of metallic materials. The main emphasis has been on aluminium alloys and steel. The programme was closely coupled to Professor Hopperstad´s FRIPRO Toppforsk project "Microstructure-based Modelling of Ductile Fracture in Aluminium Alloys, FractAl (2016-2022).

MICROSTRUCTURES AND LIFE-SAVING RESEARCH
BJØRN HÅKON FRODAL (2015-2019)

Thesis: Micromechanical modelling of ductile failure in aluminium alloys.

In his doctoral work, Bjørn Håkon Frodal submerged into the microstructures of aluminium alloys.
The mission? To predict the behaviour of elements impossible to see with the naked eye. To most of us, a mission impossible. All the more reason to send a loving thought to Dr Frodal and his fellow researchers who embark on journeys into the universe of metallic materials with its grains, particles and atoms. Their motivation to understand and predict the behaviour of these tiny and invisible inhabitants helps to make structure´s safer. In fact, this is life-saving research.



PREDICTING WHEN FRACTURE OCCURS
SONDRE BERGO (2016-2020)

Thesis: Micromechanical modelling of fracture in ductile alloys with application to high-strength steel.

Sondre Bergo loves equations. That passion brought him closer to the goal of predicting the exact moment when fractures occur in ductile metals.
Materials that crack, fail and cause structures to collapse are every engineer's biggest nightmare. An essential part of engineering applications is to make reliable predictions and assessments to prevent such failure. Bergo aimed to improve the accuracy, and thus the reliability of these applications. His PhD work revealed some of the underlying physical phenomena that lead to undesired material failure. It is all about determining more accurately when a fracture in ductile metallic alloys occurs and how they subsequently develop.

THE ROLE OF PRIMARY PARTICLES
ASLE TOMSTAD (FRACTAL 2017-2022)

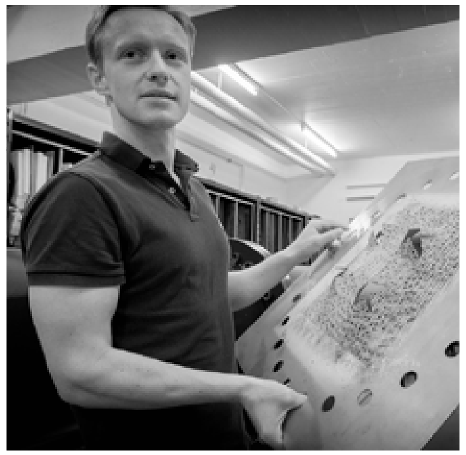
Thesis: Ductile fracture of aluminium alloys in the low to moderate stress triaxiality range

They are incomprehensibly small but significantly impact the safety of aluminium structures. Asle J. Tomstad' pinpoints the importance of primary particles, and how they affect ductile fracture in the 6000 series of aluminium alloys. Almost all industries rely upon aluminium alloys; from automotive to aerospace, construction, and consumer goods.
This promotes the need for reliable and efficient models to determine the different alloy´s strength and ductility. Tomstad hopes his work contributes to the ongoing joint efforts to provide the industry with more accurate models of fracture behaviour.

MODELLING OF RUNNING DUCTILE FRACTURE
ANNE-SOPHIE SUR (FME NCCS 2020-2023)

Thesis: Modelling of running fracture in pressurised steel pipelines

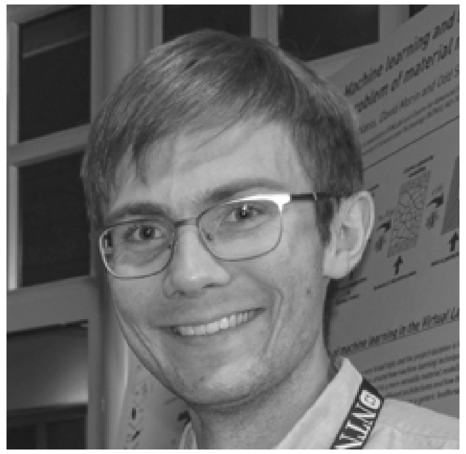
The main objective of Anne-Sophie Sur´s PhD project is to provide a phase-field model for ductile fracture in high-strength steel. The macro-scale model considers micromechanical processes to better capture fracture initiation and evolution. The introduction of the phase-field variable induces damage regularisation and reduces mesh dependency. Furthermore, modelling of running ductile fracture on a larger structural scale, such as a pipeline, requires large shell elements and makes a scaling method necessary for the phase-field fracture model. Sur´s work is part of FME NCCS (Centre for Environment-friendly Energy Research on CO2 capture, transport, and storage).



ADDING VALUE TO THE VIRTUAL LABORATORY
HENRIK GRANUM (FRACTAL 2016-2020)

Thesis: Multiscale modelling and simulation of ductile fracture in aluminium alloys

What happens inside a material before it breaks and fails? How do deformations and cracks occur, and how do they propagate?
Some people's urge to study almost unimaginable details can save lives and improve the quality of life for the rest of us. Henrik Granum worked with microstructure-based modelling of ductile fracture in aluminium alloys. Ductility is a measure of the ability of a material to undergo significant deformations such as bending or stretching before fracturing and failure. Thanks to his PhD work, he added a new building block to the virtual laboratory under construction at SFI CASA. This will be a powerful tool for simulating and predicting such fracture.



THE POTENTIAL OF MACHINE LEARNING
HÅVARD NÆSS (2021-2025)

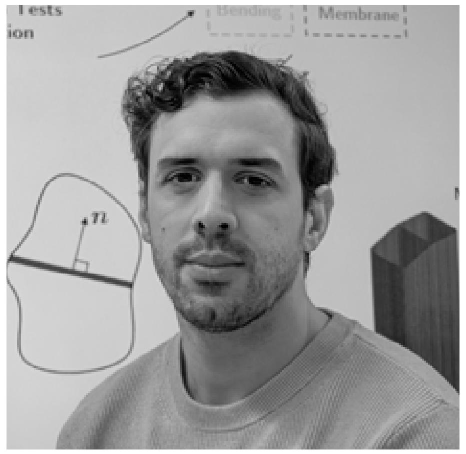
Thesis: Machine learning for upscaling in material mechanics

Håvard Næss studies how machine learning can contribute to solving the upscaling problem in material mechanics. He aims to make numerical simulations concerning plasticity and fracture more accurate without increasing the computational and calibration costs. He says the industry can save money in design by applying this technology. Besides, more accurate simulations lead to less material consumption and thus more sustainable structures.
«Furthermore, the research community will be interested in the potential of machine learning in upscaling problems», Næss says.

FRACTURE AND CRASH BEHAVIOUR
KRISTIN QVALE (FRACTAL 2018-2022)

Thesis: Energy absorption and failure in aluminium alloys: an experimental and numerical study

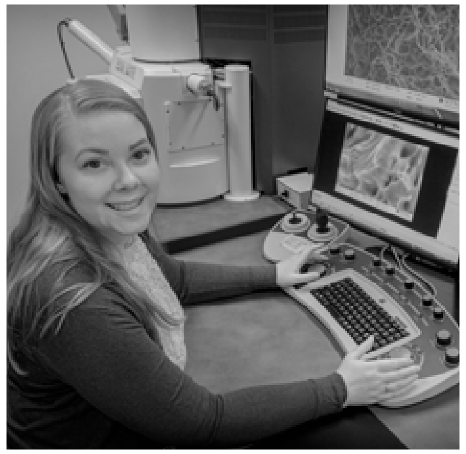
Kristin Qvale is an expert in energy absorption and fractures in aluminium components, such as crash boxes in cars. The key to more knowledge lies in the microstructures. Qvale studied how certain changes in the microstructure affect the fracture behaviour at higher scales and how fracture affects the crash behaviour of aluminium components.
«By introducing a modelling procedure, we are working to develop crash components almost completely virtually», Kristin Qvale says.



PAVING THE WAY FOR SAFER STRUCTURES
MARCOS FERNANDEZ (ALLDESIGN 2018-2022)

Thesis: On the use of a virtual laboratory for aluminium alloys: application to large-scale analyses of extruded profiles

Marcos Fernandez's research aimed to improve cutting-edge technology for large-scale modelling and simulation of aluminium components. He focused on extruded profiles designed to absorb energy. We find them in the wheel suspensions, bumper systems, engine cradles, crash boxes, and other parts of our cars. Fernandez´s work extends and refines the Virtual Laboratory for aluminium alloys. His efforts may pave the way for safer cars, planes, ships, and other structures. He was part of, and mainly financed by, the Rational Alloy Design (ALLDESIGN) project.



EXPLORING THE BASICS
SUSANNE THOMESEN (FRACTAL 2016-2019)

Thesis: Plastic flow and fracture of isotropic and anisotropic 6000-series of aluminium alloys: experiments and numerical simulations.

By extensive use of experiments, Susanne Thomesen uncovered some of the secrets of aluminium.
The inside information filled in the big picture under construction by Toppforsk project FractAl. Thomesen was the first of five PhD candidates in FractAl to defend a thesis. She investigated the microstructures and what happens inside aluminium alloys when subjected to severe loading conditions. «I explore the basics. Knowledge about the smallest parts helps us to explain how the material behaves under large deformations and fracture», she said before her dissertation.

MORE ACCURATE MATERIAL MODELS
VETLE ESPESETH (FRACTAL 2018-2023)

Thesis: Ductile failure of aluminium plates: experiments, modelling and simulations

Traditionally, engineers seek to avoid plastic deformations in the design of structures. While this conservative approach is fundamental in designing many structural applications, it is not justifiable where plastic deformation and potential material failure may occur due to unsought incidents. Vetle Espeseth investigated ductile failure in 6xxx series aluminium alloys. His work improves our understanding of the micromechanical mechanisms involved, and thus contributes to more accurate material models and reliable predictions of ductile damage and failure.

STRUCTURES

Programme Head:
Professor Tore Børvik

The programme aimed to develop advanced computational tools and establish validated modelling guidelines for computer-aided design of safer and more cost-effective structures. Another objective was to replace phenomenological models with physical models to reduce the number of mechanical tests as much as possible in the design phase.

SAFER GLASS-DESIGN
KAROLINE OSNES (2015-2019)

Thesis: Monolithic and laminated glass under extreme loading: Experiments, modelling, and simulations.

Our craving for daylight has accelerated the use of glass in modern constructions. However, for those concerned about safety, our passion for the light comes with a dark side. As the use increases, glass remains as the weakest points in a building. This means less protection for vulnerable human bodies. During an explosion, glass, concrete, aluminium, or steel can transform into thousands of potentially deadly fragments. In the event of an urban explosion, 80 per cent of the injuries suffered are caused by pieces of glass. Karoline Osnes´ glass models contribute to safer, and more predictive glass design.

PROTECTING PIPELINES
OLE VESTRUM (2016-2020)

Thesis: Impact on porous polymer-coated pipelines

The primary task of a polymeric coating is to insulate and protect steel pipelines from corrosion. A surprising side effect is that they also work as bumpers at extreme water depths.
«When pipelines are subjected to sudden impact, we can clearly see that the porous polymeric coating absorbs the impact energy very effectively. Thus, the coating makes a considerable contribution to protecting pipelines», says Ole Vestrum.
In his PhD work he established a new method to describe how the coating contributes to the behaviour of the pipeline when subjected to sudden impact.

COMBINED BLAST AND IMPACT LOADING

BENJAMIN STAVNAR ELVELI (2018-2022)

Thesis: Behaviour, modelling, and simulation of thin steel plates subjected to combined blast and impact loading.

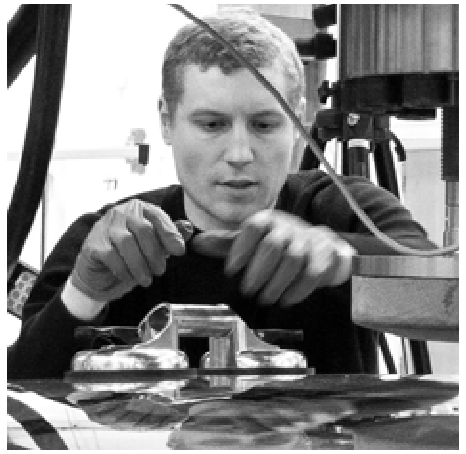
During an explosion, the shock wave may be accompanied by fragments accelerating to an immense speed.
«This is the scariest load. It works the same way as shrapnel bombs», says Benjamin Elveli.
Such complex, combined loads is a massive challenge for those working with blast-resistant designs. The basis of Elveli´s work is more than 80 small-scale blast experiments. He recreated the blast loads in computer simulations. Understanding the physics of a load will enable future engineers to design more accurate, safer, and sustainable structures.

SANDWICH LAYERS FOR BLAST PROTECTION

KRISTOFFER AUNE BREKKEN (2017-2023)

Thesis: Sacrificial claddings for blast protection

The idea behind the project is that a sacrificial sandwich layer can be used to attenuate blast loads on structures. Kristoffer Brekken uses experimental and numerical techniques to understand and characterise the behaviour of sandwich components subjected to blast loading. An extension to the SIMLab shock tube facility has been designed and verified to allow for detailed studies of such components subjected to blast loading and fluid-structure interaction effects.



MICRO CRACKS AND GLASS DESIGN

JONAS RUDSHAUG (2019-2023)

Thesis: Modelling of fracture initiation and crack propagation in monolithic and laminated glass under extreme loadings.

Glass is brittle. When it breaks, it happens suddenly and unexpectedly. It is precisely this unpredictable and violent behaviour that attracts the interest of Jonas Rudshaug.
«These capacities make it extremely difficult to predict when failure happens because that is determined by the small microcracks or flaws that are randomly distributed across the glass surface», he says.
Rudshaug has zoomed in on these cracks and flaws. His primary focus has been to develop numerical tools that can predict the capacity of glass components.

CONCRETE AT EXTREME LOADING

ØYSTEIN EIRIK KVIST JAKOBSEN (2021-2025)

Thesis: Modelling of concrete under extreme loading

Concrete is the most used construction material globally. Owing to its high compressive strength, durability and abundance, concrete is used for almost any type of structure, and it is a well-suited material for protective structures. Øystein Eirik Kvist Jacobsen works with mesoscale modelling of concrete under extreme loading. The further improvement of numerical models allows for better and safer design of structures. He also investigates and compares the ballistic performance of standard and low-carbon concrete.

ENSURING SAFETY IN SPACE

RANNVEIG MARIE FÆRGESTAD (2021-2025)

Thesis: Modelling and simulation of hypervelocity impact against debris shields for spacecraft protection.

Rannveig Marie Færgestad works on models crucial to ensure safety and sustainability in space. Low Earth orbit is full of space debris, posing a significant threat to current and future space missions. Accurate and reliable modelling of debris impacts at hypervelocity is crucial to ensure safety and sustainability in space. The goal of Færgestad´s PhD work is to improve and develop numerical methods and models of hypervelocity impact to increase reliability and versatility. The research is valuable for space agencies and companies when designing and developing shielding for space stations, satellites, and crew capsules.

Fracture surface of extruded aluminium alloy specimen. (Credit: FractAl)

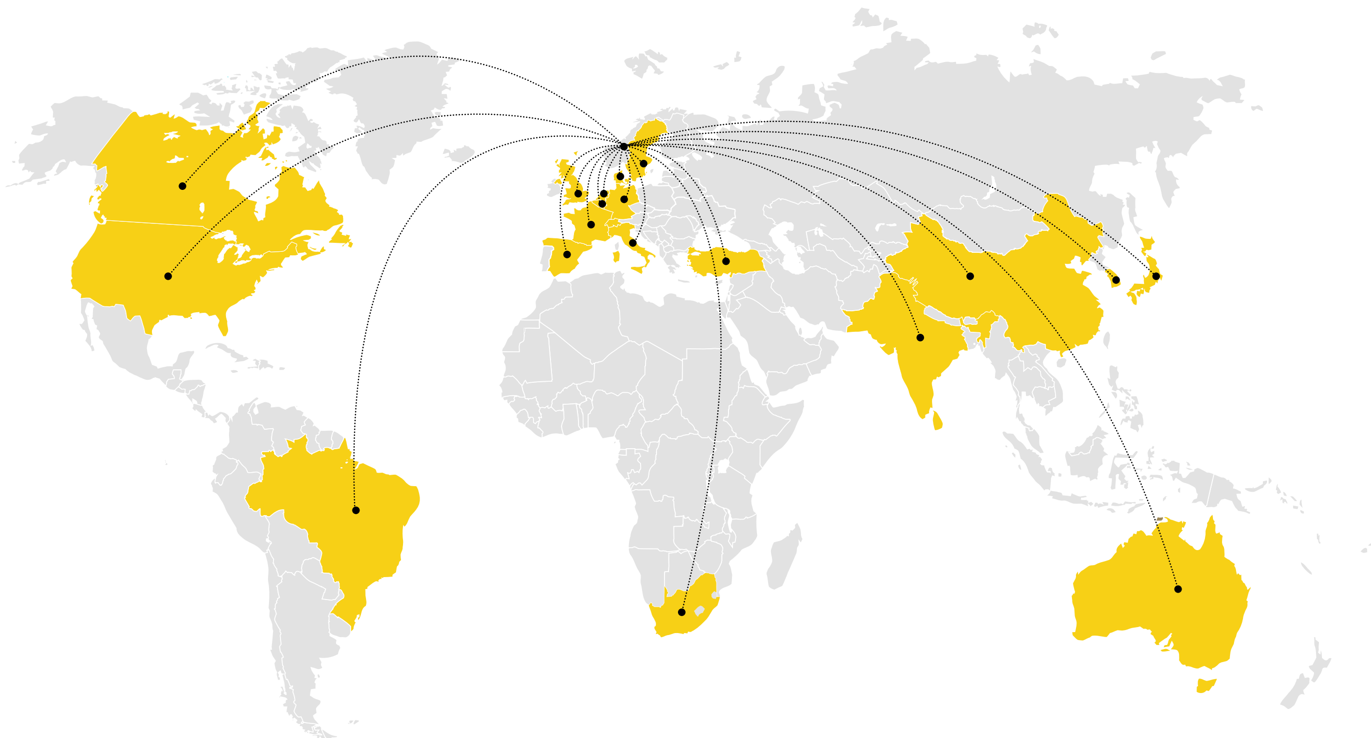
International cooperation

A main goal for the SFI scheme is to facilitate innovation in Norway. Still, international cooperation is one of the success criteria for an SFI centre. SFI CASA has been an international undertaking in many ways. During the eight years of SFI CASA, seven of its company partners have come from outside Norway; Audi, BMW, Honda, Renault, Sapa, SSAB and Toyota. In addition, several of the Norwegian company partners have subsidiary companies abroad and offer services and goods on an international market. Academically, close interaction and cooperation with researchers and research groups at universities and research organizations abroad has been of great importance.

SFI CASA has been a member of the European Automotive Research Partners Association, EARPA, an association of automotive R&D organizations. Four key researchers in SFI CASA are members of DYMAT, a European association for the promotion of research into the dynamic behavior of materials and its applications. The Centre Director has a seat on the governing board of DYMAT.

The cooperation with top international research groups has helped ensure that the Centre transfers leading-edge technology to its partners. Exchange of personnel has been done in several ways. Firstly, many international researchers, both graduate students, PhD students and faculty staff have worked at CASA, and CASA personnel have worked abroad, both with collaborating research institutions, and with CASAs international company partners. This mobility of personnel benefits research, as new people quite literally bring new ideas and adds new knowledge and perspectives.

Being an SFI centre also helps international cooperation directly. The long-term funding helps the strategic work and gives financial stability. For example, SFI CASA hosted two international conferences, in 2017 and 2022, both partly funded by the Centre. Also, the SFI scheme's midway evaluation provided the research group with an independent assessment of the Centre's research and strategic work.



Training Talents – Exporting Excellence

Impact against windscreens. Early summer 2022, PhD candidate Jonas Rudshaug (right) and MSc-student Einer Herrem went to Germany to present their results for partner BMW. (Photo: Sølvi W. Normannsen)

«If you want to join the national team in structural analysis and get a job, SFI CASA is the place to be».

This call went out to potential master's and doctoral candidates at a recruitment seminar in 2018.
The person who said those words was Dr Johan Kolstø Sønstabø. He is one of many former PhD-candidates employed by our partners. Over the years, these engineers became the Centre's best ambassadors; always enthusiastic about sharing their stories and helping us recruit new talents. Sønstabø has since left Multiconsult and joined the staff of CASA's spinoff company Enodo AS. The company now has four employees, all of whom earned their PhDs in the Centre.

2-3 SUPERVISORS PER PHD
Multi-disciplinary projects require supervisors with complementary areas of expertise. All candidates in our PhD programme were guided by 2-3 supervisors. The research team taught courses relevant to the Centre at the master's and PhD levels. Members of the research group also developed courses on Material mechanics and Impact Mechanics.
Many students found their way to MSc and PhD degrees through summer internships at the Centre.

INCLUDING STUDENTS IN THE VALUE CHAIN
Most of the master's theses we offered were linked to collaboration projects with well-known industrial partners and connected to running PhD projects. We always emphasised the importance of involving students in our value chain, from basic research to implementation. Through active dissemination work, we have made the student's efforts visible to the partners, the research community, and the public.

PIONEERS IN SAFETY GLASS
In 2015, Karoline Osnes became a pioneer glass researcher in Norway. She had a fresh master's degree in her pocket and had landed a job with a well-known engineering consultancy. Then, Professor Tore Børvik invited her to a meeting in his office.
«Flattered by the invitation, I accepted. When I got there, CASA Director Magnus Langseth was present as well», she said in an interview.

«NOBODY WHO TAKES A PHD EVER REGRETS IT»
«They wanted me to consider going for a PhD. We didn't talk for very long, but there was something in their message that triggered me. Something like, «This is a chance you only get once. It made me think, «This is a bigger challenge than I'll get at the consultancy».
In 2019, she defended her thesis «Monolithic and laminated glass under extreme loading: Experiments, modelling and simulations». During her studies, she also spent 3 months at partner BMW in München.

FROM SCIENCE TO CONSULTANCY
Osnes is now a Structural Engineer at partner Multiconsult and has also been an Associate Professor II at NTNU. She is part of PhD-student Jonas Rudshaug's supervision team. Rudshaug attended the 2018-seminar mentioned above. He continues the work carried out by Osnes but with a focus on impact against windscreens. Early summer 2022, Rudshaug and MSc-student Einer Herrem went to Germany to present their results for BMW.

MAKING SPACE A SAFER PLACE
Rannveig Færgestad became one of SFI CASA's most profiled PhD candidates ever. Her research aims to make space a safer place. In 2018, she attended a CASA seminar specially designed to attract female students. Already back then, she was a long-time passionate space enthusiast. She first signed up for a summer internship, which was also an essential means for recruitment to our PhD programme.

A GREAT IMPRESSION OF THE CENTRE
«I got to know CASA through the internship and later during my MSc thesis. The research quality, the staff, and the culture gave a great first impression. The chance to do a PhD at the Centre with international partners in the space industry is very motivating», she says.
Færgestad's topic is «Modeling and simulation of hypervelocity impact against debris shields for spacecraft protection».
«It is exciting – and complicated», she says with a big, enthusiastic smile on her face.

ORIGINAL TOPIC – AND A FAMOUS BIG BRAND
In 2017, Einar Schwenke chose a master's project entitled «Cold Impact Performance of Polypropylene». The project collaborated with the then CASA partner Toyota Europe (2015-2020).
«As it was both an original topic plus involved a famous big brand, the project caught my interest. I was eager to try something a bit off the beaten path», says Schwenke.
As he delved further and further into the project, he became tempted to go for a PhD.
«Of course, some parts have been hard. But being in a place like CASA helps. Even if we work on different tasks, colleagues are always eager to help, open for discussions, and happy to exchange ideas».

SIGNING UP WITH THE PARTNERS
The list of PhD and master's candidates who stayed at, and/or later signed up for positions at our partners is extensive. Ole Vestrum stayed at the Equinor research centre in Trondheim for 3 months working on 3D scanning of polymer coating of pipelines. After his dissertation, he took on a position at NDEA. That was also the case for Jonas Rudshaug and Benjamin Stavnar Elveli.

A PHD POSITION - THE BEST CHOICE
Ruben Sælen found his way into CASA via a summer internship. He studies 3D printed polymers. He says that after writing his master's thesis at CASA, he knew a PhD position here was the best choice as he wanted to work with advanced simulations for a period.
Sælen has spent 3 months of his PhD studies working at partner Equinor, which will also be his future employer.

76 PERCENT OF CANDIDATES ARE NORWEGIAN
We have put effort into recruiting talented Norwegian doctoral students. We are proud to report that we have succeeded. 19 out of the 24 PhD candidates, counting 76 percent, educated in CASA were Norwegians. Four candidates came from Europe and one from Asia.

THE ART OF ATTRACTING FEMALE RESEARCHERS
Our media strategy aimed to make female researchers particularly visible and thus to motivate and attract female fellowship holders. Five of our PhD students were women. The numbers reflect our recruitment base in our professional field. The Mid-term evaluation in 2019 also pointed to the gender imbalance.
In response to the comment, CASA Centre director Magnus Langseth said:
«We have made considerable efforts to attract more female researchers and will continue to do so. The challenge is that the number of females in our field is low, nationally as well as internationally. We cannot conjure them up».

The Art of Attracting Attention


Disse bilprodusentene kommer til Trondheim når de skal bli bedre


Kunsten å koble kunnskap og kommers

Forskning kan spare industrien for tid og enormt mye penger. Men hvordan får vi bedrifter som både har dårlig tid og vet lite om forskning til å utnytte vitenskap i verdensklasse?


Forsvarsbygg tester betong mot beskytning – miljøbetongen er oppsiktsvekkende sterk

Miljøvennlig betong står seg like godt mot prosjektiler og missiler som normalbetong.


BBC World Radio popped into the Shock Tube


Regjeringen lener seg på mangelfullt regelverk


Midtnorsk debatt


Hvordan lage bygg som tåler de mest ekstreme påkjenningene?


Measuring the Impact of Extreme Waves on Offshore Structures


Midtnorsk debatt

Vi må tette hullene i sikkerhetsloven


NYHETER

Karoline har sprengt og skutt i stykker mer enn 100 glassruter


Sikrere biler og bygg starter på nano-nivå

Når ulykken er ute, kan materialene i bilen, båten eller bygget du befinner deg i bety forskjellen på liv og død. Skal vi oppnå best mulig beskyttelse, må vi vite mest mulig om hvordan for


Østlands-Posten

Ole (29) har gjort noe som kan spare industrien og samfunnet for mange penger

Dissemination of popular science is an important way of spreading knowledge beyond the confines of the research environment. Another way is to play an active, committed, and courageous role in social debates. CASA has chosen to do both.

From day one, we established a strategy for disseminating knowledge in various media forms. First and foremost, the website sfi-casa.no was created as a platform for presenting news, stories on PhD candidates, ongoing projects, and in-depth interviews with key personnel.
The website has been essential for sharing and spreading the news about our activities. The content was distributed in a monthly newsletter and from time to time our stories were published on NTNU's tech blog.

A FLYING MEDIA START
Our media presence hit the ground running thanks to our host, the SIMLab research group. In May 2015, the Research Council of Norway (RCN) released the international evaluation of Norwegian research in the field of technology. It drew the media's attention when SIMLab received a top score and was described as world-leading in this field.

VISIBILITY BY VIDEO
Our impressive test facilities and the offer of exclusive images and videos of crashes, explosions, and penetrating bullets have been the Centre's privilege. The work on enhanced safety and our spectacular visuals are a magnet for media attention.
Our presentation video premiered in January 2017. It has been a successful and effective tool throughout CASA's lifetime. The video reiterates how generic research serves as a foundation for innovation. Plus, it explains in layman's terms how CASA's research benefits society. All visitors have seen it and our lecturing staff have shown it to hundreds of NTNU students yearly.

TUNNELS, ROADS, AND WAVES THAT WENT ABROAD
In 2018, American National Public Radio and the BBC World Service made a documentary on the Norwegian Public Roads Administration's (NPRA) Ferry-free E39-project. CASA was involved and the reporters visited the Shock Tube. Also CNN.com published a story on the project, where Martin Kristoffersen explained how the NPRA worked with NTNU and CASA, «using live explosives to investigate how tubular concrete structures behave when subjected to internal blast loads».
Other stories that found their way overseas was «Measuring Extreme Waves» on the SLADE KPN project, and «Creating Buildings That Can Withstand the Most Extreme Stress Loads». The latter was a report on Benjamin S. Elveli´s PhD project. The stories spread via NTNU and SINTEF's research magazine Gemini and Technical Weekly (Teknisk Ukeblad), before finally being picked up by international media outlets.

TECHNICAL NEWSLETTER AND ANIMATION VIDEO
2019 saw the launch of a one-page Technical Newsletter series for the partners. In total we distributed 21 such newsletters with the intention of disseminating new research. We also had a short, animated video produced by Rastlaus Media AS. The idea was to offer a quick, visual, and straightforward introduction to our work on improving physical security.

IN-HOUSE VIDEOS SHOWCASING MASTER'S PROJECTS
«Maraging Steel under Ballistic Penetration», «Testing bullet impact on concrete», «Protecting batteries in electric cars», «Master's degree». These are the titles of some of our in-house-made videos. You'll find them on SIMLab's YouTube channel. Also in our collection are several Christmas greeting videos. Just for fun, but also to show the way we work in a different - if slightly unconventional - light.

CHRONICLES AND DEBATES
In spring 2018, Centre Director Magnus Langseth published a chronicle in the Norwegian Business Daily (Dagens Næringsliv (DN)). He warned against using timbered facades and wood as a load-bearing component in Oslo's new government administration complex. As a result, he was called for a hearing on the subject in the Norwegian Parliament which led to interviews and coverage in national media.

OBJECT SECURITY AND INNOVATION
Later that year, Professor Langseth argued for more societal and object security research in the regional paper Adresseavisen. The chronicle was republished on Gemini.no and NTNU TechZone.
Innovation is a topic that we are actively engaged in. We have published several chronicles on the subject in DN and the online newspaper Khrono. In the latter, we directly addressed the Minister of Research and Higher Education on innovation, Ola Borten Moe.

INFORMING POLITICAL PROCESSES
After submitting a written contribution to the public hearing on the Parliament's white paper on societal security, Professor Langseth attended the Parliament's open hearing on the topic on 19th January 2021. That same day, he and Professor Tore Børvik addressed the white paper's challenges in a chronicle in Adresseavisen. Some weeks later, CASA recieved valuable attention from the country's top rostrum. The occasion was the Parliament's debate on the white paper.

COMMENTS LED TO A MEETING WITH THE MINISTER
After providing comments on the government's Long-Term Plan for Research and Higher Education (LTP), CASA was invited to meet with Henrik Asheim, the then Minister of Research and Higher Education. Asheim wanted to learn how SFI CASA helps its partners to put research to use. We also provided input to the Research Council's natural science and technology portfolio plan.
This kind of attention comes only with regular media coverage. CASA wouldn't have been able to make such a contribution without actively choosing to engage.

Research Partner and Strategic Player

«Our main goal with participation in any SFI centre is to develop a scientific competence platform as a basis for innovation through spin-out projects with industrial partners.

(Rudie Spooren, Research director Sintef Industry)

As a part of the Lower Scale programme, Anette Brocks Hagen from SINTEF Industry has worked to determine the nanomechanical properties of Al-Mg-Si alloys. (Photo: Sølvi W. Normannsen)

«We see the Centre as highly successful with regards to competence building, scientific production, and excellence», says SINTEF Industry's (SI) Research director Rudie Spooren.

SINTEF Industry´s man in SFI CASA´s Board has been Research director Rudie Spooren. (Photo: Sølvi W. Normannsen)

This is quite a testimony at the end of an eight-year-long joint journey. For an independent research organisation like SINTEF with its core activities in applied science and consistent aim for research-based innovation, the SFI scheme is essential. Currently, the institute is involved in 13 Centres for Research-based Innovation.

A JOINT TEAM - BOOSTING COMPETITIVENESS
The top-level executives of NTNU and SINTEF have described the players in the various SFIs as national teams that unite research institutes, universities, and companies to boost the Norwegian industry's international competitiveness. Rudie Spooren has been a member of the SFI CASA's board for 8 years. To him, being a research partner is a perfect position on the team to score innovations.

ENABLING TECHNOLOGIES
SI is one of six SINTEF institutes working in materials science, applied chemistry, biotechnology, geoscience, and industrial economy. They develop generic competence, enabling technologies and multi-disciplinary solutions for many applications, in close collaboration with other parts of SINTEF, other research partners, and customers.

QUESTIONS FROM THE SIDELINE
The introductory words of praise at the beginning of this article were, in fact, Mr. Spooren's final remarks at the end of this interview. We questioned him in order to build up an idea of what the long-time team-play looks like – from SINTEF's position on the field.
What triggered one of Europe's largest independent research organisations to join the CASA team in the first place?

A NATION WELL POSITIONED
Rudie Spooren says that Norway is well-positioned to participate in the next industrial revolution to solve global societal challenges.
«In SINTEFs strategy, industrial development has always had a pronounced priority. SINTEF has specifically identified the "manufacturing industry" as one prioritised business area which fits well with the industries that SFI CASA addresses».

AMBITION: MAKING RESEARCH RESULTS AVAILABLE
«The research in CASA within experimental and computational mechanics is highly generic and relevant for several of our market segments», Rudie Spooren says.

«And it is SINTEF Industry's ambition to make the results of CASA's research available to any relevant industry segment and company, in a collaborative effort with other parts of SINTEF».

A BASE FOR RECRUITING NEW SINTEF-PLAYERS
Spooren and the other 2 200 SINTEF employees navigate with the vision of «Technology for a better society». He says that, to realize this vision together with the Norwegian manufacturing industry, a significant boost in long-term development and integration of scientific competence was necessary.

A POTENTIAL RECRUITMENT BASE
«The SFI scheme is crucial for SINTEF to build long-term strategic competence since our basic funding is low. The education of researchers through PhD and postdoc programs is essential to the Centre's activities. Candidates from CASA form a potential recruitment base for us. In fact, we have employed 3 highly skilled candidates from the Centre».

PUBLICATIONS AND COLLABORATION
-What goals did you have when joining CASA, and have these goals been achieved?
«Our main goal with participation in any SFI centre is to develop a scientific competence platform as a basis for innovation through spin-out projects with industrial partners. It is also important for SINTEF to document this competence through the scientific publication of results. We have published more than 30 scientific papers in CASA with SINTEF personnel as main or co-authors».

STRENGTHENED POSITION IN THE EU-LEAGUE
SI also aimed to maintain and further develop a close collaboration with scientists and students at NTNU and the user partners as a basis for further cooperation in competence and innovation projects.
«The collaboration within CASA has resulted in 10 projects granted, including 6 Innovation Projects. The developed competence has strengthened SI's international visibility and credibility, thereby achieving increased attractiveness as a partner in EU projects».

THE CRITICALLY IMPORTANT TOOLBOX
In the Centre, SINTEF has been responsible for integrating the science produced into a user-friendly research-based toolbox. Spooren says that the toolbox strengthens the Centre's efficiency and research quality. Also, it is crucial for further development and exploitation of the generic results in various application areas.
«Participating in the Centre has contributed to a steadily growing portfolio of spin-out innovation projects nationally and internationally. Several researchers active in the Centre within software development are now key contributors to the strategic digitalisation of SINTEF's business», he says.

«AN IMMENSE POTENTIAL FOR INNOVATION
SFI CASA has focused on building long-term scientific competence. Rudie Spooren considers the potential for long-term innovation and value creation of the Centre's results as «immense». He says that the value creation is realised by user partners who actively implement the results. Furthermore, the achieved scientific competence and tools are disseminated and exploited for the benefit of the larger industrial community.

INNOVATION-ORIENTED SINTEF TOOK RESPONSIBILITY
«Partly due to the composition of the centre, CASA has not actively stimulated the establishment of spin-out innovation projects. However, SINTEF has unilaterally taken on this responsibility», the Research director says.
SINTEF's extensive innovation-oriented project portfolio has rapidly disseminated the results from CASA to various industrial sectors and companies beyond the CASA consortium. IPNs like HiSAl, CMS, HotCaSe, AluBridge, AlChassis, and IntoWell have been or are being executed with user partners from CASA and partners not involved in the Centre.

PHYSICISTS THAT STRENGTHENED THE TEAM
In Rudie Spooren's opinion, the partners of CASA have collaborated well with a clear common goal and a systematic approach for transferring short-term results to user partners.
«Thus, CASA contributed to enforce close collaboration between the partners and industrial relevance, which enabled SINTEF to develop spin-out innovation activities, particularly with Norwegian user partners», he says.
Compared with its predecessor, SFI SIMLab, Spooren thinks that NTNU's Department of Physics and the SINTEF Material Physics group have significantly strengthened the SFI CASA team.

«ACKNOWLEDGED AS A LEADER IN THE FIELD»
- Could you have collaborated with other research groups and achieved similar gains, or did CASA provide knowledge you could not obtain elsewhere?
«Partially through CASA and its predecessor SIMLab, NTNU has built a sound international acknowledgment as a leader in the field. SINTEF collaborates with different research groups nationally and internationally, but our collaboration with NTNU is strategically the most important. The scientific quality of CASA's research has been qualified as excellent by the Research Council and the Scientific Advisory Board».

CONTINUED TEAM-PLAY?
Does Rudie Spooren have any thoughts about continued cooperation after the project period? The answer is affirmative: «SINTEF is determined to continue the cooperation with SIMLab by sharing scientific personnel and research infrastructure resources. SINTEF is also interested in continuing the long-term collaboration among the CASA partners through the establishment of a new centre in some form».

Eight Years of Bridge Building

SFI CASA has reached the end of the road. What impact did we have on those who invested time and money in the Centre to transform our research into innovation?

Over eight years, the Centre has brought together world-leading scientists, public enterprises, and private industrial players as collaborators with one common goal: to transform advanced research to commercially viable technologies and innovations.

RISKY BUSINESS OR PROFITABLE INVESTMENT?

Equinor, Hydro, Benteler Automotive, Audi, BMW, Honda, DNV, and all the other user partners spent a total of 126 MNOK on SFI CASA. Has the investment proved profitable? Did we contribute to new inventions and more-effective products? Improved processes, services, technologies, business models? Or to the establishment of spin-off companies? We did a small survey to find out.

Our partners comprise some of the world's most prominent players in their respective fields. Among them are both collaborators and fierce competitors. Strict confidentiality rules and secrecy governed their feedback on our survey in respect of finance, design, and innovation details. Anyway, some agreed to share their views.

THE PARTNER WHO SEARCHED IN PUBLISHED PAPERS

«The biggest gains we have seen by being partners at SFI CASA have been our strengthened knowledge base and improved network with other partners and the Center researchers,» says Eric DeHoff, Chief Engineer at Honda Development and Manufacturing of America, LLC.

The starting point of the US car maker's interest was the Centre´s work on modelling aluminium and joints with self-piercing rivets (SPR).
«We found published papers describing material characterization and dynamic impact simulations involving aluminum extrusions joined with SPRs», DeHoff says.
Well-documented research was precisely what Honda were looking for at the time.

THE NEED FOR BETTER METHODOLOGIES

Some partners were inspired to join because of the Centre's focus on physical security. Others signed up strategically, like Honda did, to gain access to the latest research in their fields and develop better methodologies. CASA was also regarded by many partners as an important recruitment base.
Nicolas Neumann, Head of the structural designs section at Multiconsult, says their starting point of interest was the research on civil engineering connections.
«However, the general focus on advanced structural analyses was also very relevant for us».

Some partners report that collaborating with industry-oriented researchers facilitated the implementation of specific components and new technologies in their industrial processes.

NETWORKING AND IMPROVING METHODS

Honda´s Eric DeHoff says that their methods and processes were more mature than some of the other partners when they joined. Thus, it was difficult for Honda to directly implement the computational tools created during the consortium activity.
«We used the knowledge gained through the activity to confirm and improve our methods. Networking with other partners allowed us to discuss several topics of concern in the industry», Eric DeHoff says.

A DEDICATED IMPLEMENTATION STRATEGY

Predicting crash behaviour in aluminium crash management systems and CASA's dedicated implementation strategy for industrial applications also captured the partners' interest.
«For us, it was the need for more in-depth knowledge related to the use of material models to predict better the local behaviour of structures subjected to impact loading», says Agnes Horn.
She is a Senior Principal Engineer at DNV AS, an internationally accredited registrar, and world-leading classification society headquartered in Høvik, Norway.
Horn mentions examples such as ship collisions and trawler impact of pipelines.
«Also, efforts on the advance modelling of polymers at CASA offer potential for more active uses in assessing polymer structures», she says.

THE RISK OF INVESTING IN RESEARCH

The Research Council of Norway has acknowledged that there is an inherent risk associated with investments in ground-breaking research and radical innovation. Since «neither the researchers nor those funding the research can be sure that the time and money spent (…) will bring about a valuable result».

So, what do those who dared to join CASA conclude? Have their objectives been accomplished?

MORE EFFICIENT DESIGN PROCESSES

Several partners report that improved simulation tools and the Virtual Laboratory have made design processes more efficient and reduced the need for physical tests. Car manufacturers have implemented models developed at the Centre into their standard design and development processes.
Further, partners praise the access to and close collaboration with the scientific team. They say that it has improved their understanding and evaluation of simulation methods and generated new ideas for solving technical challenges.

Senior Principal Engineer at DNV AS, Agnes Horn. (Photo: Sølvi W. Normannsen)

MISMATCH: SHORT AND LONG-TERM GOALS

Eric DeHoff highlights some fundamental issues for an SFI: «We have had many fruitful discussions about the mismatch of expectations between the automotive industry and academia regarding research time scales. The industry partners need answers in 3 years or less so that we can apply them to the next vehicle development. The Centre seeks research to support their activities and students for a much longer term. We have continued to collaborate by trying to introduce both short and long-term goals that can be used by the industry as we complete the research programmes».

IMPROVING PROCESSES AND REDUCING RISKS

One aim for Honda was to address shortcomings in their computer simulations with the activity at the Centre. They hoped to find solutions to integrate into their processes and build up a picture of similar technical challenges across the industry.
«Implementing the CASA activity has not directly filled our technical gaps. But it has given us ideas for improving our already mature processes. The seminars and meetings have allowed us to discuss with CASA and our partners where the issues in the automotive industry are now and, in the future, and find some common ground to investigate».

REDUCING RISKS EARLY

Other user partners state that CASA has benefited them through improved products and extended networks.
«The results from the Centre have contributed to identifying failure areas more accurately during the design phase. This has allowed us to reduce risks early and thereby increase the likelihood of reaching the expected value creation», one partner commented.

IMPROVING EXISTING SERVICES

DNV's goal was to increase its knowledge of material modelling. To a large extent the goal has been fulfilled in relation to steel structures, according to Agnes Horn. Models developed by CASA have been used and evaluated both in projects and internal research activities. Knowledge created in the Centre primarily contributes valuable improvements to existing services provided by DNV.
Polymer modelling techniques developed at The Centre serve as a basis for projects that DNV are also currently involved in. Horn points out the development of the "leak-limit state" concept for pipelines as an example of opportunities that have greatly benefited from activities in CASA.

NEW, TIME-SAVING SOLUTIONS

«The leak-limit state concept was developed by Equinor and DNV. Knowledge from CASA has been crucial to identifying design criteria», Horn says.
Such design solutions can prevent the need for intervention work and lead to optimised structures where less steel is

required. The developed models can also be used to extend the life of existing structures.
Another partner points out that several activities involving the implementation of models, procedures, and experimental data would have required far longer time scales without the collaboration with NTNU.

NETWORKING AND RECRUITMENT

Nicolas Neumann lists five goals that Multiconsult defined when entering the partnership. The three that were achieved are linked to networking and business opportunities as well as influencing research and higher education through master's and doctoral theses. Multiconsult and several others highlight the advantages of the possible early recruitment of talented candidates.
«We believe that some of our recruitments and the influence on research would not have been possible without the Centre», Neumann says.
Multiconsult aimed to achieve research-driven innovation by further developing their competence and methodologies in advanced structural analyses. The secondary goal was to strengthen their capabilities in steel structures to match the already strong position held in advanced concrete analyses. The two latter goals have been partially achieved at the time of writing this report; the collaboration is still ongoing.

NEW KNOWLEDGE THAT IMPROVES METHODS

«A major opportunity afforded by working with CASA was seeing the issues at many levels. In other words, having physics, material, and mechanical experts in the Centre involved at every step has allowed the partners to gain understanding from the micro to macro level that may have been separate research projects with the different areas», says Chief Engineer Eric DeHoff at Honda.
Nicolas Neumann says that the partnership has benefited Multiconsult with improved methods, a strengthened knowledge base, a consolidated network with other partners, and recruitment possibilities.
«All this has delivered a boost in competitiveness», says Neumann, who estimates that the potential income increase as a result of being a CASA partner is at least NOK 1 mill. per year.

EXCELLENT COLLABORATION

Another industrial partner says, "There are no other research groups that offer the same portfolio and long-term focus as CASA. The emphasis on implementing scientific results is crucial. The SFI is an excellent scheme for us».
Some partner-representatives express great pride in having been involved with the Centre. Others show appreciation for the ease of access to plentiful information, transparency, and opportunities for exchanged visits. Further, the possibility of excellent collaboration with world-leading, skilled researchers is highly regarded.
«The collaboration with the CASA-researchers has been great. They are pleasant to work with, very supportive, and helpful when we contact them for clarifications and questions», says Agnes Horn at DNV.

POTENTIAL FOR IMPROVEMENTS

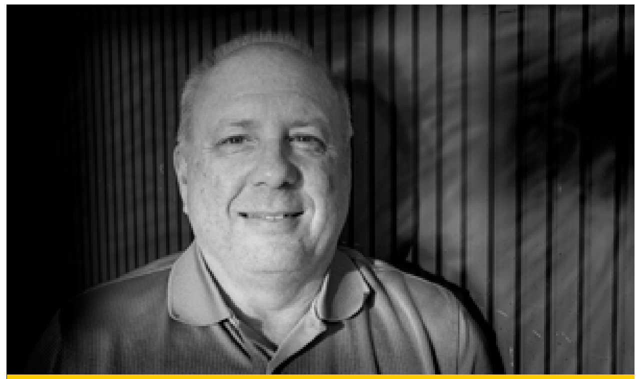
Our small survey has earned CASA high praise and indicates that most responders are satisfied with our eight years of bridge-building efforts. From this, good advice may be extracted for future centres to have a positive impact on their partners. At the same time, notes for potential improvement can also be gathered.
One suggestion is that the Centre interacts with multiple contact persons instead of only one at each of the 13 partners. Some have experienced that involving their colleagues on all topics could be very challenging. Other suggested that even though their goals have been met to a large extent, a higher level could have been achieved by supporting CASA with more internal experts. More active participation in the research activities as a result would transfer even more knowledge to the partner.

BRIDGING THE GAPS – IMPROVING THE BALANCE

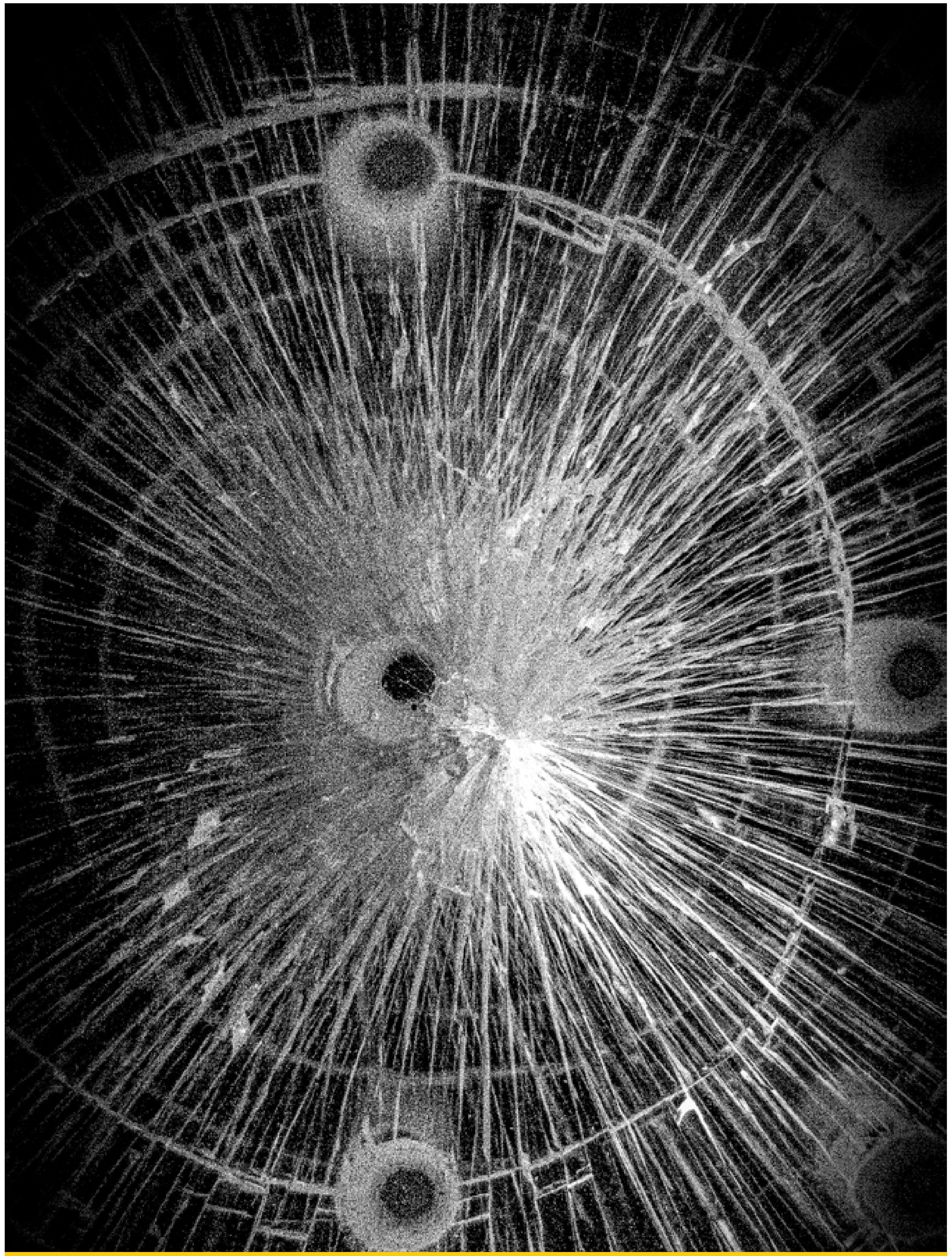
Eric DeHoff and Honda have a couple of suggestions for eventual future consortiums:
«First, get a clear picture from all partners on their current processes and the necessary technical gaps. The solution may need to be flexible enough to do several different ways to satisfy most of the partners».

Secondly, DeHoff finds it essential to consider the difference in time scales between the industry and researchers.
«There needs to be a balance between these long-term projects with short-term or intermediate application of the research so the partners can demonstrate that progress is being made», says the Chief Engineer of Honda Development and Manufacturing of America, LLC.

Nicolas Neumann.



Eric DeHoff.



Laminated glass subjected to blast loading. (Photo: Sølvi W. Normannsen)

Research for the Future

In May 2022, we concluded a seven-month strategy process facilitated by consultant firm Karabin AS. The work resulted in a strategy plan, identifying electric vehicle (EV) batteries and recycled aluminium as new research activities. These areas align well with societal challenges, international priorities, and industrial and research needs.
The aim of the strategic plan was to maintain SIMLab's existing areas of competence and preserve the critical know-how we have built over decades: for the industry, civil security, governmental institutions, and NTNU's cutting-edge research ambitions. All CASA's key employees were involved.

WE AIMED TO:

- Address societal challenges defined by EU, RCN, and national and international authorities.
- Solve research challenges addressed by key industries.
- Facilitate internal collaboration at NTNU in research and education.

For us, securing long-term public and industry funding was essential to foster the development of international research excellence and education.

Parallel to the strategy process, we worked on our wind-up plan. On 2nd May 2022, we presented the status and maturity of the activities to the partners. We highlighted activities ready for industrial implementation, activities that would be terminated after CASA's close-down, and activities that had already stopped. We also gave an overview of PhD projects to be finished after 30th June 2023.

To the industrial partners, industrial implementation has been a critical factor. The wind-up process made it clear that there was a strong industrial demand to continue our research. As a direct response, Audi AG secured continued collaboration with NTNU and SIMLab. The car manufacturer signed its first-ever Higher Education Framework Research Agreement outside a non-German-speaking region in autumn 2022.

In spring 2023, the agreement includes 3 PhD scholarships. The topics are virtual certification, safety in EV batteries, and glass failure prediction on windshields.
We have been encouraged to apply to the RCN for a Centre for Environment-friendly Energy Research (FME). The themes of the call are energy, transport, and low emissions. These topics are relevant to our ongoing research and the areas we identified for future ventures.
In the proposed Centre for Sustainable Electric Mobility (C-SEM), we join forces with the world-leading aluminium producer Hydro, plus four world-leading car manufacturers and suppliers.

We continue to pursue our eight-year-long effort to establish a National Centre on Research for Societal Security at NTNU.

*1st row from left: Benjamin Stavnar Elveli, Andria Antoniou, Kamila Zablocka, Håvard Næss, Rannveig Marie Færgestad.
2nd row from left: Rene Kaufmann, Sigurd Aune, Sølvi Waterloo Normannsen, Tore Børvik, Knut Marthinsen, Stephane Dumoulin, Terence Coudert, Virgile Delhaye, Peter Karlsaune, 3rd row from left: David Morin, Ruben Løland Sælen, Øystein Eirik Kvist Jacobsen, Jonas Rudshaug, Vetle Espeseth, Karoline Osnes, Anne-Sophie Sur, Magnus Langseth, Susanne Thomesen, Lars Edvard Blystad Dæhli,
Vegard Aune, Martin Kristoffersen, Odd Sture Hopperstad. Row 4: Tore Wisth, Victor André, Miguel Costas, Einar Schwenke, Jonas Hund, John Fredrick Berntsen, Torodd Berstad, Marcos Fernandez, Randi Holmestad, Bjørn Håkon Frodal. (Photo: Ole Martin Wold)*

Closing the Gap

Final remarks on SFI CASA´s closing seminar on 3 May 2023. From left: Julien Arts (Renault), Florian Meyer (Audi) and Arjan Strating (Audi). (Photo: Sølvi W. Normannsen)

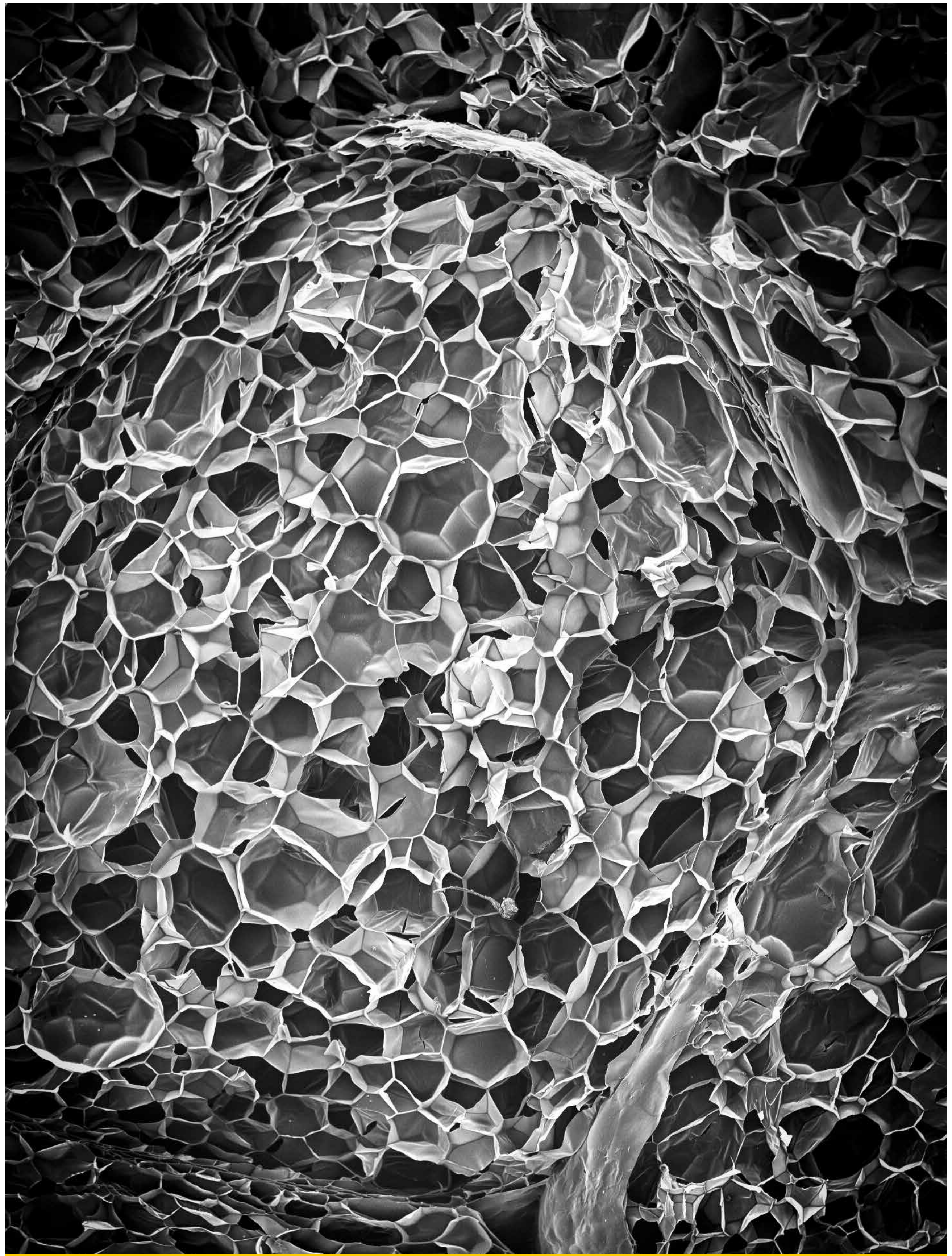
In spring 2019, SFI CASA was scrutinised by the mid-term evaluation team of international experts. Their main conclusion was: «This is an excellent competence Centre with many examples of best practice in its research, research training, organisation, and industry support operations».

A few years later, in November 2022, SFI CASA's Scientific Advisory Board published a final report stating that «CASA has achieved its objectives in conducting long-term, business sector-relevant research of high international quality». Further, the SAB declared that the Centre is world-leading, with scientists publishing influential papers in leading journals. «CASA has met its objectives in educating many researchers (Masters, and PhDs) who have conducted work well aligned with the partners' interests».

On 4 May 2023, we gathered our partners for the last time. In his final remarks, Audi's Arjan Strating said that the efforts on industrial implementation made the most prominent difference. Mr. Strating, who also served as Head of CASA´s Industrial Reference Group, thanked everyone for contributing to cutting-edge research and making a difference in future product development. He described it as a joint effort and acknowledged the whole CASA team. However, special recognition was paid to two people in particular:
Professor Magnus Langseth, for never growing tired of facing challenges from the industry, and Associate Professor David Morin, who spared no effort in programming tools for the industrial partners. «You definitely made a difference! », Mr. Strating concluded.

The SFI scheme is bridge-building in practice. At CASA, we channelled our efforts into closing the gap between academia and the industry. We were fortunate to have active, competent, committed partners that were eager to understand research. At the end of the journey, we believe the happiest partners are those who worked purposefully to innovate and improve their products by implementing our research.

As scientists, this is as far as we can go. On the other side of the bridge, others must take our work further.



The interior of polymer foam. (Credit: Daniel Thor Morton).

APPENDIX 1

FUNDING (KNOK)

	Activity/Item	Lower Scale	Metallic materials	Polymeric materials	Structures	Structural joints	Methods and Tools	Industrial Implementation -Fundamental research	Industrial Implementation	Management	Sum
	RCN	8178	23771	13427	21974	20288	0	2065	0	6297	96000
Host institution	NTNU	7502	4763	8280	12869	5534	7388	10841	0	8000	65177
Research partner	SINTEF	0	0	0	0	0	8144	0	0	0	8144
Company partners	Aker Solutions 2015-2016	50	105	0	0	32	214	100	250	199	950
	Audi AG 2015-2023	303	121	95	54	428	562	1333	1750	2554	7200
	Benteler Automotive Raufoss AS 2015-2023	167	121	0	0	92	554	1165	1875	2026	6000
	BMW Group 2015-2023	303	152	95	1043	784	545	1065	1875	1338	7200
	DNV AS 2015-2023	50	2567	0	105	0	77	258	2002	541	5600
	Equinor Energy AS 2015-2023	50	747	1570	910	91	703	1703	1875	6351	140000
	Honda R&D Americas, LLC 2015-2023	342	121	0	0	427	556	1155	1875	2724	7200
	Hydro Aluminium AS 2015-2023	4589	1522	0	0	91	495	1156	3250	3772	14875
	Multiconsult Norge AS 2018-2023	0	0	0	214	0	200	909	1375	1427	4125
	Renault 2017-2023	252	0	0	0	320	247	982	1625	2424	5850
	Sapa 2015-2018	404	121	0	0	92	308	176	500	1524	3125
	SSAB 2015-2016	189	50	0	0	32	272	112	250	445	1350
	Toyota Motor Europe 2015-2020	303	121	1001	0	429	477	385	1250	984	4950
Public partners	Gassco 2015-2017	245	122	0	0	91	368	169	500	1130	2625
	MinistryofLocalGovernmentandRegional Development 2015-2023	50	166	0	3221	92	495	909	0	3067	8000
	Norwegian Defence Estates Agency 2015-2023	50	198	0	3403	92	544	1144	1875	2694	10000
	Norwegian National Security Authority 2015-2023	50	121	0	3206	92	492	939	0	3100	8000
	Norwegian Public Roads Administration 2015-2023	50	121	0	164	92	709	1271	3375	1418	7200
	Total	24881	33256	24468	47163	35181	23350	15039	38425	51885	287571

COST (KNOK)

	Activity/Item	Lower Scale	Metallic materials	Polymeric materials	Structural joints	Structures	Methods and Tools	Industrial Implementation -Fundamental research	Industrial Implementation	Management	Sum
Host institution	NTNU	19786	27033	23800	35429	35377	7536	10582	9334	50186	219063
Research partner	SINTEF	5020	5225	668	2918	2543	14909	4457	2544	1699	39983
Company partners	Aker Solutions 2015-2016	0	0	0	0	0	50	0	300	0	350
	Audi AG 2015-2023	0	0	0	0	0	63	0	1937	0	2000
	Benteler Automotive Raufoss AS 2015-2023	0	0	0	0	0	63	0	1937	0	2000
	BMW Group 2015-2023	0	0	0	0	0	63	0	1937	0	2000
	DNV AS 2015-2023	75	998	0	0	0	62	0	2065	0	3200
	Equinor Energy AS 2015-2023	0	0	0	0	0	63	0	1937	0	2000
	Honda R&D Americas, LLC 2015-2023	0	0	0	0	0	63	0	1937	0	2000
	Hydro Aluminium AS 2015-2023	0	0	0	0	0	63	0	3312	0	3375
	Multiconsult Norge AS 2018-2023	0	0	0	0	0	0	0	1375	0	1375
	Renault 2017-2023	0	0	0	0	0	0	0	1625	0	1625
	Sapa 2015-2018	0	0	0	0	0	63	0	562	0	625
	SSAB 2015-2016	0	0	0	0	0	63	0	312	0	375
	Toyota Motor Europe 2015-2020	0	0	0	0	0	63	0	1312	0	1375
Public partners	Gassco 2015-2017	0	0	0	0	0	63	0	562	0	625
	MinistryofLocalGovernmentandRegional Development 2015-2023	0	0	0	0	0	0	0	0	0	0
	Norwegian Defence Estates Agency 2015-2023	0	0	0	0	0	63	0	1937	0	2000
	Norwegian National Security Authority 2015-2023	0	0	0	0	0	0	0	0	0	0
	Norwegian Public Roads Administration 2015-2023	0	0	0	0	0	100	0	3500	0	3600
	Total	24881	33256	24468	38347	37920	23350	15039	38425	51885	287571

APPENDIX 2 - LIST OF POST-DOCS, CANDIDATES FOR PHD AND MSC DEGREES DURING THE FULL PERIOD OF THE CENTRE

POSTDOCTORAL RESEARCHERS WITH FINANCIAL SUPPORT FROM THE CENTRE BUDGET

Name	M/F	Nationality	Scientific area	Years/period in the centre	Scientific topic	Main contact
Jens Kristian Holmen	M	Norway	Structures	2016-2018	Modelling and simulation of impact	Tore Børvik
Vegard Aune	M	Norway	Structures	2016-2017	Modelling and simulation of impact	Tore Børvik
Miguel Costas	M	Spain	Structural Joints	2017-2019	Behaviour and modelling of joints	David Morin
Maria-Jesus Perez Martin	F	Spain	Structures	2018-2021	Behaviour and modelling of steel	Tore Børvik
Panagiotis Manoleas	M	Greece	Structural Joints	2018-2020	Behaviour and modelling of joints	Arild Holm Clausen
Sunita Mshra	F	India	Structures	2019	Blast	Tore Børvik
Emil Christiansen	M	Norway	Lower Scale	2019-2021	Nanoscale characterization of aluminium	Randi Holmestad
Karoline Osnes	F	Norway	Structures	2019-2021	Behaviour and modelling of glass	Tore Børvik
Susanne Thomesen	F	Norway	Metallic materials	2019-2021	Behaviour and modelling of cast aluminium	Odd Sture Hopperstad
John Fredrick Berntsen	M	Norway	Polymeric materials	2021-2023	Multi-material joints	Arild Holm Clausen
Andria Antoniou	F	Cyprus	Structures	2020-2022	Blast loading	Tore Børvik
Sindre Olufsen	M	Norway	Polymeric materials	2020-2022	Modelling of ductile damage and fracture in polymers	Arild Holm Clausen
Marcos Fernandez	M	Spain	Metallic materials	2022-2024	Modelling of aluminium	David Morin

POSTDOCTORAL RESEARCHERS WORKING ON PROJECTS IN THE CENTRE WITH FINANCIAL SUPPORT FROM OTHER SOURCES

Name	M/F	Nationality	Source of funding	Scientific area	Years/period in the centre	Scientific topic	Main contact
Egil Fagerholt	M	Norway	SFI SIMLab	Measuring tech-niques	2012-2015	Digital Image Correlation	Odd Sture Hopperstad
Gaute Gruben	M	Norway	EUROSTARS project GEPEU	Metallic materials	2012-2015	Modelling of high strength steel	Tore Børvik
Mikhail Khadyko	M	Norway	SINTEF project	Metallic materials	2014-2016	Multiscale modelling	Odd Sture Hopperstad
Martin Kristoffersen	M	Norway	Fergefri E39	Sructures	2015-2017	Blast loading	Tore Børvik
Marius Endre Holtermann Andersen	M	Norway	AluMast	Metallic materials	2015-2017	Behaviour and modelling of aluminium columns	Arild Clausen
Lars Edvard Dæhli	M	Norway	FractAl	Metallic materials	2017-2021	Modelling of aluminium	Odd Sture Hopperstad
Bjørn Håkon Frodal	M	Norway	FractAl	Metallic materials	2019-2022	Modelling of aluminium	Odd Sture Hopperstad
Rene Kaufmann	M	Germany	KPN Slade	Structures	2019-2023	Impact response	Vegard Aune
Kinga Somlo	F	Hungary	IPN EXPECT	Metallic materials	2021-2023	Modelling of aluminium	Tore Børvik
Jonas Hund	M	Germany	IPN STIP	Polymeric materials	2021-2023	Flexible risers	Arild Clausen
Lucas Lapostolle	M	France	NTNU/Audi AG	Structures	2023-2025	Mechanical modelling of lithium ion batteries for electric vehicles	David Morin

PHD CANDIDATES WHO HAVE COMPLETED WITH FINANCIAL SUPPORT FROM THE CENTRE BUDGET

Name	M/F	Nationality	Scientific area	Years/period in the centre	Thesis title	Main thesis advisor
Karoline Osnes	F	Norway	Structures	2015-2019	Monolithic and laminated glass under extreme loading: Experiments, modelling and simulations	Tore Børvik
Emil Christiansen	M	Norway	Lower Scale	2015-2019	Nanoscale Characterization of Deformed Aluminium Alloys	Randi Holmestad
Bjørn Håkon Frodal	M	Norway	Metallic materials	2015-2019	Micromechanical modelling of ductile fracture in aluminium alloys	Odd ture Hopperatad
Sindre Olufsen	M	Norway	Polymeric materials	2015-2020	Experimental and numerical study of dilation in mineral filled PVC	Arild Holm Clausen
John Fredrick Berntsen	M	Norway	Polymeric materials	2015-2020	Testing and modelling of multi-material joints	David Morin
Ole Vestrum	M	Norway	Structures	2016-2020	Impact on porous polymer coated pipelines	Tore Børvik
Jianbin Xu	M	China	Lower Scale	2016-2021	An experimental and numerical study of the Portevin-Le Chatelier effect in an AlMg alloy	Knut Marthinsen
Sondre Bergo	M	Norway	Metallic materials	2016-2020	Micromechanical modelling of fracture in ductile alloys with applications to high-strength steel	Odd ture Hopperatad
Daniel Morton	M	Norway	Polymeric materials	2016-2021	Characterization and modelling of the mechanical behaviour of polymer foam	Aase Reyes
Jonas Frafjord	M	Norway	Lower Scale	2016-2020	Atomistic Scale Modelling of Defects in Aluminium Alloys	Randi Holmestad
Matthias Reil	M	Germany	Structural Joints	2016-2019	Connections between steel and aluminium using adhesive bonding combined with self-piercing riveting: Testing, modelling and analysis	David Morin
Christian Oen Paulsen	M	Norway	Lower Scale	2015-2019	Experimental characterization of two-phase steels	Ida Westermann
Einar Schwenke	M	Norway	Polymeric materials	2017-2021	Polymers at various rates and temperatures	Arild Holm Clausen
Benjamin Stavnar Elveli	M	Norway	Structures	2018-2022	Behaviour, modelling, and simulation of thin steel plates subjected to combined blast and impact loading	Vegard Aune
Marcos Fernandez	M	Norway	Metallic materials	2018-2022	On the use of a virtual laboratory for aluminium alloys: application to large-scale analyses of extruded profiles.	David Morin

PHD CANDIDATES WHO HAVE COMPLETED WITH OTHER FINANCIAL SUPPORT, BUT ASSOCIATED WITH THE CENTRE

Name	M/F	Nationality	Source of funding	Scientific area	Years in the centre	Thesis title	Main contact
Joakim Johnsen	M	Norway	SINTEF project	Polymeric materials	2014-2017	Thermomechanical behaviour of semi-crystalline polymers: experiments, modelling and simulation	Arild Clausen
Lars Edvard Dæhli	M	Norway	SFI SIMLab	Metallic materials	2013-2017	Numerical studies on ductile failure of aluminium alloys	Odd Sture Hopperstad
Petter Henrik Holmstrøm	M	Norway	SFI SIMLab	Polymeric materials	2013-2019	An experimental and numerical study of the mechanical behaviour of short glass-fibre reinforced thermoplastics.	Arild Holm Clausen
Jens Kristian Holmen	M	Norway	SFI SIMLab	Structures	2013-2016	Modelling and simulation of ballistic impact	Tore Børvik
Vegard Aune	M	Norway	SFI SIMLab	Structures	2012-2017	Behaviour and modelling of flexible structures subjected to blast loading	Tore Børvik
Marius Endre Holter-mann Andersen	M	Norway	SFI SIMLab	Polymeric materials	2011-2016	An Experimental and Numerical Study of Thermoplastics at Large Deformation	Arild Holm Clausen
Arne Ilseng	M	Norway	Aker Solutions	Polymeric materials	2013-2016	Mechanical Behaviour of Particle-filled Elastomers at Various Temperatures. An Experimental and Numerical Study	Arild Holm Clausen
Erik Løhre Grimsmo	M	Norway	SFI SIMLab	Structures	2013-2017	Behaviour of steel connections under qua-si-static and impact loading - An experimental and numerical study	Arild Holm Clausen
Johan Kolstø Sønstabø	M	Norway	Honda project	Structural joints	2013-2018	Behaviour and modelling of flow-drill screw connections	Magnus Langseth
Susanne Thomesen	F	Norway	FractAl (Toppforsk)	Metallic materials	2016-2019	Plastic flow and fracture of isotropic and anisotropic 6000-series aluminium alloys: experiments and numerical simulations	Odd Sture Hopperstad
Henrik Granum	M	Norway	FractAl (Toppforsk)	Metallic materials	2016-2019	Multiscale modelling and simulation of failure in aluminium structures	Odd Sture Hopperstad
Asle Joachim Tomstad	M	Norway	FractAl (Toppforsk)	Metallic materials	2017-2022	Ductile fracture of aluminium alloys in the low to moderate stress triaxiality range	Tore Børvik
Kristin Qvale	F	Norway	FractAl (Toppforsk)	Metallic materials	2018-2022	Energy absorption and failure in aluminium alloys: An experimental and numerical study	Tore Børvik
Vetle Espeseth	M	Norway	FractAl (Toppforsk)	Metallic materials	2018-2023	Ductile failure of aluminium plates: experi-ments, modelling and simulations	Odd Sture Hopperstad
Anne-Sophie Sur	F	Germany	FME NCCS	Metallic materials	2020-2023	Modelling of running ductile fracture in high-strength steel pipelines	Odd Sture Hopperstad
Daniele Cioni	M	Italy	NTNU/Audi AG	Structures	2022-2025	Modelling of batteries for electric vehicles	David Morin

PHD CANDIDATES WITH FINANCIAL SUPPORT FROM THE CENTRE WHO ARE STILL IN THE PROCESS OF FINISHING STUDIES

Name	M/F	Nationality	Scientific area	Years in the centre	Thesis title	Main thesis advisor
Kristoffer Aune Brekken	M	Norway	Structures	2017-2023	Sacrificial claddings	Tore Børvik
Victor André	M	Germany	Structural Joints	2019-2022	Modelling of multilayered joints	David Morin
Jonas Rudshaug	M	Norway	Structures	2019-2023	Modelling of glass	Tore Børvik
Ruben Løland Sælen	M	Norway	Polymeric materials	2019-2023	Modelling of polymers	Arild Holm Clausen
Sigurd Aune	M	Norway	Structural Joints	2020-2024	Modelling of joints	Odd Sture Hopperstad
Rannveig Marie Færgestad	F	Norway	Structures	2021-2025	Hypervelocity impact	Tore Børvik
Øystein Jacobsen	M	Norway	Structures	2021-2026	Penetration in concrete	Tore Børvik
Håvard Næss	M	Norway	Metallic materials	2021-2027	Machine leaning in material mechanics	Odd Sture Hopperstad
Fanny Dameme	F	France	Structural Joints	2021-2028	Dynamic loading and ageing of adhesives	David Morin
Debora Obkircher	F	Italy	Structural Joints	2022-2025	Modelling of aluminium	Arild Holm Clausen

MSC CANDIDATES WITH THESIS RELATED TO THE CENTRE RESEARCH AGENDA AND AN ADVISOR FROM THE CENTRE STAFF

Name	M/F	Nation-ality	Scientific area	Years in the centre	Thesis title	Main thesis advisor
Bengtson, Olav Ingvaldsen	M	Norway	Structural Engineering	2016	Mechanical behaviour of sacrificial sandwich panels	Tore Børvik
Bergo, Sondre	M	Norway	Structural Engineering	2016	Micromechanical Modelling and Simulation of Ductile Fracture in Metallic Materials	Odd Sture Hopperstad
Boger, Beate	D	Norway	Structural Engineering	2016	Behaviour and modelling of TPU	Arild Holm Clausen
Brekken, Kristoffer Aune	M	Norway	Structural Engineering	2016	Modelling of Window Glasses Exposed to Blast Loading	Tore Børvik
Dalen, Fredrik Schjelderup	M	Norway	Structural Engineering	2016	Progressive collapse of buildings caused by explosion	Magnus Langseth
Eek, Marius	M	Norway	Structural Engineering	2016	Modeling of Work Hardening for Aluminum Alloy Structures	Odd Sture Hopperstad
Granum, Henrik Møgster	M	Norway	Structural Engineering	2016	Experimental and Numerical Study on Perforated Steel Plates Subjected to Blast Loading	Tore Børvik
Guddal, Sigurd	M	Norway	Structural Engineering	2016	Welding on Power Pylons in Aluminium	Magnus Langseth
Hillestad, Eivind	M	Norway	Structural Engineering	2016	Experimental and Numerical Studies of Plain and Reinforced Concrete Plates Subjected to Blast Loading	Tore Børvik, Martin Kristoffersen
Ingier, Petter Tønsberg	M	Norway	Structural Engineering	2016	Modelling of Window Glasses Exposed to Blast Loading	Tore Børvik, Martin Kristoffersen
Johansen, Stian	M	Norway	Structural Engineering	2016	An experimental and numerical study of bolt and nut assemblies under tension loading	Magnus Langseth

Kaldager, Kristian Kolstø	M	Norway	Structural Engineering	2016	Modeling of Work Hardening for Aluminum Alloy Structures	Odd Sture Hopperstad
Lien, Even Josten	M	Norway	Structural Engineering	2016	Impact Behaviour of Stiffened Aluminium Plates	Magnus Langseth
Løken, Lars Marcus	M	Norway	Structural Engineering	2016	Experimental and Numerical Study on Perforated Steel Plates Subjected to Blast Loading	Tore Børvik
Myrang, Andreas	M	Norway	Structural Engineering	2016	Oppførsel av plastmaterialer ved lave temperaturer	Arild Holm Clausen
Nesje, Andreas Vestermo	M	Norway	Structural Engineering	2016	Power Pylons in Aluminium	Magnus Langset, Marius Andersen
Nilsen, Pål Arild	M	Norway	Structural Engineering	2016	Power Pylons in Aluminium	Magnus Langset, Marius Andersen
Pettersen, Jon Eide	M	Norway	Structural Engineering	2016	Experimental and Numerical Studies of Plain and Reinforced Concrete Plates Subjected to Blast Loading	Tore Børvik
Sigurdsson, Bjarki	M	Norway	Structural Engineering	2016	Foam Materials used for Energy Absorption and Damage Prevention during Blast Loading	Tore Børvik
Skyrud, Aleksander	M	Norway	Structural Engineering	2016	Impact Behaviour of Stiffened Aluminium Plates	Magnus Langseth
Thomesen, Susanne	F	Norway	Structural Engineering	2016	Impact Behaviour of Steel at Low Temperatures	Tore Børvik
Waldeland, Espen	M	Norway	Structural Engineering	2016	An experimental and numerical study of bolt and nut assemblies under tension loading	Arild Holm Clausen
Øygarden, Jesper	M	Norway	Structural Engineering	2016	Polymers subjected to shear loading	Arild Holm Clausen
Amundsen, Niklas	M	Norway	Structural Engineering	2017	Knekking av hule aluminiumssøyler med og uten sveis	Magnus Langseth
Berdal, Sindre	M	Norway	Structural Engineering	2017	Impact behaviour of foam-based protective structures	Tore Børvik
Bjørgo, Lars Einar	M	Norway	Structural Engineering	2017	Impact behaviour of foam-based protective structures	Tore Børvik
Bratsberg, Ola S.	M	Norway	Structural Engineering	2017	Window glasses exposed to blast loading	Tore Børvik
Gulbrandsen, Daniel	M	Norway	Structural Engineering	2017	Stålplater utsatt for støtlast i kaldt klima	Tore Børvik
Gunathasan, Piraveena	F	Norway	Structural Engineering	2017	Ballistisk oppførsel av stålplater ved lave tempera-turer	Tore Børvik
Hammersvik, Steffen	M	Norway	Structural Engineering	2017	Impact against coated steel pipes	Tore Børvik
Hellum, Gry Myrmo	F	Norway	Structural Engineering	2017	Ductile-brittle transition in offshore steel	Odd Sture Hopperstad
Kittilsen, Eirik Thanem	M	Norway	Structural Engineering	2017	Behaviour and modelling of cast aluminium rims	Magnus Langseth
Kjus, Eivind Sogn	M	Norway	Structural Engineering	2017	Modelling, simulation and optimization of crash components in aluminium	Magnus Langseth
Kolsaker, Mathias	M	Norway	Structural Engineering	2017	Window glasses exposed to blast loading	Tore Børvik
Kulsrud, Eirik B.	M	Norway	Structural Engineering	2017	Impact against coated steel pipes	Tore Børvik
Lynum, Aksel	M	Norway	Structural Engineering	2017	Knekking av hule aluminiumssøyler med og uten sveis	Magnus Langseth
Nordhaug, Marie	F	Norway	Structural Engineering	2017	Identification of material properties of an aluminium alloy	Tore Børvik
Pettersen, Erlend Eksaa	M	Norway	Structural Engineering	2017	Simulation and behaviour of dual-phase steels	Odd Sture Hopperstad
Schwenke, Einar	M	Norway	Structural Engineering	2017	Cold impact performance of polypropylene	Arild Holm Clausen

Solhjem, Espen	M	Norway	Structural Engineering	2017	Modelling, simulation and optimization of crash components in aluminium	Magnus Langseth
Stensjøen, Jon M.	M	Norway	Structural Engineering	2017	Blast loading on flexible aluminium plates	Tore Børvik
Storheim, Birgitte	F	Norway	Structural Engineering	2017	Mechanical behaviour of a mineral filled elastomer modified polypropylene compound	Odd Sture Hopperstad
Swanberg, Emil	M	Norway	Structural Engineering	2017	Behaviour and modelling of cast aluminium rims	Magnus Langseth
Thorgeirsson, Sondre	M	Norway	Structural Engineering	2017	Mechanical behaviour of a mineral filled elastomer modified polypropylene compound	Odd Sture Hopperstad
Tjønn, Else	F	Norway	Structural Engineering	2017	Modelling and simulation of hyper velocity impact against debris shields for spacecraft protection	Tore Børvik
Tomstad, Asle J.	M	Norway	Structural Engineering	2017	Modelling and simulation of ductile fracture	Odd Sture Hopperstad
Engebretsen, Rasmus S.	M	Norway	Structural Engineering	2017	Modelling of PA in inner liner in flexible pipes	Arild Holm Clausen
Qvale, Kristin	F	Norway	Structural Engineering	2017	Static and dynamic crushing of aluminium profiles	Tore Børvik
Mads Bakken Iddberg	M	Norway	Structural Engineering	2018	Experimental and numerical study on perforated steel plates subjected to blast loading	Vegard Aune
Benjamin Stavnar Elveli	M	Norway	Structural Engineering	2018	Experimental and numerical study on perforated steel plates subjected to blast loading, male	Vegard Aune
Simen Kjernlie	M	Norway	Structural Engineering	2018	Modelling of windshields subjected to impact loading	Tore Børvik
Tormod Grue	M	Norway	Structural Engineering	2018	Modelling of windshields subjected to impact loading	Tore Børvik
Tobias Lund	M	Norway	Structural Engineering	2018	Behaviour and failure of aluminium extrusions under bending and stretching	David Morin
Sigurd Lekve	M	Norway	Structural Engineering	2018	Sacrificial sandwich panels exposed to blast loading	Tore Børvik
Olaf Kielland	M	Norway	Structural Engineering	2018	Sacrificial sandwich panels exposed to blast loading	Tore Børvik
Vetle Espeseth	M	Norway	Structural Engineering	2018	Micromechanical modelling of plasticity, damage and fracture in aluminium alloys	Odd Sture Hopperstad
Vegard Haraldseid	M	Norway	Structural Engineering	2018	Design of aluminium power pylons	Magnus Langseth
Anders Engebakken	M	Norway	Structural Engineering	2018	Cold impact performance of polypropylene (PP)	Arild Holm Clausen
Jørgen Skjennum	M	Norway	Structural Engineering	2018	Cold impact performance of polypropylene (PP)	Arild Holm Clausen
Kevin Mandt Ofstad	M	Norway	Structural Engineering	2018	Finite element modelling of steel bridge structures exposed to ship collisions	Odd Sture Hopperstad
Jostein Hals	M	Norway	Structural Engineering	2018	Thermomechanical analysis of casing systems for supercritical geothermal wells	Odd Sture Hopperstad
Lars-Endre Johannessen	M	Norway	Structural Engineering	2018	Thermomechanical analysis of casing systems for supercritical geothermal wells	Magnus Langseth
Christoffer Martinsen	M	Norway	Structural Engineering	2018	Design of die cast aluminium rims	Magnus Langseth
Torodd Lønning	M	Norway	Structural Engineering	2018	Polymer foam used in bumper systems	Magnus Langseth
Nikolai Korvald Skaare	M	Norway	Structural Engineering	2018	Internal blast loading of submerged floating tunnels in concrete	Tore Børvik, Martin Kristoffersen
Erika Krone	F	Norway	Structural Engineering	2018	Internal blast loading of submerged floating tunnels in concrete	Tore Børvik, Martin Kristoffersen

Mari Skarstein	F	Norway	Structural Engineering	2018	Simulation of Ductile Crack Propagation in Steel Pipelines	Odd Sture Hopperstad
Elise Sterner	F	Norway	Structural Engineering	2018	Simulation of Ductile Crack Propagation in Steel Pipelines	Odd Sture Hopperstad
Jonas Rudshaug	M	Norway	Structural Engineering	2019	Modelling of windshields subjected to quasi-static loading	Tore Børvik, Martin Kristoffersen
Eyvind Evensen	M	Norway	Structural Engineering	2019	Modelling of windshields subjected to quasi-static loading	Tore Børvik, Martin Kristoffersen
Chris-Mikael Rom Bjorvand	M	Norway	Structural Engineering	2019	Dynamic response of flexible structures subjected to blast loading	Vegard Aune
Anders Berrum	M	Norway	Structural Engineering	2019	Dynamic response of flexible structures subjected to blast loading	Vegard Aune
Nicholas Thuve	M	Norway	Structural Engineering	2019	Testing and modeling of thick aluminum castings under impact loadings	Magnus Langseth
Fredrik Bonnevie Dahler	M	Norway	Structural Engineering	2019	Testing and modeling of thick aluminum castings under impact loadings	Magnus Langseth
Ruben Løland Sælen	M	Norway	Structural Engineering	2019	Dynamic Behaviour of Polymeric Foams	Tore Børvik
Anders Hald	M	Norway	Structural Engineering	2019	Dynamic response of steel plates subjected to combined impact and blast loading	Vegard Aune
Marte Vestermo Nesje	F	Norway	Structural Engineering	2019	Combined impact and blast loading on concrete plates	Tore Børvik, Martin Kristoffersen
Guri Lillehaug	F	Norway	Structural Engineering	2019	Combined impact and blast loading on concrete plates	Tore Børvik, Martin Kristoffersen
Ole Kristian Rønning	M	Norway	Structural Engineering	2019	Thermomechanical Response of Virgin and Degraded PA11	Arild Holm Clausen
Håvard Houmb Kristiansen	M	Norway	Structural Engineering	2019	Dynamic response of blast-loaded steel plates with and without pre-formed holes	Vegard Aune
Gunnar Sigstad	M	Norway	Structural Engineering	2019	Dynamic response of blast-loaded steel plates with and without pre-formed holes	Vegard Aune
Kristian Ullern Faksvåg	M	Norway	Structural Engineering	2019	Material parameters for stainless steel in numerical simulations	Arild Holm Clausen
Lars Omland Jakobsen	M	Norway	Structural Engineering	2019	Material parameters for stainless steel in numerical simulations	Arild Holm Clausen
Håkon Dahle	M	Norway	Structural Engineering	2019	Thermomechanical Response of Virgin and Degraded PA11	Arild Holm Clausen
Sigurd Aune	M	Norway	Structural Engineering	2020	Modelling and simulation of yielding, work-hardening and fracture of advanced high-strength steels	Odd Sture Hopperstad
Jostein Lima	M	Norway	Structural Engineering	2020	Modelling and simulation of yielding, work-hardening and fracture of advanced high-strength steels	Odd Sture Hopperstad
Jørgen Sørbøl	M	Norway	Structural Engineering	2020	Performance of perforated aluminium plates subjected to blast loading	Vegard Aune
Odin Celius	M	Norway	Structural Engineering	2020	Plated aluminium structures exposed to extreme pressure loads	Vegard Aune
Magnus Leivik Knoph	M	Norway	Structural Engineering	2020	Plated aluminium structures exposed to extreme pressure loads	Vegard Aune

Anja Murud Gahre	F	Norway	Structural Engineering	2020	Dynamic response of steel plates subjected to combined blast and impact loading	Vegard Aune
Ragnhild Hembre Haug	F	Norway	Structural Engineering	2020	Dynamic response of steel plates subjected to combined blast and impact loading	Vegard Aune
Håkon Frydenberg	M	Norway	Structural Engineering	2020	Impact on polymer-coated pipelines	Tore Børvik, Martin Kristoffersen
Magnus P Torp	M	Norway	Structural Engineering	2020	Impact on polymer-coated pipelines	Tore Børvik, Martin Kristoffersen
Lars Otto Lofthus Ose	M	Norway	Structural Engineering	2020	Modelling of laminated glass	Tore Børvik
Steinar L Harneshaug	M	Norway	Structural Engineering	2020	Modelling of laminated glass	Tore Børvik
Håkon Johannessen	M	Norway	Structural Engineering	2020	Experimental and numerical study on the static and dynamic behaviour of notched square hollow sections made of three types of S355	Arild Holm Clausen, Miguel Costas
Oddvar Hestetræet Johannessen	M	Norway	Structural Engineering	2020	Experimental and numerical study on the static and dynamic behaviour of notched square hollow sections made of three types of S355	Arild Holm Clausen, Miguel Costas
Erla C. Gudding	F	Norway	Structural Engineering	2020	Welded joints	Arild Holm Clausen
Ådne Lund	M	Norway	Structural Engineering	2020	Joints between hollow sections made of high-strength steel	Arild Holm Clausen
Bjørn Gjertsen	M	Norway	Structural Engineering	2020	Testing and Modelling of Thick Aluminium Castings Under Impact Loadings	Magnus Langseth
Sondre Tjessem	M	Norway	Structural Engineering	2020	Testing and Modelling of Thick Aluminium Castings Under Impact Loadings	Magnus Langseth
Alexander Tangen	M	Norway	Structural Engineering	2020	Modelling of heat-affected zones in aluminium structures	David Morin
Håvard Næss	M	Norway	Structural Engineering	2021	Plated offshore structures exposed to violent wave impact	Vegard Aune
Rannveig Marie Færgestad	F	Norway	Structural Engineering	2021	Modelling and simulation of hypervelocity impact against debris shields for spacecraft protection	Tore Børvik
Even Garshol	M	Norway	Structural Engineering	2021	Modelling of steel plates subjected to impact and blast loading	Magnus Langseth
Vegard Skauge Hjelmeland	M	Norway	Structural Engineering	2021	Fluid structure interaction effects during the dynamic response of blast-loaded plates	Vegard Aune
Sigurd Vattekar Sandvoll	M	Norway	Structural Engineering	2021	Design and modelling of vehicle security barriers	Tore Børvik, Martin Kristoffersen
Ola Fjelltun Stensvand	M	Norway	Structural Engineering	2021	Design and modelling of vehicle security barriers	Tore Børvik, Martin Kristoffersen
Amatul Syed	F	Norway	Structural Engineering	2021	Dynamic response of flexible structures subjected to blast loading	Vegard Aune
Ingrid Gisnås	F	Norway	Structural Engineering	2021	Dynamic response of flexible structures subjected to blast loading	Vegard Aune
Vetle Solheim Gjesdal	M	Norway	Structural Engineering	2021	Projectile impact on plain and reinforced concrete slabs	Tore Børvik, Martin Kristoffersen
Øystein Eirik Kvist Jacobsen	M	Norway	Structural Engineering	2021	Projectile impact on plain and reinforced concrete slabs	Tore Børvik, Martin Kristoffersen

Kamila Zablocka	F	Norway	Structural Engineering	2021	Additive manufactured protective structures	Tore Børvik, Miguel Costas
Olav Nordvik	M	Norway	Structural Engineering	2021	Machine learning in material mechanics	Odd Sture Hopperstad
Tameem Karim Pathan	M	Norway	Structural Engineering	2021	Optimization of extruded aluminium profiles for battery protection in electric cars	David Morin
Oskar Homme Misund	M	Norway	Structural Engineering	2021	Additive manufactured protective structures	Tore Børvik, Miguel Costas
Kristoffer Frøyd Eriksen	M	Norway	Structural Engineering	2021	Modelling of ductile fracture in steel structures	Odd Sture Hopperstad
Eirik Hegre	M	Norway	Structural Engineering	2021	Modelling of Joints in Large-Scale Analyses of Steel Structures	Arild Holm Clausen, David Morin
Hjalmar Emil Moter Hauge	M	Norway	Structural Engineering	2021	Modelling of Joints in Large-Scale Analyses of Steel Structures	Arild Holm Clausen, David Morin
Ådne Skretting	M	Norway	Structural Engineering	2021	Fatigue assessment of a generic steel bridge	Arild Holm Clausen
Mari Solheim	F	Norway	Structural Engineering	2021	Fatigue assessment of a generic steel bridge	Arild Holm Clausen
Marie Bacher	F	Norway	Structural Engineering	2022	Thin steel plates subjected to confined, close-range blast loading	Vegard Aune
Anne Myran Larsen	F	Norway	Structural Engineering	2022	Thin steel plates subjected to confined, close-range blast loading	Vegard Aune
Ingebrigt Sæther	M	Norway	Structural Engineering	2022	Modelling of running fracture in steel pipes for CO2 transport	Odd Sture Hopperstad
Henrik Lorentz Burchardt	M	Norway	Structural Engineering	2022	Modelling of running fracture in steel pipes for CO2 transport	Odd Sture Hopperstad
Tiril Elea Narvestad	F	Norway	Structural Engineering	2022	Additive manufactured protective structures	Tore Børvik
Cornelia Reinholdtsen Brantenberg	F	Norway	Structural Engineering	2022	Additive manufactured protective structures	Tore Børvik
Stian Gundersen Raniszewski	M	Norway	Structural Engineering	2022	Mechanical testing and numerical simulation of car batteries subjected to extreme loads and deformations	Miguel Costas
Daniele Cioni	M	Italy	Structural Engineering	2022	Mechanical testing and numerical simulation of car batteries subjected to extreme loads and deformations	Miguel Costas
Ludvig Reichborn-Bjørneklett	M	Norway	Structural Engineering	2022	Modelling of tensile ductility using artificial neural networks	Odd Sture Hopperstad
Sarah Stradel Garn Hansen	F	Denmark	Structural Engineering	2022	Design and modelling of vehicle security barriers	Tore Børvik, Martin Kristoffersen
Yushi Li	F	Norway	Structural Engineering	2022	Design and modelling of vehicle security barriers	Tore Børvik, Martin Kristoffersen
Anders Aamodt Resell	M	Norway	Structural Engineering	2022	Modelling of fluid-structure interaction with fixed grid methods: Opportunities and application to shock tube simulations	Vegard Aune
Einer Herrem	M	Norway	Structural Engineering	2022	Modelling of laminated glass	Tore Børvik
Simen August Ruste	M	Norway	Structural Engineering	2022	Behaviour and modelling of welded aluminium joints	Arild Holm Clausen, David Morin
Jonas Tofte Røhne	M	Norway	Structural Engineering	2022	Impact loading on beam of glulam timber	Arild Holm Clausen, Haris Stamatopoulos

Matias Mortensen	M	Norway	Structural Engineering	2022	Impact loading on beam of glulam timber	Arild Holm Clausen, Haris Stamatopoulos
Sondre Skau Kentsrud	M	Norway	Structural Engineering	2022	Impact loading on beam of cross-laminated timber	Arild Holm Clausen, Haris Stamatopoulos
Lars Gruben	M	Norway	Structural Engineering	2022	Impact loading on beam of cross-laminated timber	Arild Holm Clausen, Haris Stamatopoulos
Ola Berge	M	Norway	Structural Engineering	2022	An experimental and numerical study of eccentrically placed rectangular hollow section braces on chords under out-of-plane bending moment	Arild Holm Clausen, Arne Aalberg
Martin Melandsø	M	Norway	Structural Engineering	2022	Dynamic material behaviour of wood	Arild Holm Clausen, Haris Stamatopoulos
Tilde Hattestad Weider	F	Norway	Structural Engineering	2023	Additively manufactured maraging steel as ballistic protection	Tore Børvik
Maria Sagberg Bakk	F	Norway	Structural Engineering	2023	Additively manufactured maraging steel as ballistic protection	Tore Børvik
Børge Grødem	M	Norway	Structural Engineering	2023	Effect of a high axial compression force on the burst capacity of a pipeline	Odd Sture Hopperstad
Thomas Fiskå	M	Norway	Structural Engineering	2023	Effect of a high axial compression force on the burst capacity of a pipeline	Odd Sture Hopperstad
Erlend Hepsøe	M	Norway	Structural Engineering	2023	Necking behaviour of pipe under internal pressure, axial load, and large bending moment	Odd Sture Hopperstad
Jonas Nordbø	M	Norway	Structural Engineering	2023	Necking behaviour of pipe under internal pressure, axial load, and large bending moment	Odd Sture Hopperstad
Marius Valan Dørmenen	M	Norway	Structural Engineering	2023	Behaviour and modelling of welded aluminium connections	Arild Holm Clausen, David Morin
Petter Andersen	M	Norway	Structural Engineering	2023	Behaviour and modelling of welded aluminium connections	Arild Holm Clausen, David Morin
Eivind Solhaug	M	Norway	Structural Engineering	2023	Wrinkling of Liner Inside a Carbon Steel Pipe for a Mechanically Lined Pipe	Odd Sture Hopperstad
Selma Hjelde Ellingsen	F	Norway	Structural Engineering	2023	Beam-column connection subjected to quasi-static and dynamic loads	Arild Holm Clausen, Miguel Costas
Ola Roppen	M	Norway	Structural Engineering	2023	Beam-column connection subjected to quasi-static and dynamic loads	Arild Holm Clausen, Miguel Costas
Therese Gransjøen	F	Norway	Structural Engineering	2023	Modeling and simulation of hypervelocity impact against debris shields for spacecraft protection	Tore Børvik
Chris Pillai Johnson	M	Norway	Structural Engineering	2023		
Jørgen Rødal Høstmark	M	Norway	Structural Engineering	2023		
Markus Myrvoll	M	Norway	Structural Engineering	2023	Numerisk og eksperimentell undersøkelse av momentkapastiteten til X-knutepunkt med sentrisk og eksentrisk plasserte rektangulære hulprofiler	Arild Holm Clausen, Arne Aalberg
Eivind Landsverk	M	Norway	Structural Engineering	2023	Numerisk og eksperimentell undersøkelse av momentkapastiteten til X-knutepunkt med sentrisk og eksentrisk plasserte rektangulære hulprofiler	Arild Holm Clausen, Arne Aalberg

APPENDIX 3 - CASA PUBLICATIONS 2015-2023

2015

1. **V. Aune, T. Børvik, M. Langseth.** Behaviour of plated structures subjected to blast loading. Proceedings of the XI International Congress on the Mechanical and Physical Behaviour of Materials under Dynamic Loading (DYMAT), European Physical Journal – Web of Conference 94, 01015 (2015).

2. **T. Børvik, S. Dey, L. Olovsson** Penetration of granular materials by small-arms bullets. International Journal of Impact Engineering 75 (2015) 123-139.

3. **M. Fourmeau, C.D. Marioara, T. Børvik, A. Benallal, O.S. Hopperstad.** A study of the influence 0f precipitate free zones on the strain localization and failure of the aluminium alloy AA7075-T651. Philosophical Magazine (2015).

4. **H. Fransplass, M. Langseth, O.S. Hopperstad.** Experimental and numerical study of threaded steel fasteners under combined tension and shear at elevated loading rates. International Journal of Impact Engineering 76 (2015) 118–125.

5. **E.L. Grimsmo, A.H. Clausen, M. Langseth, A. Aalberg.** An experimental study of static and dynamic behaviour of bolted end-plate joints of steel. International Journal of Impact Engineering, 85 (2015) 132–145.

6. **N.-H. Hoang, O.S. Hopperstad, O.R. Myhr, M. Langseth, C. Marioara.** An improved nano-scale material model applied in axial-crushing analyses of square hollow section aluminium profiles. Thin-Walled Structures 92 (2015) 93–103.

7. **J.K. Holmen, T. Børvik, O.R. Myhr, H.G. Fjær, O.S. Hopperstad.** Perforation of welded aluminum components: microstructurebased modelling and experimental validation. International Journal of Impact Engineering 84 (2015) 96–107.

8. **J.K. Holmen, O.S. Hopperstad, T. Børvik.** Low-velocity impact on multi-layered dual-phase steel plates. International Journal of Impact Engineering 78 (2015) 161–177.

9. **M. Khadyko, S. Dumoulin, T. Børvik, O.S. Hopperstad.** Simulation of large-strain behaviour of aluminium alloy under tensile loading using anisotropic plasticity models. Computers & Structures, 157 (2015) 60-75.

10. **T. Mánik, B. Holmedal, O.S. Hopperstad.** Strain-path change induced transients in flow stress, work hardening and r-values in aluminum. International Journal of Plasticity 69 (2015) 1–20.

11. **K.O. Pedersen, I. Westermann, T. Furu, T. Børvik, O.S. Hopperstad.** Influence of microstructure on work-hardening and ductile fracture of aluminium alloys. Materials and Design 70 (2015) 31–44.

12. **A. Saai, I. Westermann, S. Dumoulin, O.S. Hopperstad.** Crystal plasticity finite element simulations of pure bending of aluminium alloy AA7108. International Journal of Material Forming (2015).

13. **M. Storheim, H.S. Alsos, O.S. Hopperstad, J. Amdahl.** A damage-based failure model for coarsely meshed shell structures. International Journal of Impact Engineering 83 (2015) 59–75.

14. **J.K. Sønstabø, P.H. Holmstrøm, D. Morin, M. Langseth.** Macroscopic strength and failure properties of flow-drill screw connections. Journal of Materials Processing Technology 222 (2015) 1-12.

15. **V. Vilamosa, A.H. Clausen, T. Børvik, S. R. Skjervold, O.S. Hopperstad.** Behaviour of Al-Mg-Si aluminium alloys under a wide range of temperatures and strain rates. International Journal of Impact Engineering 86 (2015) 223-239.

16. **K. Zhang, B. Holmedal, O.S. Hopperstad, S. Dumoulin, J. Gawad, A. Van Bael, P. Van Houtte.** Multi-level modelling of mechanical anisotropy of commercial pure aluminium plate: Crystal plasticity models, advanced yield functions and parameter identification. International Journal of Plasticity 66 (2015) 3–30.

2016

1. **V. Aune, E. Fagerholt, K.O. Hauge, M. Langseth, T. Børvik.** Experimental study on the response of thin aluminium and steel plates subjected to airblast loading. International Journal of Impact Engineering 90 (2016) 106-121.

2. **V. Aune, E. Fagerholt, M. Langseth, T. Børvik.** A shock tube facility to generate blast loading on structures. International Journal of Protective Structures 7(3) (2016) 340-366.

3. **T. Børvik, L.A. Marken, M. Langseth, O.S. Hopperstad, G. Rørvik.** Influence of sigma-phase precipitation on the impact behaviour of duplex stainless steel pipe fittings. Ships and Offshore Structures 11 (2016) 25-37.

4. **M. Costas, D. Morin, M. Langseth, L. Romera, J. Díaz.** Axial crushing of aluminum extrusions filled with PET foam and GFRP. An experimental investigation. Thin-Walled Structures 99 (2016) 45-57.

5. **L.E.B. Bryhni Dæhli, T. Børvik, O.S. Hopperstad.** Influence of loading path on ductile fracture of tensile specimens made from aluminium alloys. International Journal of Solids and Structures 88-89 (2016) 17-34.

6. **L.E.B. Dæhli, J. Faleskog, T. Børvik, O.S. Hopperstad.** Unit cell simulations and porous plasticity modelling for recrystallization textures in aluminium alloys. Procedia Structural Integrity 2 (2016) 2535-2542

7. **E.L. Grimsmo, A. Aalberg, M. Langseth, A.H. Clausen.** Failure modes of bolt and nut assemblies under tensile loading. Journal of Constructional Steel Research 126 (2016) 15-25.

8. **E.L. Grimsmo, A.H. Clausen, A. Aalberg, M. Langseth.** A numerical study of beam-to-column joints subjected to impact. Engineering Structures 120 (2016) 103-115.

9. **G. Gruben, M. Langseth, E. Fagerholt, O.S. Hopperstad.** Low-velocity impact on high-strength steel sheets: An experimental and numerical study. International Journal of Impact Engineering 88 (2016) 153-171.

10. **M. Helbig, E. Van Der Giessen, A.H. Clausen, T. Seelig.** Continuum-micromechanical modeling of distributed crazing in rubber-toughened polymers. European Journal of Mechanics – A/Solids 57 (2016) 108-120.

11. **J.K. Holmen, J. Johnsen, O.S. Hopperstad, T. Børvik.** Influence of fragmentation on the capacity of aluminum alloys subjected to ballistic impact. European Journal of Mechanics – A/Solids 55 (2016) 221-233.

12. **J.K. Holmen, L.E.B. Dæhli, O.S. Hopperstad, T. Børvik.** Prediction of ductile failure using a phenomenological model calibrated from micromechanical simulations. Procedia Structural Integrity 2 (2016) 2543–2549.

13. **A. Ilseng, B.H. Skallerud, A.H. Clausen.** Tension behaviour of HNBR and FKM elastomers for a wide range of temperatures. Polymer Testing 49 (2016) 128-136.

14. **M. Khadyko, S. Dumoulin, O.S. Hopperstad.** Texture gradients and strain localisation in extruded aluminium profile. International Journal of Solids and Structures 97 (2016) 239-255.

15. **M. Khadyko, S. Dumoulin, G. Cailletaud, O.S. Hopperstad.** Latent hardening and plastic anisotropy evolution in AA6060 aluminium alloy. International Journal of Plasticity 76 (2016) 51-74.

16. **M. Kristoffersen, T. Børvik, M. Langseth, O.S. Hopperstad.** Dynamic versus quasi-static loading of X65 steel pipes. European Physical Journal, 225(2) (2016) 325-334.

17. **M. Kristoffersen, T. Børvik, O.S. Hopperstad.** Using unit cell simulations to investigate fracture due to compression-tension loading. Engineering Fracture Mechanics 162 (2016) 269-289.

18. **A. Saai, I. Westermann, S. Dumoulin, O.S. Hopperstad.** Crystal plasticity finite element simulations of pure bending of aluminium alloy AA7108. International Journal of Material Forming (2016), (9(4)), 457-469.

19. **J.K. Sønstabø, D. Morin, M. Langseth.** Macroscopic modelling of flow-drill screw connections in thin-walled aluminium structures. Thin-Walled Structures 105 (2016) 185–206.

20. **V. Vilamosa, A.H. Clausen, T. Børvik, S.E. Skjervold, O.S. Hopperstad.** A physically-based constitutive model applied to AA6082 aluminium alloy at large strains, high strain rates and elevated temperatures. Materials and Design 103 (2016) 391-405.

21. **D. Vysochinskiy, T. Coudert, O.S. Hopperstad, O.G. Lademo, A. Reyes.** Experimental detection of forming limit strains on samples with multiple local necks. Journal of Materials Processing Technology 227 (2016) 216-26.

22. **I. Westermann, K.O. Pedersen, T. Børvik, O.S. Hopperstad.** Work-hardening and ductility of artificially aged AA6060 aluminium alloy. Mechanics of Materials 97 (2016) 100–117.

2017

1. **V. Aune, G. Valsamos, F. Casadei, M. Larcher, M. Langseth, T. Børvik.** Numerical study on the structural response of blast-loaded thin aluminium and steel plates. International Journal of Impact Engineering 99 (2017) 131–144.

2. **V. Aune, G. Valsamos, F. Casadei, M. Larcher, M. Langseth, T. Børvik.** Use of damage-based mesh adaptivity to predict ductile failure in blast-loaded aluminium plates. Procedia Engineering 197 (2017) 3-12.

3. **V. Aune, G. Valsamos, F. Casadei, M. Langseth, T. Børvik.** On the dynamic response of blast-loaded steel plates with and without pre-formed holes. International Journal of Impact Engineering 108 (2017) 27–46.

4. **M. Costas, D. Morin, M. Langseth, J. Diaz, L. Romera.** Static crushing of aluminium tubes filled with PET foam and a GFRP skeleton. Numerical modelling and multiobjective optimization. International Journal of Mechanical Sciences 131-132 (2017) 205-217.

5. **L.E.B. Dæhli, J. Faleskog, T. Børvik, O.S. Hopperstad.** Unit cell simulations and porous plasticity modelling for strongly anisotropic FCC metals. European Journal of Mechanics A/ Solids. Volume 65 (2017) 360-383.

6. **L.E.B. Dæhli, D. Morin, T. Børvik, O.S. Hopperstad.** Influence of yield surface curvature on the macroscopic yielding and ductile failure of isotropic porous plastic materials. Journal of the Mechanics and Physics of Solids 107 (2017) 253-283.

7. **B.H. Frodal, K.O. Pedersen, T. Børvik, O.S. Hopperstad.** Influence of pre-compression on the ductility of AA6xxx aluminium alloys. International Journal of Fracture 206 (2017) 131-149.

8. **E.L. Grimsmo, L.E. Bryhni Dæhli, O.S. Hopperstad, A. Aalberg, M. Langseth, A.H. Clausen.** Comparison of damage models in numerical simulations of fillet welds under quasi-static and impact loading. Procedia Engineering 197 (2017) 79–88.

9. **E.L. Grimsmo, L.E.B. Dæhli, O.S. Hopperstad, A. Aalberg, M. Langseth, A.H. Clausen.** Numerical study of fillet welds subjected to quasi-static and impact loading. International Journal of Mechanical Sciences 131-132 (2017) 1092-1105.

10. **E.L. Grimsmo, A.H. Clausen, A. Aalberg, M. Langseth.** Fillet welds subjected to impact loading – an experimental study. International Journal of Impact Engineering 108 (2017) 101-113.

11. **E.L. Grimsmo, A. Aalberg, M. Langseth, Arild H. Clausen.** How placement of nut determines failure mode of bolt-and-nut assemblies. Steel Construction 10 (2017).

12. **G. Gruben, D. Morin, M. Langseth, O.S. Hopperstad.** Strain localization and ductile fracture in advanced high-strength steel sheets. European Journal of Mechanics A/Solids 61 (2017) 315-329.

13. **G. Gruben, D. Morin, M. Langseth, O.S. Hopperstad.** Ductile fracture of steel sheets under dynamic membrane loading. Procedia Engineering 197 (2017) 185–195.

14. **G. Gruben, S. Sølvernes, T. Berstad, D. Morin, O. S. Hopperstad, M. Langseth:** Low-velocity impact behaviour and failure of stiffened steel plates. Marine Structures 54 (2017) 73–91.

15. **J.K. Holmen, L. Olovsson, T. Børvik.** Discrete modeling of low-velocity penetration in sand. Computers and Geotechnics 86 (2017) 21–32.

16. **J.K. Holmen, O.S. Hopperstad, T. Børvik.** Influence of yield-surface shape in simulation of ballistic impact. International Journal of Impact Engineering 108 (2017) 136-146.

17. **J. K. Holmen, J.K. Solberg, O.S. Hopperstad, T. Børvik.** Ballistic impact of layered and case-hardened steel plates. International Journal of Impact Engineering 110 (2017) 4-14.

18. **J.K. Holmen, B.H. Frodal, O.S. Hopperstad, T. Børvik.** Strength differential effect in age hardened aluminum alloys. International Journal of Plasticity 99 (2017) 144-161.

19. **J.K. Holmen, T. Børvik, O.S. Hopperstad.** Experiments and simulations of empty and sand-filled aluminium alloy panels subjected to ballistic impact. Engineering Structures 130 (2017) 216–228.

20. **A. Ilseng, B.H. Skallerud, A.H. Clausen.** Volume growth during uniaxial tension of particle-filled elastomers at various temperatures –Experiments and modelling. Journal of the mechanics and physics of solids 107 (2017) 33-48.

21. **A. Ilseng, B.H. Skallerud, A.H. Clausen.** An experimental and numerical study on the volume change of particle-filled elastomers in various loading modes. Mechanics of Materials 106 (44-57) 2017.

22. **J. Johnsen, J.K. Holmen, T.L. Warren, T. Børvik.** Cylindrical cavity expansion approximations using different constitutive models for the target material. International Journal of Protective Structures (2017) 204141961774132.

23. **D. Morin, B.L. Kaarstad, B. Skajaa, O.S. Hopperstad, M. Langseth.** Testing and modelling of stiffened aluminium panels subjected to quasi-static and low velocity impact loading. International Journal of Impact Engineering 110 (2017) 97-111.

24. **M.S. Remøe, K. Marthinsen, I. Westermann, K.O. Pedersen, J. Røyset, C.D. Marioara.** The effect of alloying elements on the ductility of Al-Mg-Si alloys. Materials Science & Engineering: A 693 (2017) 60-72.

25. **D. Vysochinskiy, T. Coudert, O.S. Hopperstad, O.-G. Lademo, A. Reyes.** Experimental study on the formability of AA6016 sheets pre-strained by rolling. International Journal of Material Forming (2017) 1-17.

2018

1. **V. Aune, F. Casadei, G. Valsasmos, M. Langseth, T. Børvik.** A Shock Tube Used to Study the Dynamic Response of Blast-Loaded Plates. Proceedings 2(8) (2018), 503.

2. **E. Christiansen, C.D. Marioara, K. Marthinsen, O.S. Hopperstad, R. Holmestad.** Lattice rotations in precipitate free zones in an Al-Mg-Si alloy. Materials Characterization 144 (2018), 522-531.

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FINANCING THROUGH THE LIFE OF THE CENTRE

Contributor	Cash	In-kind	Total
Host	8	58	65
Research partners	0	8	8
Companies	61	23	84
Public partners	29	6	34
RCN	96	0	96
Sum	**194**	**95**	**288**

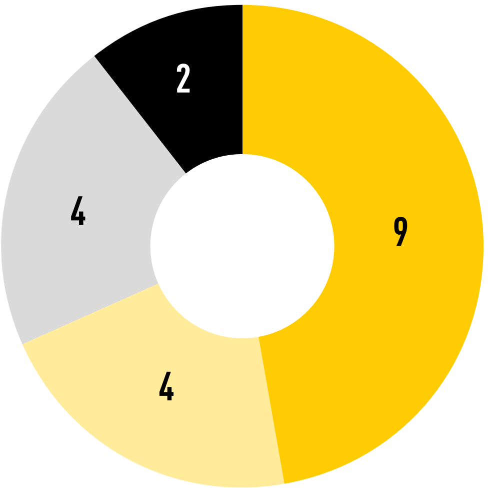
DISTRIBUTION OF RESOURCES

Type of activity	NOK million
Research projects	236
Common centre activities	2
Equipment	5
Administration	45
Total	**288**

RESULTS – KEY FIGURES

	2015	2016	2017	2018	2019	2020	2021	2022	2023	Total
Scientific publications (peer reviewed)	16	22	25	18	16	24	16	18	8	163
Dissemination measures for users		12	12	12	12	9	4	3		64
Phd degrees completed in SFI CASA					5	5	2	2	5	19
Master's theses		23	25	20	16	18	19	20	16	157
Number of new/improved methods/models/ prototypes finalised		8	1	1	7	7				24
New business activity					1					**1**

Employment of SFI CASA PhD candidates



- By Centre Company
- By university
- By other companies
- Outside Norway

**7 PhD candidates are still working on their PhD projects*

Crashbox in aluminium after impact test. (Photo: SIMLab)

CASA

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