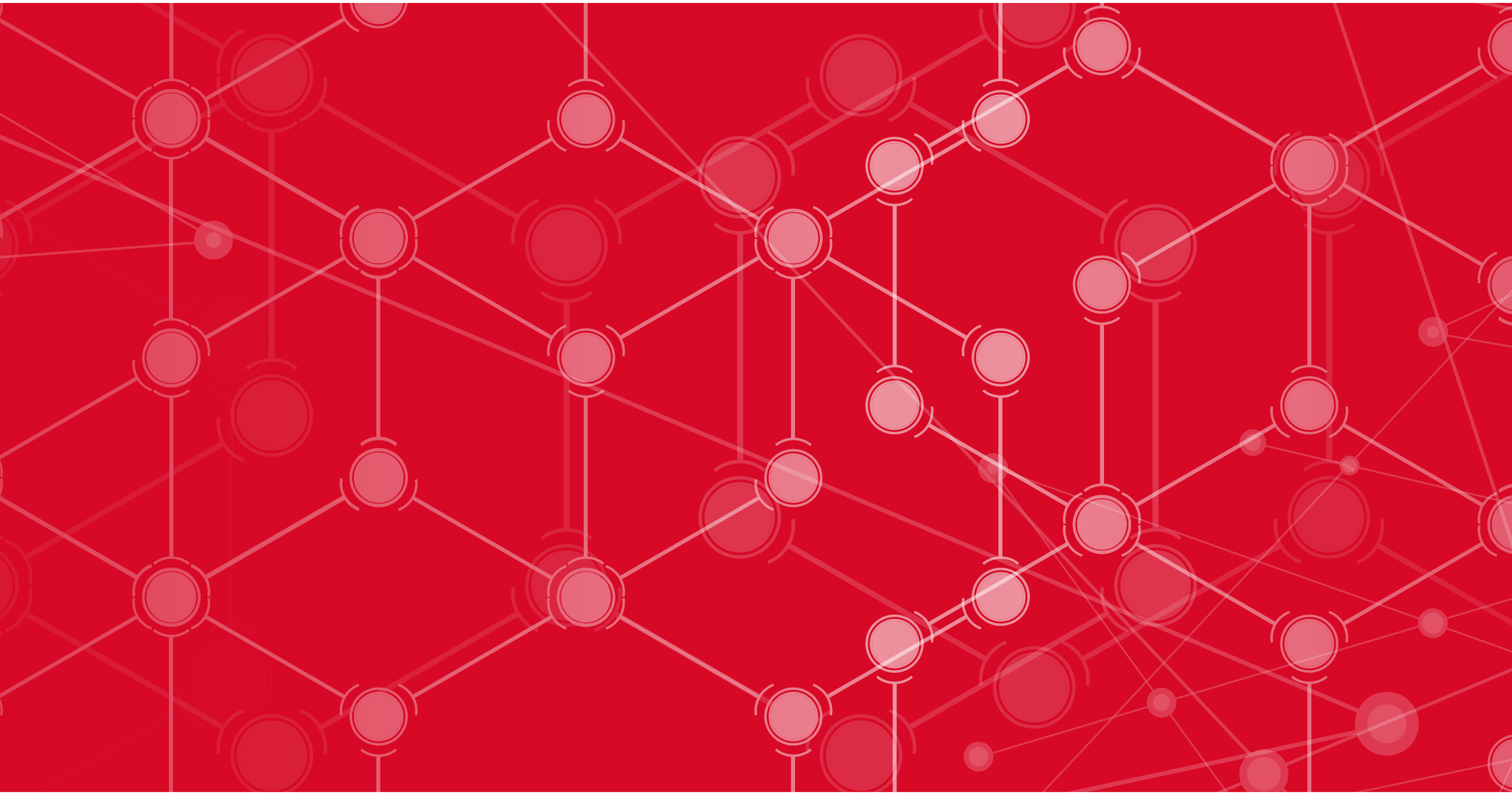
SIRIUS

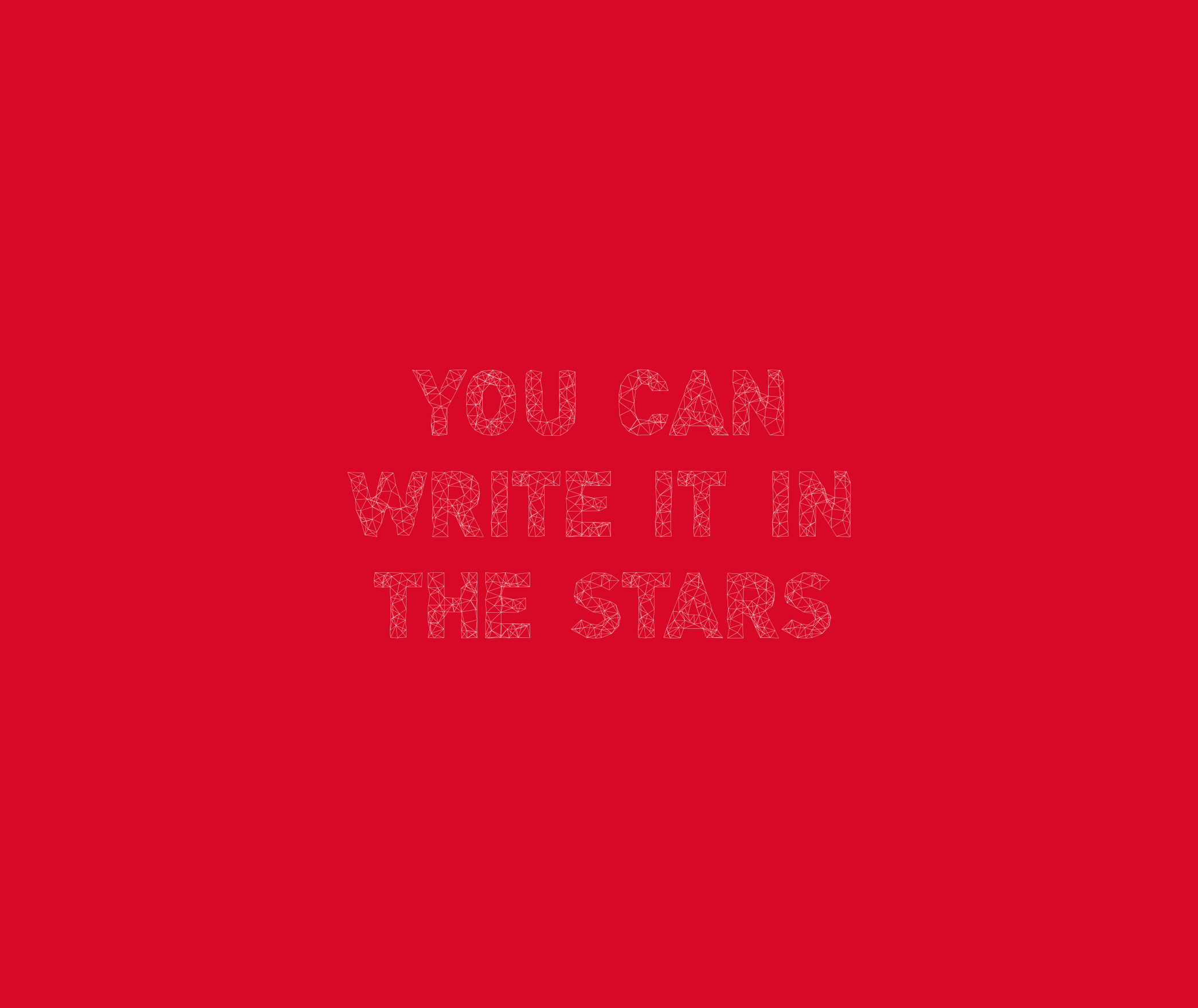
ANNUAL REPORT 2016



Centre for Research-based Innovation

The Research Council of Norway

UiO : University of Oslo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2016: **Building the Centre's Shared Understanding**

2016 was a year where SIRIUS participants successfully completed the European Projects that provided the background for the centre. At the same time, we have defined the technological roadmaps for scalable data access and used scoping activities to build a portfolio of project ideas, feasibility actions and projects for the 2017-2018 work plan.

Kick-off

May. SIRIUS was officially opened on 19th May by Dilek Ayhan, the State Secretary for Trade and Industry. Arvid Hallen from the Research Council of Norway also used this opportunity to present centre plaques to SIRIUS and the BigInsight centre. The kick-off was combined with the initial General Assembly of the centre. Read more on page 58.

Brazil

September. SIRIUS participated in the Norwegian Minister for Education's delegation to Brazil. A presentation was held at a joint seminar on Energy in Sao Paulo and meetings were also held with IBM's oil and gas research group in Rio de Janeiro and Petrobras' CENPES research centre. Read more on page 64.

BIGMED

April. SIRIUS was partner in a successful proposal to the Norwegian Research Council for BIGMED, a lighthouse project in the application of Big Data methods to development of personalized medicine. The successful projects were announced on 28th April 2016 at the Norwegian Computer Society's E-Health Conference. Read more on page 26.

DataScience@UiO

Collaboration between the SIRIUS and BigInsight centres for Research-Based innovation was reinforced by the award by the University of Oslo of four innovation Ph.D. scholarships to the DataScience@UiO program. Two of the students will work with SIRIUS and the other two with BigInsight. Together they form a core of data science research at the University of Oslo. Read more on page 52.

Optique

December. The final review meeting for the Optique FP7 project was held in Luxembourg. The project received excellent reviews for execution, technical content and innovation. Optique provides a basis for further development in SIRIUS. Read more on page 32.

Optique for Patient Safety at Akershus University Hospital

DNV GL and the University of Oslo collaborated on an Innovation Project, financed by South-East Norway Regional Health, that applied Optique project methods to demonstrating a system to improve patient safety in hospital. Read more on page 26.

BYTE

December. The BYTE EU project concluded in 2016, with a workshop at the BDVA Summit in Valencia and a conference in London in February 2017. Read more on page 64.

Envisage

December. The Envisage FP7 European project also ended in 2016 with a successful review, good innovation results and a software deliverable that will be a valuable component in the SIRIUS laboratory. Read more on page 42.

Scoping work and workshops

November 7th and 8th and December 12th and 13th. SIRIUS hosted scoping workshops for the Exploration and Operations work packages. This brought together end-users and experts from the partner companies with the SIRIUS researchers with the aim of defining the end-user needs for projects in the 2017 work plan.

Semantics Seminar

SIRIUS hosts a regular seminar on Industrial Semantics. This brings together academic and industrial practitioners to discuss how knowledge representation can be used to improve engineering and industrial production. Read more on page 67.

ECIM

September 12th-14th. SIRIUS contributed a keynote address at the annual ECIM (E&P Community for Data and Information Management) conference in Haugesund. ECIM is the annual meeting place for sub-surface data managers in the oil and gas industry and SIRIUS partners are active in the leadership of ECIM. Read more on page 20.

Cloud workshop

November 18th. SIRIUS held a public seminar and scoping workshop on the application of cloud technology in oil and gas. This had presentations from Statoil, Evry, Computas and IBM. A review was also given on related European projects: PaaSAGE, Melodic, Envisage and Hyvar. Read more on page 42 (Cloud workshop, PaaSAGE and Melodic) and page 49 (Envisage and Hyvar).

Christmas Lecture with Statoil

December. Peter Nielsen, Chief Geologist at Statoil, was guest speaker at the SIRIUS Christmas lunch. He held an informative lecture on Oil and Gas Exploration Geology for Non-Geologists. Read more on page 63.

Schlumberger courses in Oil and Gas

Three SIRIUS doctoral students travelled to Pau in France to receive a week's intensive introductory training on the oil and gas industry. The course was contributed by Schlumberger as an in-kind contribution. Read more on page 62.

Summary, Vision and Objectives

SIRIUS
Centre for Scalable Data Access in the Oil and Gas Domain

SIRIUS is a Centre for Research Based Innovation for Scalable Data Access in the Oil and Gas Domain. It conducts interdisciplinary research leading to innovations that will advance and support digitalisation in the oil and gas industry.

SIRIUS started in November 2015 and has now finished its first full year of operations. This has been a year spent building mutual understanding between our industrial partners and the researchers in the centre so that the best possible portfolio of projects can be initiated. This portfolio of projects has now been defined and the first projects are underway. SIRIUS combines public funding for basic research with funding from its industrial partners in an eight-year programme of industrial, research-based innovation. Its partner consortium consists of companies across the oil and gas value chain: including operators (Statoil), service companies (Schlumberger and DNV-GL) and IT companies (Computas, Evry, Dolphin Interconnect Solutions, fluid Operations AG, IBM, Kadme, Numascale and OSISoft). These companies work with researchers from the University of Oslo, NTNU, University of Oxford and Simula Research Laboratories. These researchers bring expertise in knowledge representation, natural-language technologies, databases, scalable computing, execution modelling and analysis and working practices.

The centre provides the industry with better ways to access and use the massive amounts of data that are generated in exploration, projects and daily operation. The advent of big data, digitalisation, the internet of things and data science has made problems with data access more acute. Data access is the bottleneck that can prevent successful digitalisation. SIRIUS approaches these problems through interdisciplinary work, as successful innovation requires a combination of methods. Technical innovation is generated through a portfolio of projects approved by the Centre's strategic board. Basic technology is developed in laboratory projects. This technology is then moved through prototypes into pilots that solve business problems in industrial applications. The centre has an intellectual property model that is designed to build a core of open knowledge on which commercial solutions can be built. SIRIUS aims to be an intellectual hub for applied industrial IT in Norway. It has dedicated premises in the Department of Informatics at the University of Oslo and collaborates widely, both nationally and internationally. Many of the results generated by the centre are also applicable outside the oil and gas sector. The centre is therefore also active in communicating and applying its results to other sectors, such as Healthcare, Energy, Manufacturing and Public Administration, through its cross-domain applications work package. This report gives an overview of the centre's ambitions, scientific programme and activities from start-up in 2015 until the end of 2016.

Vision	
To accelerate the development and adoption of innovative data access technology in the oil & gas industry via a broad-based collaboration with a short feedback loop across the whole value chain	Smart ways of finding and getting data from new and existing data sources
	Oil companies, service companies, IT vendors and universities
	Industry-near research and innovation: experiments, prototypes and pilots
	Exploration, field development, operations and downstream

Objectives	
Accelerate the innovation process for data access in the oil and gas domain	Implement prototype components in industrial pilots. Implement research results in commercial products provided by SIRIUS partners.
Transfer knowledge and expertise via feedback loop in the innovation cycle	Identify constraints imposed by existing tools Identify opportunities for changes in work practices. Demonstrate the role of tools provided by the partners in prototypes.
Transform end-user work practices	Identify technical, social and cognitive barriers to use of technology. Identify ways to assess operational uncertainties.
Deliver scalable information systems for accessing disparate data sources	Integrate access to text, semi-structured and streaming data. Allow scalable access to large volumes of data, such as seismic data. Allow scalable access to real-time streams of sensor data. Make complex data accessible through end-user interfaces. Reduce the cost and risk of maintaining and changing systems.
Deliver a scalable, efficient and robust computational environment	Allow scalable processing and storage of big volumes of data. Process real-time streams of sensor data. Exploit affordable hardware platforms.
Reinforce mutual understanding and shared vision	Define and maintain shared vision. Establish new collaborations. Track evolving technologies and challenges. Achieve equal opportunity and gender equality within SIRIUS.
Establish SIRIUS as an internationally recognised centre of excellence	Attract additional funding (e.g. from EU programmes). Influence future research directions and funding policy. Influence society on big data, data access and digitalisation. Set up a PhD track that combines research and industry skills. Influence the international research community.

Digital Transformation in the **Energy Industry**

Digitalization can and will disrupt the balance in this ecosystem

The following is an edited transcript of the Chairman's address to the SIRIUS General Assembly held in Oslo in November 2016.

What is the current setting in the oil and gas domain?

We see a growing demand for energy in a changing energy market. This is most notably in power generation and buildings, but also cars are shifting to other power sources. We need to move to a low-carbon future and be less dependent on oil and gas. This means that oil and gas companies are growing business in renewables and using oil and gas in a cleaner way. Some, like Dong, plan to leave oil and gas, others, like Total, are investing in solar. Statoil is trying to leverage its expertise in offshore development to build the world´s largest offshore floating windfarm. Oil and gas will become a smaller part of the energy mix in the next 40 years and so, in order to grow, oil and gas companies need to diversify.

However, current oil and gas discoveries are not enough to satisfy future demand. We still need to find oil and gas that can be produced safely and cheaply. We do not want production where is leads to hazardous operations or environmental risk. In addition, the price of energy is low, challenging both traditional oil and gas and alternative energy sources. However, development of renewables benefits from improvements in technology: the more you do it, the lower the price. In oil and gas, cost increases for the new discoveries, so we are working to increase the amount of oil we can get from existing fields and develop concepts for cheaper field developments.

Renewables are also changing how the ecosystem of producers and consumers works. This means that what used to be mainly a flow from large energy producers to energy consumers is changing into a grid, where different producers and consumers also provide energy.

The role of Statoil and Digital Technologies

Like the rest of the industry, we have experienced a period of complex change. Statoil's response is outlined in our vision: to shape the future of energy through being competitive at all times, transforming the oil and gas industry and providing energy for a low carbon future.

We believe that digital technologies play an important role in realizing our vision. We already have a long history of using these technologies but our efforts have mainly been aimed at resolving issues within specific areas: improving existing operations and work processes but not making quantum leaps.

Now that digital technology development moves much faster and access to data processing and storage capacity is almost unlimited, we see two new opportunities for capitalizing on digitalisation and improving the impact of our efforts. Firstly, digital technologies can defend and expand our current business, for instance to enable increased safety or better operations and secondly, these technologies can change our business models, creating new opportunities and new revenue streams.

Knut Sebastian Tungland

Knut Sebastian Tungland is a Senior Advisor in Statoil. He works within the digitalisation unit the CIO office and is Chairman of the SIRIUS General Assembly. He has spent 25 years in the intersection between software and the energy industry, with software products, as a consultant, and with Statoil

Digital Maturity of the Oil and Gas Industry

The oil and gas industry is not necessarily viewed as frontrunner within digitalisation, but my impression is that the pace of change is increasing: most players have fairly clear digital ambitions and are looking to step up their efforts. Who can we learn from and what are the key lessons for us?

Looking at companies like Uber or AirBnB, we see that value seems to be shifting from physical assets towards data and algorithms and that a market can be quickly disrupted. How will this will affect an asset-heavy industry like oil and gas? Who are the potential disruptors?

Pricing models in, for instance manufacturing and agriculture, are affected by digitalisation. There is a shift towards paying for performance or uptime or charging a premium based on improved outcomes. What is the potential impact on pricing mechanisms in our industry?

Others have perhaps come further in applying digital technologies to improve safety and productivity. For example, frontrunners in mining have integrated and automated operations to achieve reductions in cost, improved efficiency and up to 70% fewer employees exposed to risk-exposed work environments.

These are just a few examples that show that digital technologies impact across industries and underline that we should learn where we can, including from the many exciting companies in SIRIUS.

What could the future look like for a company like Statoil?

We do not have all the answers, but the following things could happen. We will:

- Improve existing core business through automation of both back-office processes and "front-office" operations in risky areas, such as automated drilling: This will improve safety for our staff
- Improve efficiency and reduce cost through condition based maintenance and optimized use of facilities.
- Use artificial intelligence with subsurface knowledge to find and produce more hydrocarbons.

> **We assume** that parts of jobs will disappear, technology will replace some roles but opportunities will emerge through needs for new skills.

Some of the companies in SIRIUS today seem to have technologies and offerings that can help support us in these ambitions.

The oil and gas value chain will change. We have had a stable ecosystem for decades with vendors, service companies and oil companies. Digitalisation can and will disrupt the balance in this ecosystem – changing the role of the players – and it can also bring new business options and opportunities.

Digital technologies will also affect the workforce and the capabilities we require. We assume that parts of jobs will disappear, technology will replace some roles but opportunities will emerge through needs for new skills.

SIRIUS' role and challenges

This is also the context for SIRIUS. How can we as group contribute to this change journey for the industry? The activities and scientific content are well defined and the build-up of the centre is under way. However, I believe that in building a successful centre we face challenges that we need to take seriously. The first of these is the dynamics of the centre. Important partners are located in Stavanger and Bergen. This means that we do not have the physical and easy access to each other that such a centre needs. I think we need to lower the barriers, and see how we can improve interaction in the centre. We need to get to know each other better. Video conferencing and collaboration tools can help. The second challenge is related. How can we facilitate a flowing, open discussion of technology and solutions in SIRIUS, especially given that the resources each partner has committed are limited? Work needs to be done to assure partners that the centre will help them to solve the improvement challenges that they have. Finally, we have the ongoing struggle of matching business demand to technology supply. We want to present problems where this centre has viable and relevant capability to solve them. However, to do this you need to understand what the capabilities are. This means we need to continue and expand the kind of structured dialogue that has been set up this year. This also requires academics to try to set themselves into the mind-set of the problem owners.


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Mind the Gap!

Innovation to meet Oil & Gas Challenges

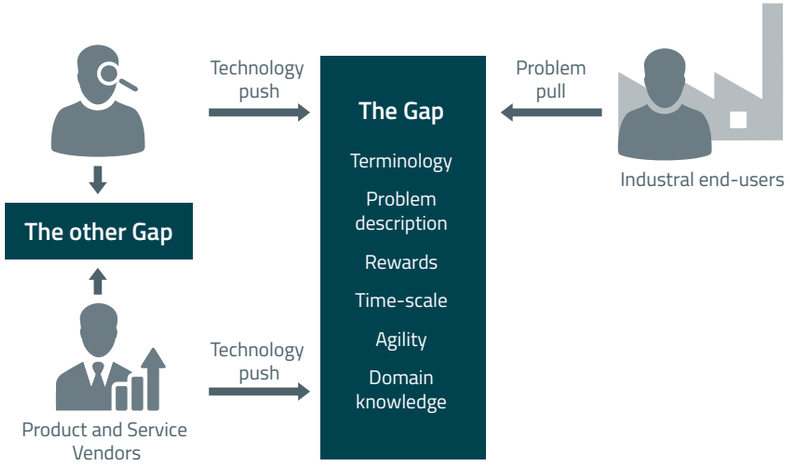
You are on the Tube in London and you hear the simple words "Mind the gap". Just three words. These words could be the motto for any centre for research based innovation, but are especially relevant for SIRIUS. We have several gaps to mind.

David Cameron

David Cameron is the Centre Coordinator for the SIRIUS Centre for Scalable Data Access at the University of Oslo. He is a Chemical Engineer with 30 years of industrial experience in the metals, chemicals and petroleum industries. His technical specialization is the application of simulation to the optimization of operations. He has worked in applied research, strategy and development management roles in BHP Billiton, Norsk Hydro, Kongsberg Group and then in consulting and senior business development roles related to the internet of things in IBM and Sopra Steria. He earned his doctorate in simulator-based process analytics from the University of Cambridge.

The first gap is that between information technology (IT) and business problems. Perhaps there are two gaps to mind here: one between academic IT and commercial IT and then another between IT (academic and commercial) and business problems. Bridging this latter gap is a constant challenge. Bring academic IT research into the mix adds to the difficulty.

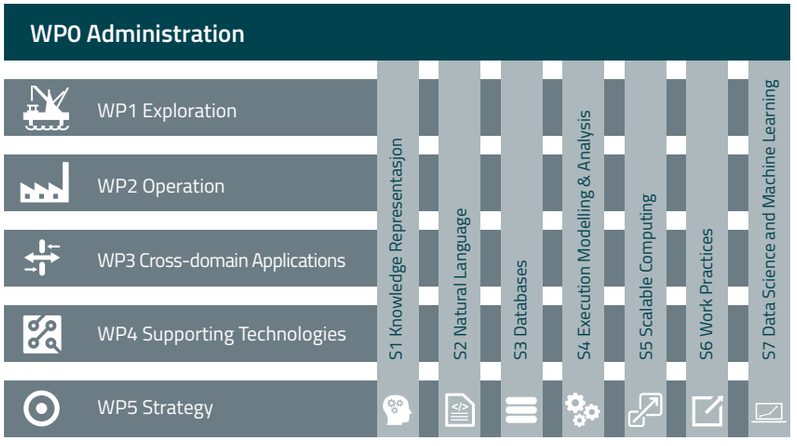
SIRIUS minds the gap by creating an innovation ecosystem that brings academics, commercial IT firms and end users together to work on research that solves pressing industrial problems through implementation in commercial products and services.



Within this ecosystem, we have set up a framework that allows researchers to pursue excellent research while delivering innovation. SIRIUS runs projects that are organized in business-aligned work-packages: exploration (page 20), operations (page 24), and cross-domain applications (page 26). The portfolio of projects and project ideas in each work package provides the problem pull in the centre.

The researchers provide the resources and technology push in the projects. They are organised into six strands or research areas: knowledge representation (page 30), language technology (page 35), databases (page 38), execution modelling and analysis (page 42), scalable computing (page 40) and work practices (page 46). In addition, SIRIUS is working with the BigInsight centre to build skills and resources in data science and machine learning (page 52).

SIRIUS projects are developed and approved using a standard staged-gate model for innovation. Technology roadmaps are developed to define the areas of interest to the centre and ensure that the work done is novel and meets real needs. Scoping work is essential for allowing researchers, vendors and end-user to talk together, identify business needs, potential matching technologies and research and generate project ideas. This activity is essential to ensuring the relevance of our work. It is for this reason that up to a third of our partners' in-kind labour contribution is used for scoping.



Project ideas generated by scoping are put into a project pipeline, managed by the relevant work package manager. These ideas are reviewed by the centre´s Strategy Board and the most promising become feasibility activities. A feasibility activity defines a project so that it can be funded – either by preparing a proposal for external financing or as a SIRIUS innovation project.

Note that the scoping and feasibility activities are an essential part of the centre's scientific activities. Scoping work is an effective use of a busy end-user's time. It is rewarding for both the end-user and the researcher.

Scalable Innovation:

Experiments, Prototypes and Pilots

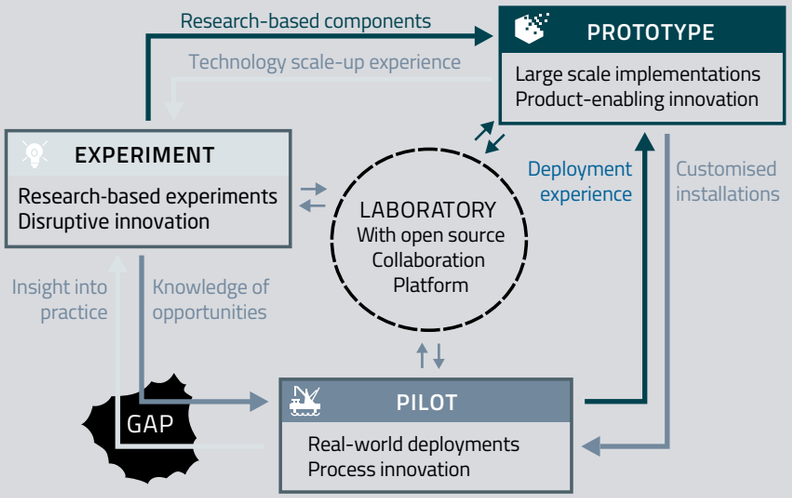
The Scalable Innovation Cycle

SIRIUS uses an innovation cycle methodology to enable user-led innovations, with early generation of ideas and later validation of results both relying heavily on end users.

This means that our partners' in-kind contributions of time are essential to the success of the centre. We use the innovation cycle consisting of an iterative, three-stage process, with a shared laboratory as its core. The method, grounded in recent insights from innovation studies[1], is designed to overcome the gap between end-user's needs and cutting-edge IT research and development.

All work in SIRIUS is aligned with this methodology and the innovation cycle. This means that research is done through either laboratory or innovation projects, depending on the scope of project and intellectual property requirements. A project is thus defined by its lifetime, partner involvement, type and stage in the innovation cycle.

1 Baldwin et. al., "How user innovations become commercial products. A theoretical investigation and case study", Research Policy, 35(9), 2006: 1291-1313



Driving the Innovation Cycle

The project portfolios in each SIRIUS work package are designed to combine cutting-edge research with real-world deployment to meet real business problems. This requires an iterative feedback loop between pilots, prototypes and experiments to identify new challenges and gaps in existing solutions that could be filled by targeted research and development.

Experiments

In the experiment stage, software components and methods are developed, configured and evaluated in the SIRIUS laboratory. These software components combine the generic, open-source tools developed in research with proprietary software from technology vendors.

The research partners have extensive experience in running laboratory-based data access solutions. This shared environment will allow extensive testing with realistic data sets.

Prototypes

SIRIUS' prototyping partners own a portfolio of IT solutions that are well established in the oil and gas industry. The usefulness and performance of these products can be improved by incorporation of research-based components and methods for data access. Prototyping work involves, among other things, the following activities within our partners' products:

- Implementing access to new information sources.
- Using semantic technologies as an integration middleware.
- Developing novel approaches that reduce the cost of owning the products.
- Improving deployment models and software scalability through use of cloud storage and processing.

In other words, prototyping projects lift the software developed in experimental projects from the laboratory stage (TRL 3-5) to form components (at TRL 6-7) that can be demonstrated in our partners' products.

Pilots

Pilots are demonstrations of software and methods developed by the centre solving real business problems in a realistic setting. The agenda for these projects is set by the problem owner, a business function in an oil or service company. Successful delivery of these pilots is of itself a research theme: tracing and optimising the complex interplay between technology and work practices. In addition, there are considerable challenges in integrating laboratory and prototype software components into a working pilot.

Intellectual Property

SIRIUS follows the following principles for managing Intellectual Property. Results from laboratory activities are automatically defined as laboratory results. The generic components produced by these projects are funded by the Research Council of Norway and are therefore released using one two suitable open-source licenses (LGPL or Apache). The use either of these licenses permits the free integration, as-is, with proprietary (closed) software.

Each consortium participant has ownership to the results that they produce. Access to all laboratory results shall be given, free of charge, to each consortium partner.

Innovation projects allow vendors and end users to choose a different intellectual property model for more commercial, piloting and prototyping projects. Each project of this type has its own contract, defining the background rights, use rights and ownership of the project results.

> **Successful** delivery of these pilots is of itself a research theme: tracing and optimising the complex interplay between technology and work practices.

Jarl Magnusson

Jarl Magnusson is the Intellectual Property Coordinator in SIRIUS. He is an innovative Information Manager, working with enterprise data-, information- and knowledge resources; strategically to improve operations, financially to capitalize on its value and technically to manage and use it over time. Mr. Magnusson has been with DNV GL since 2004 working in Norway, Washington DC and Houston TX as a Business Developer and Principal Consultant for Information Risk Management. He has more than 25 years of experience with ICT, Information Security, Information Risk Management and Information Governance issues, for a wide range of key oil & gas, maritime, process industry, healthcare, public sector and defence customers and organizations. He holds a Bachelor of Arts in Visual Communication from AIU and certificate studies in computer science, numerical analysis and statistics from Växjö Högskola

Eric Monteiro

Eric Monteiro is Professor at the Department of Computer and Information Science at NTNU and visiting professor at the University of Oslo. He has a long-standing interest in the organizational implementation of IT, in particular the dynamics of innovation and platforms and infrastructures. He has led the RCN Digital Oil project from 2012-2016 and is the Pilots Coordinator for SIRIUS and a member of the SIRIUS Strategy Board.

SIRIUS:

A vibrant hub for research-driven innovation

Data is now everywhere. The mission of SIRIUS is to foster innovation that can enable exploitation of data across the industry. Set up at just the right time, as the industry is focusing on digital transformation, SIRIUS delivers innovative solutions that can effectively expose and exploit data across silos and thereby rethink the interplay between people, enterprises and technology. SIRIUS facilitates digital transformation in industry through a programme for scientific excellence.

In SIRIUS, academic researchers engage with technology developers and end users from the oil and gas industry. Here, foundational theory collides with industrial practice. The result is a creative chain reaction, which both makes the academic research more relevant and opens for completely new solutions that address industrial challenges. SIRIUS aims to go beyond purely academic research and become an enabler which brings such solutions out of the academic laboratory through enhanced product prototypes at partner companies and through spin-offs. This programme is expressed by the SIRIUS innovation cycle: the research activities in SIRIUS are driven by pilots targeting end users and innovation is a premise for the research questions we address.

Research in SIRIUS is project-driven and project-oriented. In fact, research in the Centre is organized as a portfolio of interrelated laboratory and innovation projects. For us, projects which involve both academia and industry have been an essential, motivating experience for the existence of SIRIUS. One such example is the EU FP7 project Optique. This highly successful project in the domain of knowledge representation, led by Professor Arild Waaler, reduces turnaround time to access federated databases from the range of hours to minutes. Another such example is the EU FP7 project Envisage. This similarly successful project in the domain of execution modelling and analysis, led by Professor Einar Broch Johnsen, enables service-level guarantees when services are deployed on the cloud. These projects, which can be characterised by outstanding international networks and tight collaboration between academia and industry, have led to potential breakthroughs in key scientific domains for SIRIUS and to current on-going efforts to create spin-offs.

Building on the successful project formula of Optique and Envisage, SIRIUS brings together a scientific consortium with state-of-the-art expertise across many areas of computer science to foster scientific excellence through outstanding projects. This expertise is organised in strands. The Knowledge

Arild Waaler

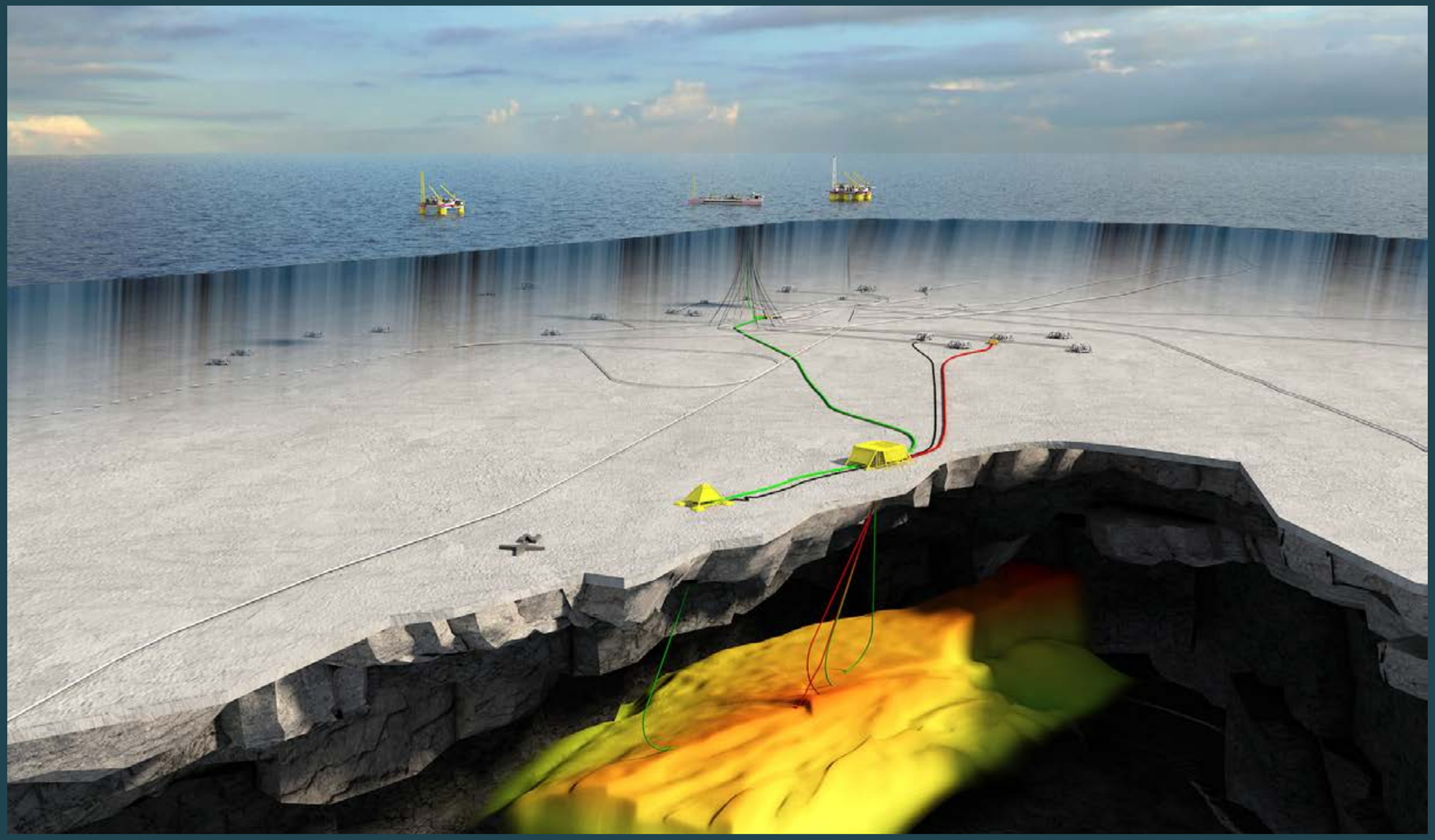
Arild Waaler is director of SIRIUS. He has over the last decade been a driving force for establishing collaboration between academic research and industry, both initiating and leading several cross-sector projects including Optique. In SIRIUS his main research interest lies in the Knowledge representation strand. After finishing a civ. ing. degree in 1989, Waaler graduated as dr. philos in Philosophy in 1995 within Philosophical logic. He then had research positions at University of Oxford, in logic, and at the Søren Kierkegaard Research Centre in Copenhagen with a project in the History of Philosophy. After a teaching post at Finnmark College, Waaler became professor at the Dept. of Informatics at University of Oslo in 2006, when he started to build up the collaboration that eventually turned into SIRIUS.

Representation strand develops semantic technologies to access and integrate data. The Language Technologies strand enables the extraction of structured data from unstructured text documents. The Databases strand develops scalable database solutions for semantically annotated data. The Execution Modelling and Analysis strand develops model-based simulation and analysis techniques to predict the behaviour of complex systems, including resource-allocation. The Work Practices strand addresses the complex interaction between organization and technology. The Scalable Computing strand develops scalable solutions for computational infrastructure, including HPC and cloud. The Data Science strand develops techniques to extract knowledge from existing data, naturally complementing and interacting with the methods of the other strands.

Einar Broch Johnsen

Einar Broch Johnsen is a professor at the Department of informatics of the University of Oslo and the Deputy Director of SIRIUS. His main research interests address the design and analysis of parallel and distributed systems, including resource-restricted and context-dependent behaviour. Johnsen was the coordinator of the EU FP7 project ENVISAGE about the design of resource-aware services for deployment on the cloud and the analysis of service-level agreements for such systems. He is the scientific coordinator of the EU H2020 project HyVar which combines sensor data, scalable cloud infrastructure and software product lines to enable context-dependent software evolution of embedded devices on cars. He leads the Frinatek project CUMULUS on formal foundations of cloud computing, funded by the Research Council of Norway, and he has previously acted as site leader for the EU projects UpScale, HATS, and Credo, and as leader of the Norwegian project CONNECT. Johnsen is or has been the supervisor of 14 PhD students and has published more than 100 internationally peer-reviewed research papers.

Excellent research often starts by asking the right questions. SIRIUS is an enabler for innovative connections between state-of-the-art research and industrial challenges. In SIRIUS, we work with the real challenges as experienced in industry, rather than the academic questions perceived inside the laboratory. It is our ambition to move research out of this laboratory, by identifying new and relevant research questions in collaboration with the industry partners of SIRIUS. This allows us not only to do excellent research but also to influence the international research agenda.



Exploration

The Exploration work-package has responsibility for defining and running a portfolio of experiment, prototype and pilot projects that support business processes in the sub-surface part of the oil and gas business: exploration, geosciences, reservoir modelling and wells.

The Statoil use case in the Optique EU project demonstrated that scalable data access could increase the speed of decisions in field assessments through giving end-users easy access to data from multiple databases. These databases have relational data models with thousands of tables and tens of thousands of columns. They are often in siloes, with each discipline maintaining its own databases. Data is also often a mixture of structured data and unstructured text and reports. Seismic data, in particular pre-stack data, also has massive volume.

Our ambitions in the Exploration work package are to:

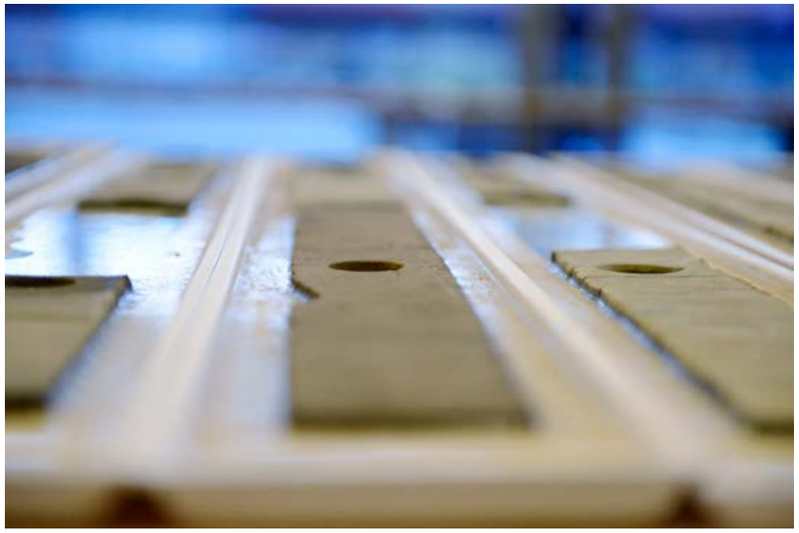
- Open up exploration data so that it is readily accessible to end-users.
- Manage the large variety of data representations used in the domain.
- Ensure that large-volume data, such as seismic, can be managed, stored and processed efficiently.
- Break down silo-based work practices.
- Develop easier and cheaper methods for ensuring data quality.
- Focus on end-users' needs.

Making the Most of Public Data Repositories

Oil and gas companies are required by law to submit subsurface data to national data repositories like DISKOS in Norway and CDA in Great Britain. This data can then be accessed by other parties and universities for use in teaching, research and further exploration. Unfortunately, much of this data is unstructured reports and the quality of data is variable. The repositories have been treated as an archive, whereas they are a treasure-trove of useful information – if the data is accessible. The regulators have recognised this, and in 2016 the British CDA issued a challenge problem to the industry. They issued documentation describing over 11 000 wells and 2000 seismic surveys, with the challenge: make sense of this data.

SIRIUS brings together Evry and Kadme, who, with CGG, are current operators of DISKOS, Statoil and Schlumberger in a consortium that can address this challenge. This requires geoscience skills, so SIRIUS has allied with the Department of Geosciences at the University Oslo to fund a position in Digital Geosciences. This activity will focus on using scalable data access to improve the University's use of DISKOS and other databases. The experiences from this work will support discussion on further developments on how DISKOS and other national repositories can be used better.

The content of this work package is determined by finding out where end-users have data access problems and then aligning these challenges with the technologies available from research and vendors. This process is demanding and time-consuming, but is critical to SIRIUS' success. It began in earnest with a workshop held on 7th-8th November 2016 in Oslo. This brought together experts from Statoil, Schlumberger, Kadme, Evry and IBM with researchers from the University of Oslo, NTNU and Simula. IBM presented ideas generated by their Research Centres in New York and Rio de Janeiro, via video link. Schlumberger presented their solution to the CDA Challenge Problem and Evry presented their vision for the DISKOS data repository. The rest of the time was spent generating ideas for projects.



The workshop identified project ideas related to:

- Increasing and maintaining corporate knowledge about projects and prospects.
- Allowing end-users easier access to data.
- Dealing with heterogeneous data: text, large volumes, pictures and diagrams.
- Ensuring, tracking and managing the quality of data.

Thirteen project ideas were identified and will received further attention in 2017, either through additional scoping as needed, or as feasibility projects preparing prototypes or pilots.

The Geological Assistant

The Geological Assistant is a project that exemplifies the approach taken by the Work Practices strand (see page 46). Statoil and Schlumberger are, together with researchers from the strand, evaluating *digital tool support for exploration geologists*. The aim is to design a tool for exploration geologists – a Geological Assistant.

The current digital tool set for exploration geologists is not always a good match for their workflows. Existing tools typically grew out of the measurements they handle, like seismic and well logs, while geological thinking uses history-based reasoning and analogies based on qualitative interpretation and a constant interplay between theory and data. This

project explores how digital tools can better support the workflows used by exploration geologists.

The project will develop prototype tools that support play evaluation. This is a workflow that currently has limited tool support and explicitly requires geological thinking rather than numerical analysis. Interviews are used to uncover demands and requirements stemming from dissatisfaction with existing tool sets. A design workshop is then used to refine and develop requirements.

This work has explicit focus on fostering tighter collaboration between the customer (Statoil) and the technology vendor (Schlumberger). This user-centred approach is an alternative to the more common technology-driven approach. This project will therefore also deliver refinement of the SIRIUS' research method for user-centric studies.

Jens Grimsgaard

Jens Grimsgaard is manager of the Exploration work-package in SIRIUS. He is a geophysicist based at Statoil's offices in Bergen. His master's degree is in Physics/Geophysics from NTNU (NTH) in 1983 and he has worked in the oil industry, in Norsk Hydro, StatoilHydro and now Statoil, since 1984. He worked for the first 15 years with geo-applications, computer operations and database programming. He has then worked as project leader in research since 1999 applying new technologies within geosciences. His main research interests are visualization, virtual reality, natural language processing and machine learning.

Operations

The operations work package covers the parts of the oil and gas supply chain that do not involve sub-surface data and exploration. It concentrates on facilities: the data about them and the data produced by them. We take a lifecycle view of the facility and are interested data from the first conceptual studies through engineering, procurement and construction, commissioning, operations, maintenance and decommissioning.

During the life of a facility, which can be over fifty years, a large amount of asset data accumulates. This data is spread across a range of legacy databases and includes many documents and other unstructured information sources. This data can be used to optimize operations and needs to be kept available and up to date to support modifications, troubleshooting and decommissioning.

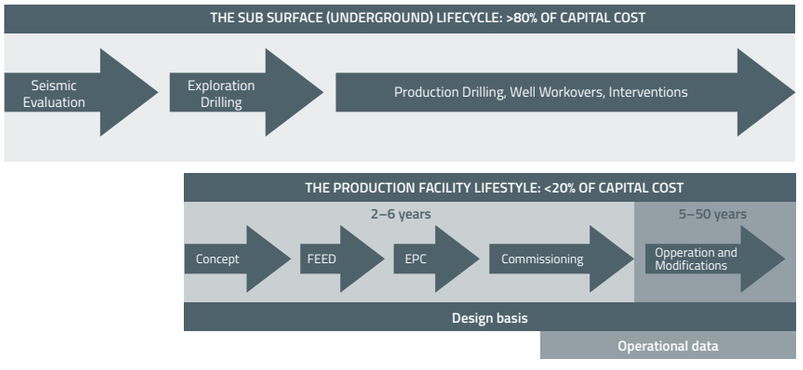
Current data warehouse(s) for an asset aggregate date from many sources, from many organizational silos and include high-velocity sensor data. This approach has the following shortcomings that SIRIUS will address:

- Real-time data with high volume and velocity exceeds processing, storage and analytical capabilities.
- The variety of data involved makes addition of new data sources complex and error prone.
- Changes to the data warehouse can break existing applications.

Our ambition in the operations work-package is to develop and prototype methods and tools that will allow us to implement pilots that use asset data to solve real operational problems. Ideally, these pilots will demonstrate the benefits of scalable data access at different points in the facility lifecycle.

Feasibility Project on Next-Generation Operations

SIRIUS ran a feasibility project on next-generation operations in the first half of 2016. The deliverable from this project was a proposal for a European Union lighthouse project on applications of big data technologies in the process industry. Unfortunately, this proposal was unsuccessful. However, the work generated a set of pilot candidates that provide a basis for defining further feasibility studies and revised proposals for funding in 2017.



Operations Scoping Workshop

A scoping workshop was held for the operations work package in Oslo on 12th-13th December 2016. Personnel from partners Statoil, Schlumberger, Evry, OSIsoft, IBM, DNV GL, and Computas worked with researchers from the University of Oslo, NTNU and invited contributors from Oslo University

College and Kongsberg Group. This initial workshop defined the scope of the work package. Position papers were presented by Schlumberger, Computas, OSIsoft, IBM, Evry and DNV GL. Several representatives from Statoil presented their vision of integrated planning and the experience of, and work that remains to be done, in integrated operations.

The meeting concluded with a set of recommendations for the work plan in 2017-2018. In short, the operations strand will work on the following areas:

- Demonstrating the application of formal methods and modelling to planning in Statoil. This work is described in more detail in the section on Execution Modelling & Analysis on page 45.
- Showing how ontology-based data access can improve the information flow and effectiveness of:
  - Data-science based processes like condition monitoring of equipment and process surveillance.
  - Capture of operational experience in product design.
  - Exchange of information along the engineering supply chain.
- Experimental research on the representation of streaming and configurational data in historians and other databases.

The widespread adoption of OPC-UA as a protocol for data access to production systems is both a boon and a challenge. Massively instrumented facilities, with a digital twin, will be overwhelmed by the amount of data that can be made available on an OPC-UA. We believe that the Knowledge Representation tools offered by SIRIUS will be essential in making the most out of this data.

Cross-Domain Applications

The oil and gas sector has been a driver for technological and intellectual progress in Norway. People and resources that would have otherwise been available for development in other sectors have been occupied in developing world-class technology for oil and gas. Recent falls in oil price and an awareness of the need for a green shift in the Norwegian economy raise the need to reallocate technical resources and knowledge from oil and gas to other economic sectors. SIRIUS will support this by organising a portfolio of cross-domain projects, which apply the scalable data access methods in areas such as health, energy and public administration. Initial focus is on health. The aim is to set up cross-fertilization of ideas and methods between the oil and gas sector and health sector.

BIGMED

Precision medicine is the customization of treatments and disease preventions based on the patient's individual characteristics, variations in genes, and lifestyle. BIGMED is an ambitious innovation project focused on the implementation of precision medicine in Norway. The project aims to build a clinical decision support platform where the underlying analyses requires joining various data types, including textual data (from patient journals, guidelines, and publications), genomic data (phenotype and genotype of individual patients, as well as the patient population), as well as structured data (EHR metadata, patient records, semantic background knowledge).

The central Big Data challenge BIGMED has to address is that of variety of healthcare data. The wide range of data and information is captured in the process of caring for a patient. Biological data from sensors, imaging, lab tests, and genetic sequencing contribute to the deluge of data. In addition, there are other types of information surrounding the care of patients, including planning and documentation of patient encounters within the healthcare system. This data is stored in disparate, incompatible and heterogeneous systems. These integration and back-end scalability challenges will be addressed by the use of domain vocabularies, ontologies, and mappings of these. Structured background knowledge in the form of medical ontologies and vocabularies can be incorporated, while unstructured sources will require pre-processing solutions from the field of language technology.

SIRIUS is involved in BIGMED because of the transferability of methods, skills and tools between health and oil and gas. Work on preparing the final, successful BIGMED proposal was organised as a Feasibility activity in 2016.

Optique Pilot at Akershus University Hospital

SIRIUS personnel, led by Guillermo Vega-Gorgojo, participated in a strategic innovation project at Akershus University Hospital that was financed by South-East Norway Regional Health and run by SIRIUS partner DNV GL. This project, "Development of a semantic IT solution and ontology for clinical use in health care" showed how the ontological data retrieval methods could be used in a clinical context to reduce administrative workload for

Laura Slaughter

Laura Slaughter is Work Package Manager for Cross-Domain Applications. Her Ph.D. was received in 2002 in Information Science from the University of Maryland. This was followed by postdoctoral training at the Department of Biomedical Informatics, Columbia University, New York. Her main focus is in the area of healthcare and biomedical informatics. She has worked on a wide variety of healthcare projects covering various types of healthcare systems, including patient oriented personal health records (PHRs) and clinical decision support. In general, she is interested in healthcare standards, biomedical ontologies and terminologies and use of semantic web technologies within the health area. Her current research centres on querying and exploring large integrated healthcare datasets, and the reuse, development and evaluation of biomedical ontologies.

The Ministry of Health has an ambition to adverse events to be reduced by 25 percent by the end of 2018.

doctors and increase patient safety. The pilot was successfully delivered in 2016 with promising results and pleased medical stakeholders. Follow-up development is planned for 2017.

A presentation of the project was given at the Optique Summit in Oxford, England on 16th September 2016 and has also been described by South-East Norway Regional Health.

The extent of patient adverse events in Norway has been stable at a high level in recent years, and it's mostly the same types of damage that recur. This means there is a large potential for learning and innovation. The Ministry of Health has an ambition to adverse events to be reduced by 25 percent by the end of 2018. In South-East Norway, the annual payments for treating these adverse events sums to NOK 500 million.

South-East Norway Regional Health challenged communities to develop solutions to reduce adverse events. The application deadline was 29th April 2016, and two of 14 projects received funding. This project was one of them.

Many of the IT systems that healthcare is dependent on, communicate poorly with each other. In addition, much of the information is represented in unstructured text files, such as medical records. We aim to develop a tool that enables search and compilation of information in the system and thereby achieve improved logistics and increased patient safety and care, said Division Director Ivar Thor Jonsson at Akershus University Hospital.

This project demonstrated how modern semantic data technology can be used to integrate data from many parallel data sources without any intermediate storage. The tailor-made ontology, based on standard medical ontologies, was used to translate the clinical language to a language the computer systems understood and could be used for both search and compilation of information. This pilot study focused on gathering information to "operational messages" at the Day-surgery Centre and was, according to Jonsson, very successful. Based on the results from this pilot study further development of the solution into a system that can be used for the entire health care sector has been planned. Source: Optique web site, **http://optique-project.eu/optique-in-heathcare-is-growing/**

Supporting Technologies

The Supporting Technologies work-package organises SIRIUS projects that are working on research problems that are of relevance to more than one of the business work packages. These projects are all experimental work and are mostly Ph.D. projects. However, larger fundamental projects in methodology for, for example, high-performance computing will also be managed in this work package.

These projects are also used to provide recruiting positions that build up SIRIUS' long-term delivery capacity.

The three doctoral students employed by the centre at start-up are all working on supporting technology projects. This is natural, since in the early phase of the centre's life we are aiming to develop tools for later use in prototypes and pilots.

Intelligent Query Builder

Vidar Klungre, at the University of Oslo, is working on a project in the Knowledge Representation strand that is developing methods and tools that can be used in pilots in exploration, operations and cross-domain applications. He is working to develop an intelligent query builder that will allow an end-user to define a query to a set of databases in a simple graphical way. The project is based on OptiqueVQS, the visual query system developed by the Optique European union project. OptiqueVQS will be extended, enhancing

Ian Horrocks

The work-package leader for this strand is Professor Ian Horrocks, FRS, Professor of Computer Science at the University of Oxford. He is also the Scientific Coordinator for SIRIUS. A profile interview with Ian can be found on page 39.

The project is based on OptiqueVQS, the visual query system developed by the Optique European Union project.

data. This will allow the system to be more intelligent, removing inconsistent or irrelevant options and highlighting likely choices. Work will also be done on the back-end of the system to precompute the data structures needed. Work in 2016 was focused on initial implementation and maintenance of the Optique VQS system and completion of required course work.

Incremental reasoning for continuous queries

Alessandro Ronca, at the University of Oxford, is looking at how ontology-based data access can deal with streaming data. The oil and gas industry is full of streams of data and events, such as the time traces from seismic hydrophones, the measurements taken while drilling and the operational data and alarms and events on a production facility. Alessandro is looking at fundamental methods for writing effective queries for streaming data. The work studies the case where the data stream is represented by triples. This allows a new approach where that exploits incremental reasoning over triples on the assumption that the stream is a set of added triples. His current work involves designing a query language with focus on features such as negation and aggregation, studying the computational complexity of the language with respect to stream reasoning tasks and building an initial implementation of a stream reasoning engine. This research has the potential to provide a tool that will allow end-users to ask very sophisticated queries about the behaviour of streaming and time-series data.

The oil and gas industry is full of streams of data and events

Materialized-based query reasoning

Anthony Potter, also at the University of Oxford, is doing research aimed at removing some of the limitations in the query system implemented in the Qptique project. This approach puts strict limitations on the expressivity of the language that can be used in the ontology. This project explores an alternative approach, based on materialization of data, which is not constrained in the same way. While materialization in triple stores is in itself well studied, this project focuses on an approach in which triples are distributed across a cluster in order to support very large datasets and to significantly speed up materialization and query answering performance.

Materialization is a well-known way of improving the performance of database systems. It involves the, at least partial pre-computation and caching of the results for a query.

CURRENT ACTIVITIES INCLUDE:

- Experimenting with different distribution strategies
- Investigate various graph partitioning algorithm for partitioning the data across the nodes in the cluster
- Investigation of various query planning and optimisation techniques
- Proof of the completeness and termination of distributed query answering algorithms

The eventual ambition is to implement and evaluate using the data from Statoil provided in the Optique project.

Knowledge Representation

Data is always related to things or ideas. Getting access to data is made much simpler if we are able to link that data to its underlying thing or idea. The things and ideas related to a certain discipline or system, together with the linkages between them, together constitute the domain knowledge for that discipline. Given a model of the relationships and connections between these things and ideas, we can reason about the related data, make predictions and check for errors and inconsistencies. This discipline, which lies in the borderlands between philosophy and computer science, is called knowledge representation.

To use a common and simple example: a pump is a widely used thing in the oil and gas industry. It is linked to other things, pipes, fittings, a motor and various sensors. Each sensor produces measurements: data on things like speed, torque, liquid flowrate, inlet pressure, outlet pressure and temperature. The pump object is also linked to ideas like specifications, requirements and model numbers and things like maintenance orders and invoices. The data about a pump is stored in many databases: data historians, ERP systems and design databases. Knowledge representation consists of creating a useful model of things like this pump and using this model to improve access to data about this pump.

This approach is essential to mastering the data produced from the Internet of Things and from complex, unit-operation based systems like oil platforms. The theory and methods necessary for these applications are supplied by the Knowledge Representation strand.

What we do

The Knowledge Representation strand specialises on machine-processable representations of domain knowledge. Often, these representations take the shape of an ontology, a tractable representation of a domain vocabulary (things and ideas) and certain kinds of facts (linkages between things and idea) concerning the domain.

We are interested in using ontologies in a variety of contexts:

- Data Integration, where ontologies mediate between data sources by lifting from the level of data to the level of information.
- Data Access, where ontologies can be used to present information to end-users.
- Requirement management, where ontologies are used to represent, check, and solve complex combinations of definitions and constraints, e.g. on engineering designs.

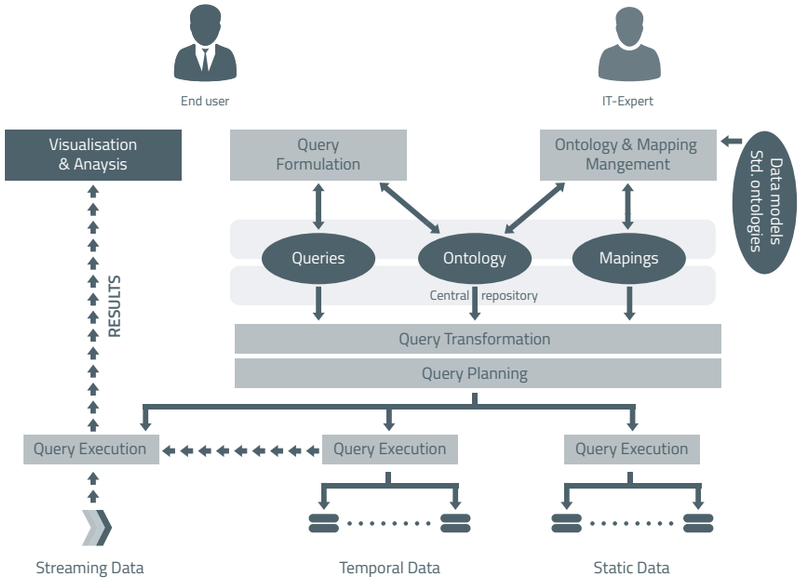
We develop ontology-based tools and methods for these and other applications. A particular focus is on tools and methods needed to set up and maintain necessary artefacts, like ontologies and mappings, that control the remaining tool chain.

The goal of Optique was to enable "Scalable End-User Access to Big Data."

Martin Giese

Martin Giese is a professor of informatics at the University of Oslo. He has a PhD in logic and automated reasoning from Karlsruhe University, and has spent time as a researcher at Chalmers University in Gothenburg and the Austrian Academy of Sciences before coming to Norway. For the past 10 years, he has been working in projects to bring ontologies and other knowledge representation techniques to applications in industry and the public sector. He was part of the team that attracted the Optique project, and acted as the project's Assistant Scientific Director during 2012–2016.

We will explore how different kinds of user interaction can be driven using the same ontology-level control.



Our Ambitions

- Integration of information sources. Experience in the Optique project (see below) shows that ontology-based techniques have a strong potential as enabling technology for data integration. In coming years, we will mature this approach and verify its applicability in a range of industrial settings. This will include amongst others further insights into entity alignment, schema (ontology) alignment, the treatment of combinations of streaming and static data, and the connection of semantic technologies to language technologies.
- Construction and maintenance of ontology-based systems. Ontology-based tool chains rely on a number of artefacts like ontologies, mappings, query collections, etc., that are rather high-level and declarative, compared to conventional solutions. Still, these artefacts need to be created and maintained, like other software. Our goal is to provide a proven set of technology and methods for the engineering of ontology-based solutions.
- Analytics-aware ontology-based data access. In the Optique project, there was a hard boundary between the data access and data analytics tasks: the Optique tool extracts information from data sources, which is then passed to analytics and visualisations tools that were not in the scope of the project. Our ambition is to intertwine these two tasks: on one hand, the analytics tasks to be performed should control which data needs to be accessed. On the other hand, some amount of analytical processing can be performed already while extracting information from the sources. Our goal is a holistic view of ontology-based data access and analytics.
- Ontology-driven User Interfaces. Ontologies formalise a domain as end-users think and speak about it. That makes ontologies suitable as a driver for end-user interfaces. In Optique, this idea was used for an interface to elicit information needs. We envisage that similar principles can be applied to any situation where end-users interact with information systems, be it information dashboards, entry forms, wizards, etc. We will explore how different kinds of user interaction can be driven using the same ontology-level control.

Optique

Optique (http://www.optique-project.eu) was a 4 year integrated project funded by the European Commission under the FP7 programme, with a total budget of 14M€. The project was driven by two industrial use cases, one with the exploration department of Statoil ASA, the other turbine sensor data with Siemens AG. Optique was coordinated from UiO, by the group of researchers that are now gathered under SIRIUS. The project had its final review in December 2016, and received superlative praise from the Commission and all external reviewers throughout the 4 years.

The goal of Optique was to enable "Scalable End-User Access to Big Data." It is based on the observation that too much time is used by domain experts in industry on data-related tasks: locating, getting access, assuring quality, cleaning, etc. can take up to 80% of the time of non-IT personnel, hindering actual value creation. Moreover, dependence on IT-personnel for specialised tasks can mean waiting times of up to weeks for data access. Optique could reduce the turnaround time for data access from weeks to minutes in some of the use cases considered. As the accompanying figure shows, the Optique software is tied together by an ontology that describes the domain, and that is used to specify both the end-users' view of the domain, and the meaning of the data in the data sources.

Results of the Optique project are one of the main starting points for the Knowledge Representation strand of SIRIUS.

Our Man in Stavanger

- bringing knowledge-based information systems to the masses

Martin G. Skjæveland lives and works in Stavanger as a full-time employee of the University of Oslo and project manager in SIRIUS. He tells the story of the time he ordered an office chair, which was delivered to "University of Oslo – Stavanger Office" at his house. His presence in Stavanger has been a vital element in the success of the Optique European project and will be the same for SIRIUS. Having a permanent employee in Stavanger means that we are able to work embedded in Statoil and with the other suppliers and authorities in the area.

How did you come to work for the University of Oslo in Stavanger?
Well, I grew up in Sola, just outside Stavanger, where my wife is from, and most of my family still live. So, it was natural to move back when the opportunity came in 2014. The Optique project had one of its two pilot cases at Statoil and that required the full-time presence of a work package leader. I led the work package from Statoil's offices for the last three years of the project. It was stimulating to be able to apply academic theory on logic while working day-to-day with the industrial end users.

Your academic background is from outside Stavanger?
Yes, I did my Bachelor's degree at the University of Bergen and the came to Oslo to do my Master's in computer science and logic, which I completed in 2004. At that time, there was a very active student seminar in logic, which worked with topics such as the theoretical underpinnings of the OWL ontology language. Four of the students in this seminar were eventually hired by DNV GL to the team that is now called Information Risk Management in their Oil and Gas Division. I was one of those.

Then you became a consultant at DNV GL?

Yes, we were a team working with applying semantic technologies, information modelling and management to industrial applications, oil and gas in particular. This was pioneer work, proving the applicability of these methods to industrial practice. I did a lot of work related to the ISO 15926 standard for representing life-cycle data in the oil and gas domain. My role was very practical: at that time DNV GL managed the ISO 15926 reference data library and I was guardian of the system that stored and made the data available in various formats and for different purposes. I wrote for instance a converter that took the standard written in the Express language and translated it to OWL, and participated in many efforts to increase the quality of both the library and the standard.

I learnt a lot about engineering and oil and gas ontologies in this time, and also gained a lot of practical experience about the pitfalls of semantic technology and its applications: why and how it matters how you design and implement an ontology. Many decisions must be made when designing the ontology if the system is going to be maintainable, computationally tractable and useful. I also developed a strong taste for using open standard declarative specifications to define the semantics of and transformations on data, using only generic software components that make use of these specifications to work with the data.

I was at DNV GL for three years, but I had always wanted to take a doctorate, and came back to the University of Oslo when the right opportunity appeared.

What was the doctoral project about?

The PhD position was in Arild Waaler's logic group funded by the Faculty of Natural Sciences and only restricted to the area of applied logic and semantic technologies. The title of my disseration became "Engineering Semantic Data" and it took its starting point in the lack of appropriate methods to build and maintain ontology-based information systems. I had three years' commercial experience of doing this at DNV GL, so I had a basis in practical experience for the theoretical work I wanted to do.

At the time of finishing my PhD, Arild's group had been awarded the Optique project, and I went on as a post-doctoral researcher working in that project.

Having worked both in industry and academia, what makes you stay on in academia?

I find that there is more administrative and intellectual freedom at the University, even in a tightly managed European project. For better or worse,

There is more administrative and intellectual freedom at the University

you are much more responsible for your own success in academia. With this comes the freedom to work on the things that are interesting, and not just client-driven or short term. It is good to be in a framework that supports long-sighted initiatives. But it is also exciting to be in a project like Optique or a centre like SIRIUS where you get a creative tension between necessary short-term results for the industrial partners and a four-year or eight-year long-term research plan.

You are involved in an innovation project? Can you tell us a bit about that?

Yes, this innovation work follows up on the theme of my doctoral project and the experience obtained in the Optique project. Maintenance of ontology-based information systems is difficult and lacks good supporting tools. My business idea is that these tools and methods need to be commercially available if we are to get the full benefits of ontology-based systems. A team from SIRIUS has been funded by the Norwegian Research Council´s FORNY program to do a feasibility study, prepare a business plan and apply for funding for a verification of this business and product idea, which we call GoOptique. We have interest from important industrial clients and will be working hard in 2017 to refine our product and service idea. We have worked with Inven2, the University's Technology Transfer Organisation, who have provided good support in this work.

This innovation work is intertwined with my ambitions in SIRIUS, which are to bring about innovation through bringing insights and experiences at the forefront of theoretical knowledge to practical use in industry.

Language Technologies

The Language Technologies strand provides the SIRIUS consortium with knowledge, skills and tools for processing, interpreting and working with text documents.

Documents, so-called unstructured data, are an essential, perhaps dominant, part of the information used in the oil and gas industry. Exploration geologists and operations engineers use reports and logs to summarise findings and provide context for measured and observed data. Even in cases where the original data is structured, it is all too common that this structure is lost as documents are made for reporting or handover of data. This means that any complete system for scalable data access must be able to manage, find, parse and access data in unstructured documents.

What we do

The personnel in the Language Technology strand are all members of the Language Technology group at the Department of Informatics, University of Oslo. They bring knowledge of natural language processing and knowledge and experience of the processing of textual data using machine learning methods. The strand's main goal is to enable information extraction and search in unstructured data from the oil and gas domain. Focus is on semantic enrichment of texts and prerequisite processing, such as tagging, parsing and entity classification.

Our Ambitions

- Contribute to increased availability of domain data (in particular: training data for machine learning).
- Create and evaluate distributional semantic models for domain documents and terminology and evaluate their use in Information Extraction and search
- Develop domain-adapted Information Extraction tools for the oil and gas domain
- Contribute to increased uptake of natural language processing tools in oil and gas data processing

Lilja Øvrelid

Lilja Øvrelid obtained a PhD in computational linguistics from the University of Gothenburg in 2008 and subsequently worked as a postdoctoral researcher at the University of Potsdam, Germany. She was appointed Associate Professor in the Language Technology group at the Department of Informatics, University of Oslo in August 2010. Her work focuses primarily on the extraction of structure and meaning from natural language text using machine learning techniques and incorporates areas such as syntactic parsing, distributional semantic modelling and sentiment analysis. She is a member of the Language Technology Group at the Department of Informatics, an internationally recognized, interdisciplinary research group with strong expertise in Natural Language Processing, which was recently appointed Centre for Advanced Study by the Norwegian Academy of Science.

Farhad Nooralazadeh started as a Ph.D. student at the Department of Informatics, University of Oslo in May 2016. He is working in the Language Technology strand of SIRIUS. He is one of the first tranche of SIRIUS students and is working in an area that many SIRIUS partners are interested in.

Making Natural Language Technologies Understand Oil & Gas

Can you tell us a little about your background and how you wound up in Oslo?

I am Iranian, and did my Bachelor's there in Industrial Engineering with a specialty in System Analysis and Design. Afterward I worked as information systems specialist in some automotive and petrochemical companies. I planned to pursue graduate studies in a highly-advanced learning environment to obtain both theoretical abilities and applicable skills on a higher level. In 2011, I got an opportunity to enter into European Master's programme in data mining and knowledge management under the Erasmus Mundus program.

You studied for a Master's degree in France?

Yes, in France and Romania. I spent a year at Université Lyon 2, and I spent a third semester at the Polytechnic University of Bucharest. I then obtained an internship at the Xerox Research Centre Europe (XRCE) in Grenoble, in their ParSem (Parsing and Semantics) group. This research project has helped me understand natural language processing and machine learning application beyond what one can learn in the classroom, and has given me much more real world hands-on experience. I continued as a research engineer at XRCE and afterwards at INRIA (Institut National de Recherche en Informatique et en Automatique). Being in a scientific context in a research environment it was natural to start a PhD program.

Any perceptions of difference between France and Norwegian education systems?

I don't see big difference in education systems between both countries.

However, the bilingual environment in Oslo gives more opportunities to communicate and be socialized in university.

What is your experience of Norway thus far?

I find people friendly here and open to any nationality. On the other hand, it is very fast, convenient and less paper work in administrative issues.

Can you tell us a little about the aim of your thesis?

The thesis aims at extending the capabilities of language technology systems to handle information extraction tasks in the Oil & Gas domain. In particular, we will consider available domain-specific knowledge to learn the characteristics of the target domain and afterward apply to adjustment process in knowledge extraction from text documents. Under this framework, the thesis will deal with several closely related areas, such as language technology, domain adaptation, knowledge base embeddings and information extraction.

How will you be working?

We are collaborating with Statoil, as the main stakeholder, and IBM, who has extensive experience in applying language technology in different industries. We participate in related workshops to be aware of related research and findings in the target domain. Internally I have weekly supervision meeting with my two supervisors to discuss and get their guidance in my thesis.

What challenges do you see in your work?

The oil and gas domain consists of two main sub-domains: exploration and operations. In both areas, there are very large collections of data in seismic files, log files, relational databases, sensor data and text documents with variable and/or unknown quality. The first main challenge for using language technology tools here is called the domain shift. Language used for oil and gas is different from "normal" literary language. This means that methods developed using a general text sources need to be shifted to work well with oil and gas text. Thus, the first research questions we want to explore is: What type of domain shift do we encounter? Furthermore, is there any intrinsic domain shift between sub-domains: exploration and operation? This variety of sub-domains within the target domain brings us to the second question: How can we cope with this domain shift problem during information extraction from oil and gas data?

Structured knowledge helps with a wide range of language technology tasks. Such prior knowledge is available in the oil and gas industry as relational databases or ontologies. This raises the third question for investigation: How we can improve information extraction techniques by using structured knowledge from the oil and gas domain?

> **I find** people friendly here and open to any nationality

How was progress in 2016?

I started in May, beginning the previous studies and state-of-the-art on related fields. We then collected the first set of tools and data needed for the preliminary experiments. The initial results of these benchmarking experiments were presented at the Exploration Workshop in November.

And your plans for 2017?

This year I plan to study the domain shift between the oil and gas domain and a general-domain corpus, trying to answer the thesis' first question. I am also planning to work with the second question by finding a way to cope with the domain shift issues in information extraction.

Databases

The Database strand in SIRIUS builds on observation that Scalable Data Access is dependent on good and scalable technologies for data storage and retrieval. The exploration and operations functions in the oil and gas industry rely heavily on Relational Database Management Systems (RDMS) and will continue to do so for the foreseeable future. Semantic technologies such as Optique can facilitate data access, but performance (of back-end repositories) may be a limiting factor. New technologies such as RDFox offer many exciting opportunities, but we need to demonstrate practicality in real use cases.

Performance and scalability may require innovation in both software and hardware. This means that the database strand will interact closely with the other strands, knowledge representation and scalable computing in particular. Interaction with software-vendor partners such as IBM and OSIsoft and hardware vendors like Dolphin and Numascale is also promising.

What we do

The database strand brings theoretical knowledge and practical implementations to bear in the following areas:

- Back-end data storage and processing issues in scalable data applications. The RDFox system developed by University of Oxford is a high-performance database system that can fill many back-end roles.
- Managing very large volumes of data that may be distributed, heterogeneous and semi-structured.
- Leading expertise in the theory, implementation and application of relational database and semantic systems is present in the University of Oslo, University of Oxford, IBM and OSIsoft.
- Skills and experience using high performance and cloud computing to improve the performance of databases and query systems.
- Use of novel database systems such as RDFox to support the implementation and development of knowledge representation applications.

Our Ambitions

Our ambitions in SIRIUS are to extend the capabilities and performance of database and semantic systems:

1. Increase the scale of data that can be processed
2. Increase the complexity and heterogeneity of data that can be handled
3. Increase the velocity with which data can be handled
4. Evaluate functionality and scalability in the SIRIUS pilot deployments

New technologies such as RDFox offer many exciting opportunities, but we need to demonstrate practicality in real use cases.

Boris Motik

Boris Motik is leader of the SIRIUS database strand. He completed his PhD at the University of Karlsruhe under the supervision of Prof Rudi Studer, and he is currently a Professor of Computer Science at the University of Oxford. His research interests include knowledge representation and reasoning, ontologies, automated theorem proving, databases, and the Semantic Web. His research encompasses both theory and practice, including studying and developing knowledge representation languages and reasoning algorithms, as well as practical implementation of reasoning systems. He is the main author of the HermiT reasoning system, a popular and widely used OWL 2 DL reasoner, and RDFox. He played a key role in the development of the OWL 2 DL ontology. He has an extensive collaboration network with industry partners, with whom he is working on practical applications of semantic technologies in areas as diverse as health care, energy, and travel.

RDFox

RDFox is a highly scalable in-memory RDF triple store that supports shared memory parallel datalog reasoning. This type of database provides a foundation for a wide variety of semantic applications, such as those developed by the Knowledge Representation strand. RDFox is able to store large sets of RDF triples and to access them quickly and efficiently. The software is therefore both an enabling technology for SIRIUS pilots and an item for research in its own right.

Profile Ian Horrocks

The University of Oslo has awarded honorary doctorates to prominent, usually foreign, academics and dignitaries since 1824. These degrees are presented, as a rule, once every three years, at the University's Annual Celebration on 2nd September. This year, Professor Ian Horrocks, the Scientific Director of SIRIUS, is receiving this honour. In conjunction with this, we talked to him about his background, vision for SIRIUS and its research agenda.

Can you describe your vision for SIRIUS?

My approach to research has always been driven by use cases and applications, despite being often viewed as an arch-theoretician. Theory should be the servant of applications. Theory enables us to specify precisely what an application is supposed to do and verify that it actually does it – i.e., that the content of the tin corresponds to the label.

This is challenging in practice because it needs a huge range of skills, typically beyond the capacity of a single person or even of a single research group. We need to bridge between the people with deep knowledge of application requirements and those with deep knowledge of theory. This means that we need a "food chain" of at least three roles: the practical worker, the theoretical worker and the broker in the middle.

Another challenge is to make this a two-way street or cycle. It is motivating to see ideas that bubbled up from practice providing theoretical challenges that then evolve so that they support a new generation of practical applications. This requires building tools, and now we need an implementer and then the application and system integrator.

Building teams that can implement this cycle is what SIRIUS is about, and that's why I'm here.

So, your vision is based on your career experience?

Yes. My original training is B.Sc. in Computer Science from the University of Manchester. On finishing this I worked a couple of years as a research assistant and then was tempted off to a start-up from the research group, working on text processing. It was satisfying to build things that people used but frustrating because of the lack of rigour and formality in what we delivered.

I then came back to do a Ph.D. at Manchester in medical informatics. The group I worked with was very practical, building medical terminologies for use, e.g., in driving user interfaces. However, their system for classifying (automatically organising) terminologies was very slow. I was asked to make it run faster. After following up a pointer from my supervisor (Alan Rector) I decided to retrofit a theoretical framework – called description logic – onto their existing application. The approach fitted well, but unfortunately existing description logic classifiers didn't support a rich enough logic, and were even slower than their existing classifier. So, I had to design my own algorithms and implement my own classifier, which eventually did run several orders of magnitude faster and gave provably complete results.

This work provided a basis for a research council grant and a researcher position at the University. In this role, I met people who developed ontology languages and I combined description logics with these. This was facilitated by European-funded networking projects (ESPRIT LTI). The EU projects that followed led to development of the OWL language for the semantic web and linkages to the United States' DARPA research programs. It also resulted in my promotion to professor within a few years of completing the doctorate.

How then did you come to Oxford?

Oxford University came to me in 2007 with an offer to recruit me and members of my research group. It was a hard decision to take, given the good relationships and long history at Manchester. However, I made the move and am now Head of the Information Systems Group in the Department of Computer Science, Professorial Fellow at Oriel College and a Fellow of the Royal Society. Several of my colleagues who are now active in SIRIUS moved with me down from Manchester. The group has grown from there and is very international, with at least ten different nationalities.

How did you come into contact with the University of Oslo?

Arild Waaler and I are both logicians and had met at relevant conferences. Arild invited me to the Semantic Days conference in Stavanger in 2007. We then worked together to supported Arild's switch of interests to the Semantic Web and to build engagement with industry. We wanted to work together, and the best way to do that was to get a shared EU project. It took time and effort to understand how to write a good EU proposal, with one unsuccessful try. We also applied for the previous round of Centres for Research-Based Innovation. Although disappointing at the time, these two "failures" were essential for the success of the later Optique and SIRIUS proposals. Working together on Optique and Sirius has strengthened my ties with Arild's group, and I now have an Adjunct Professor position in Oslo to support international-quality research.

How do you see your role as Scientific Coordinator in SIRIUS?

Well, I am in some way a guarantor of quality in the centre's work program. But I see my main role as a mentor and advisor: mentoring the researchers, advising the centre management and motivating students to both theoretical rigour and practical focus.

You are also a Fellow of the Alan Turing Institute. What is this?

Yes, I am active in the institute as a Fellow, in a 20% position. The Alan Turing Institute is the British national institute for data science. It has now fully started-up and is located at the British Library at St Pancras in London. It is a large and well-funded organisation with space for around a 100 staff. It is now obtaining external funding for projects and offers us the possibility to work with world-leading statisticians and data analysts. SIRIUS staff will be able to be involved in the institute as visiting researchers and workshop participants. Our industrial and innovation profile is also of great interest to the Institute.

Finally, we in Norway are concerned about the effects BREXIT. What are thoughts about this?

Nothing you can print! But seriously, it is very uncertain and worrying how things will work out for UK science. The uncertainty is tangible in the European research programs. Unfortunately, the consequences won't be apparent for several years, by which time it will probably be too late, and we will have missed out on a generation of European research projects. In the meantime, it is good to have a long-term bilateral relationship with Norway through SIRIUS, and I am looking forward to spending my summer holidays mountain biking in the Norwegian countryside.


I am in some way a guarantor of quality in the centre’s work program

Execution Modelling & Analysis

The oil and gas industry is full of complex systems. Some of these are computer systems, such as a cloud deployment of an ERP or trading system. Others are cyber-physical systems, such as the safety and automation system on an oil rig or an automated drilling system. Finally, still more are complex logistic and commercial systems, such as the execution of a maintenance turnaround for an offshore facility.

The decisions we make about these systems are critical for safety, efficiency and profitability. We want to be able to predict how these systems will behave so that we can design them properly and run them optimally. We need to know that the system will be safe and reliable. We want to know how we can change operations to deal with surprises and unwanted events. The Execution Modelling & Analysis Strand provides tools that can answer these needs.

What we do

Our aim is to predict the behaviour of complex systems using the analysis of models. Decisions can then be made based on these analyses. Our expertise lies in modelling complex parallel and distributed systems, including object-oriented and service-oriented systems, cloud computing and the Internet of Things. Analysis techniques for these models range from simulation, which analyses a single run of a system, to deductive verification, which analyses all possible runs of a system. We analyse both functional and non-functional properties such as safety properties, timing properties, resource management and scaling strategies. Our work on resource-restricted

Ingrid Chieh Yu

Ingrid Chieh Yu is Associate Professor at the University of Oslo. Her research interests include the design and analysis of concurrent, distributed, context-dependent and evolving systems. Yu worked at DNV GL as a Senior Researcher and returned to the University as Associate Professor in 2011. Yu is the leader of the Execution Modelling and Analysis strand and also is the Mentoring and Education Coordinator of SIRIUS. Moreover, she is currently one of the Principal investigators of CUMULUS, an RCN funded FRINATEK research project, and the site leader of the EU H2020 HyVar project, in which she leads the design of the scalable cloud infrastructure for monitoring and individually customizing software upgrades for remote devices.

parallel systems with timing constraints is currently being applied to planning and logistics in the context of SIRIUS.

We bring background from two European projects: Envisage and HyVar. Each of these projects provides important tools and experience that can be used in the SIRIUS experiments and pilots.

Our Ambitions

- ***Theoretical development.*** Developing tool-based, practically applicable analysis techniques that are stronger than simulation, i.e. testing and monitoring of concurrent systems, counter-example guided abstraction refinement, partial order reductions and symbolic execution, and analysis and model construction based on heuristics and machine learning. Knowledge extraction from simulations and other analyses is crucial to support decision-making. We will extend our expertise in the direction of effective visual communication of formal analyses.
- ***New application domains.*** Extending our techniques to domains with an element of reflection, such as context-dependent systems, system evolution and self-adaptive systems, and organizational systems such as planning and logistics.
- ***Tool chain.*** To better leverage our techniques, we prioritize tool development and visualization.

Envisage: EU FP7 project

Virtualized software services are able to adapt to the elasticity of cloud computing. To foster the industrial adoption of virtualized services, it is necessary to address two important problems: (1) the efficient analysis,

HyVar develops a demonstrator for a real-world scenario of embedded software in cars, in collaboration with automotive industry.

dynamic composition and deployment of services with qualitative and quantitative service levels and (2) the dynamic control of resources such as storage and processing capacities according to the internal policies of the services. The recently-completed Envisage project addresses these challenges by representing service-level agreements (SLA) into software models and allowing resource management to be considered in early phases of service design. This development of SLA-aware and scalable services, supported by highly automated analysis tools using formal methods. SLA-aware services are able to control their own resource management and renegotiate SLA across a heterogeneous virtualized computing landscape.

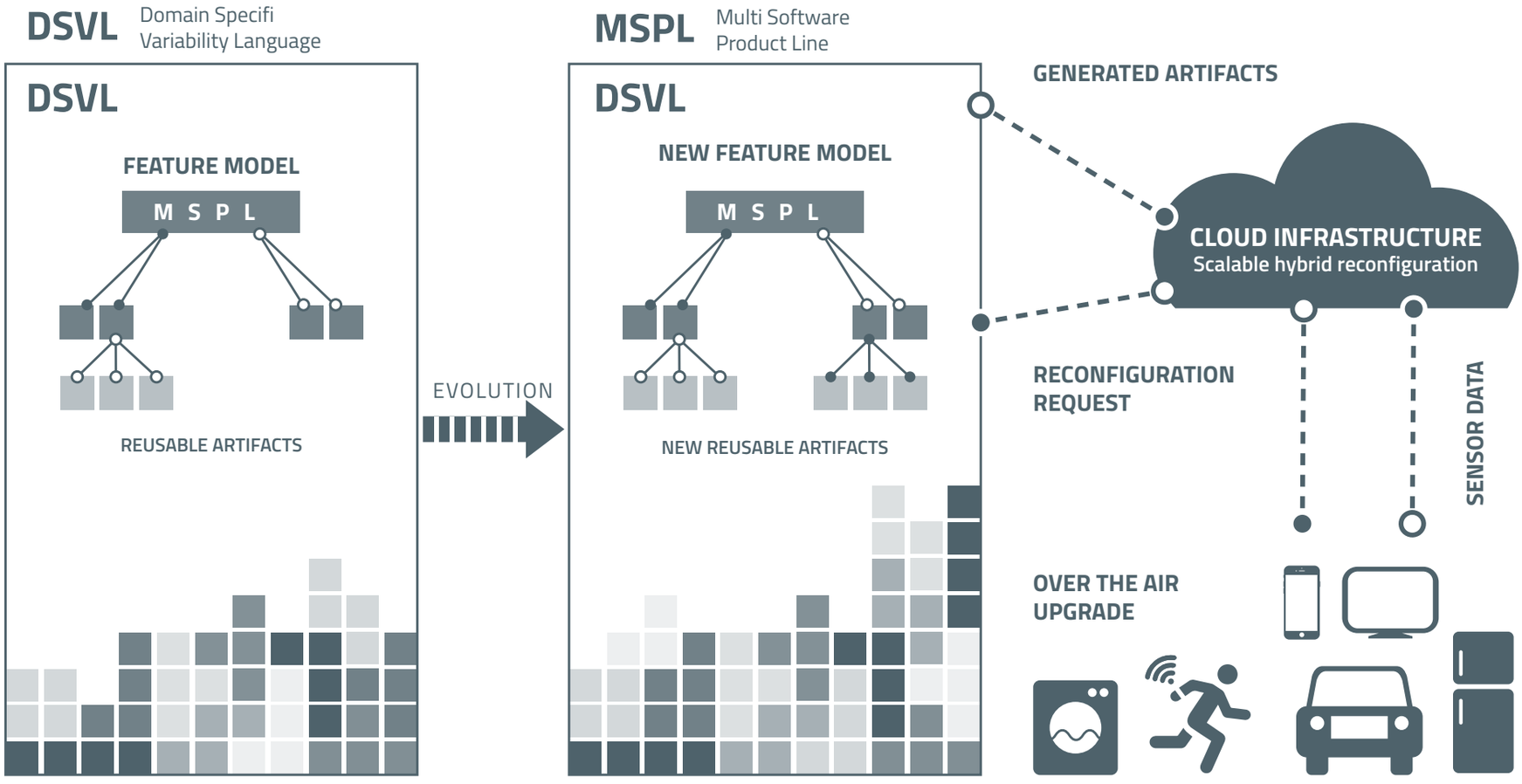
Envisage produced a practical open-source framework for model-based development of virtualized services. This includes (1) a behavioural specification language for describing resource-aware models; (2) a simulator with visualization facilities; and (3) tool support for automated resource analysis, validation of SLA, code generation, and runtime monitoring of SLA for deployed services. The methodology and tools developed in Envisage allow services to be delivered in a more effective, efficient, and reliable manner than today, accelerating the development cycle and lowering the operational costs for innovative networked services running on the cloud. This has the potential to significantly improve the competitiveness of SMEs, and profoundly influence business ICT strategies in all sectors.

For more information: **http://envisage-project.eu**

HyVar: EU H2020 Project

The HyVar project delivers a development framework for continuous and context-dependent evolution of distributed software applications. The aim is to support enterprises that manufacture, operate or maintain such systems in efficiently managing frequent or sudden events and situations where agility is required, such as changing designs and software patches. HyVar combines state-of-the-art structuring concepts from software product lines with cutting edge industrial technology for over-the-air software evolution and advanced analysis techniques from formal methods. HyVar proposes the concept of *hybrid variability:* automatic, context-aware generation and deployment of software updates by combining variability models, which describe possible software configurations, with sensor data collected from an installed device. HyVar's scalable cloud infrastructure allows software on numerous such devices to be elastically monitored and customized.

In HyVar, a technology push from European research meets a user pull from industry. By combining systematic variability with virtualization and evolution in the engineering of distributed systems, HyVar has the potential to significantly improve industrial growth and competitiveness and to encourage faster product innovation cycles. HyVar's solution enables a



remarkable decrease in maintenance costs for highly distributed software through remote software patching and updating, which is currently impossible with conventional techniques.

HyVar's framework ensures that upgrades will be seamless and sufficiently nonintrusive to enhance the user quality experience, without compromising the robustness, reliability and resilience of the distributed application instances. HyVar develops a demonstrator for a real-world scenario of embedded software in cars, in collaboration with automotive industry. The results are also applicable to other sectors such as home automation, environmental control, remote healthcare devices, condition-based maintenance, and many more.

For more information: http://**hyvar-project.eu**

The ABS Modelling Language

ABS is a language for Abstract Behavioral Specification of distributed and concurrent systems, which supports the modelling of resource restrictions and resource management. It was developed in Envisage and used in HyVar. ABS combines implementation-level specifications with verifiability, high-level design with executability, and formal semantics with practical usability. ABS is a concurrent, object-oriented, modelling language that features functional data-types.

- ABS is designed to develop executable models with an object-oriented program flow.
- ABS targets distributed and concurrent systems by means of concurrent object groups and asynchronous method calls.
- ABS supports model variability based on delta-oriented specifications.
- ABS supports deployment modelling based on high-level deployment models.
- ABS supports a range of techniques for model exploration and analysis, based on formal semantics.

Analysis tools will enable quicker and better decision-making by automatically signaling potential conflicts and possibly by proposing solutions.

We are currently moving ABS from a project-driven to a community-driven technology

We are currently moving ABS from a project-driven to a community-driven technology. To this end, the first international ABS workshop will be held in Oslo, at the end of May 2017.

Planning and Logistics at Statoil

We are now experimenting with modelling and analysis techniques developed for resource-management of services on the cloud applied to planning and supply chain logistics at Statoil. The starting point for this work is to see a plan as a program and apply analysis techniques for software to plans. There are interesting similarities between planning and cloud computing. These are related to modeling and analyzing resource restrictions and strategies to manage and optimize the use of resources such as work centers, vessels, different areas on installations, etc. Analysis tools will enable quicker and better decision-making by automatically signaling potential conflicts and possibly by proposing solutions. We start by providing simulation and visualization support to test integrated schedules and proceed by analyzing safety and liveness properties for these schedules. We are currently exploring use cases for these techniques in maintenance planning, supply base and vessel planning in logistics, and in project and commissioning planning. We are also exploring possibilities for an integrated model of maintenance and logistics to see how decisions mutually influence each other and provide better data visibility in these parts of operations.

Work Practices

Context and Business Impact

Finding and accessing high volumes of data can improve the organizational effectiveness of companies in the oil and gas industry. By implementing new digital tools and systems to access and manipulate these data, companies seek to help their employees work more effectively and make better decisions faster.

However, companies will not benefit from the data if the tools are not used. Research indicates that up to 75% of all implementation efforts fail to deliver desired effects. This happens despite the fact that the technology is working as intended, at least functionally.

Forty years of research on processes for implementation, adoption, and use shows that people use new digital technologies only if these technologies add value to, and can be integrated with, existing work practices.

The Work Practices strand will therefore work to help partner companies optimize their adoption of the novel technologies developed within the centre.

What We Do

Our expertise builds upon research methods, concepts and experiences from digital transformation processes in organizations. We use these methods to inform technology implementation, adoption, and use.

Translating new digital technologies from prototypes to working solutions woven into business organizations' everyday routines involves assessing the technology in relation to local needs and requirements, most often adjusting and modifying the technology in accordance to these needs, and establishing capacity and resources for learning, training and knowledge sharing among users.

Our role in SIRIUS is therefore to collaborate with both technology developers and user organizations. We do so in two main ways:

- Using methods for informing work-practice oriented software development and implementation processes: we will start with demands and requirements stemming from dissatisfaction with existing solutions and technologies to inform the design of new digital tools.
- Drawing upon methods for evaluating implementation processes: we will participate in the prototyping of technologies developed by SIRIUS partners to generate feedback from actual use to inform the process of adjusting and modifying the technology to practical needs.

Our Ambitions

Our overarching academic goal is to be at the forefront of theory development on the nature and dynamics of the transitions contemporary organizations are subject to: what we currently call digitalization or digital transformation. These transformations take forms that differ in interesting

The trend towards unmanned subsea installations distributed in a network on the seabed makes sensor-based information not only useful, but necessary.

Thomas Østerlie

Thomas Østerlie leads the SIRIUS technical strand on work practices. He is a senior research scientist with a shared position between Department of Computer Science, NTNU and Studio Apertura, NTNU Social Research. He holds a Ph.D. in information systems from NTNU from 2009 and has 10 years of experience as software professional prior to that. He specializes in doing empirical research in close collaboration with industry actors. Østerlie has worked extensively with the oil and gas industry since 2009, and currently heads Studio Apertura's strategic initiative on innovation in organizations.

ways from previous academic work. In particular, transformations that rely on Internet of Things and other sensor-based data remain uncharted and academically intriguing. The oil and gas industry is an invaluable place to study these developments.

Digital Oil

This strand builds on the results of the Digital Oil project, which was funded by the Norwegian Research Council's Verdikt programme from 2012 to 2015. The background for this project was that oil and gas operations are increasingly dependent on extensive networks of sensors for measurement and logging of relevant parameters (e.g. pressure, temperature, water and sand detection). The trend towards unmanned subsea installations distributed in a network on the seabed makes senor-based information not only useful, but necessary.

The project resulted in several noted papers. Springer Verlag nominated the paper 'The Digital Coral: Infrastructuring Environmental Monitoring' among the publisher's Must-Read Articles from 2015.

Daily operations generate vast amounts of data in different formats, time-scales, and granularity throughout the lifecycle of an oil and gas well. At the same time, operations are often run in extremely fragile natural submarine environments that must therefore be constantly monitored.

Digital Oil addressed this challenging research issue and pressing practical and economic concerns for exploiting the potential of ICT to obtain a sufficient overview of the subsea wells to operate them in an efficient and safe manner. The work targeted the sub-surface geoscience communities (geologists, reservoir engineers, production engineers and geophysicists) and the emerging marine biology disciplines. The goal was to identify tactics for trusting sensor-based information and user-driven heuristics for generating overviews of the well lifecycle.

Eric Monteiro led the project. Project participants were Marius Mikalsen and Elena Parmiggiani (PhD students), supported by Petter Almklov and Thomas Østerlie of NTNU Social Research, as well as Vidar Hepsø from Statoil.

The project resulted in several noted papers. Springer Verlag nominated the paper 'The Digital Coral: Infrastructuring Environmental Monitoring' among the publisher's Must-Read Articles from 2015. Another paper: 'Dual Materiality and Knowing in Petroleum Production' was picked as 2012 Editors' Choice Paper for the journal Information & Organization.

Scalable Computing

Scalable Computing is about providing the right computing resources to give users the answers they need quickly, when they need them and without delay. The algorithms used to access data and analyse data can demand substantial computing resources. Successful piloting of these methods requires that they run fast enough to provide answers within the user's limits of patience. Put simply, scalable data access needs scalable, high-performance hardware, networks and memory.

The Scalable Computing strand is new in 2017. It is a combination of the High-Performance Computing strand and the Cloud Computing strand in the original centre plan.

What We Do

The Scalable Computing strand combines tools, research areas and hardware to produce practical ways of delivering scalable computing. This strand includes research on new and improved hardware and software methods. These enable more complex queries and computations on larger datasets than currently possible. For hardware, this means developing shared memory computers that allow larger datasets to be kept in memory during computation, supplemented with fast access to data stored on disk when it is impossible to keep all data in memory. Software research activities look at new, unified programming paradigms that allow unchanged application code to scale from single computers through to deployment in the Cloud and highly parallel computers. We also do detailed work on numerical methods for faster and more scalable reservoir simulations.

During spring 2016, a feasibility activity was run with Statoil and Simula to define a collaborative research project on improving high-performance computing for reservoir simulation.

The research disciplines include model-based approaches, code-level annotations and scalability, stochastic combinatorial optimization, context-aware adaptations, stochastic mapping of resources, reinforcement learning, multi-agent systems and collaborative game theory, and numerical analysis. Our tool box consists of SIRIUS developed software, open-source tools (platforms such as Cloudiator, Hadoop, Spark, MESOS, Yarn) and products from European Research projects like Envisage, HyVar and PaaSage.

Our Ambitions

At the fundamental level, the scientific ambitions of the strand are to understand data-driven computations and scalability and to master stochastic mapping, allocation and scheduling problems.

Within SIRIUS the ambitions are to:

- To understand the scalability requirements of the data processing in SIRIUS. This involves better and more scalable data base technologies; as well as high-level models of the data sets and the applications processing the data.
- To consolidate SIRIUS, and other, results with data analytic methods using and integrating different tools and approaches to build an application execution platform for SIRIUS.
- To establish a scalability evaluation platform and methodology involving developing new hardware solutions to overcome the bottlenecks in today's systems.
- To evaluate different database technologies on different hardware platforms as we believe that we first need to assess the performance of current systems for the SIRIUS data before we successfully can develop improved solutions.

Dr. Geir Horn is Head of European ICT Research at the Faculty of Mathematics and Natural Sciences

- To evaluate large scale, cross cloud deployments on data sets with realistic sizes. SIRIUS offers a unique opportunity to scale the size of the data sets with the available computing power. It is hence important to understand the effect of various deployment solutions.

MELODIC Project

Geir Horn from SIRIUS is coordinator of the European Union Horizon 2020 project MELODIC, which was awarded a contract in the 2016 calls. Simula, another SIRIUS partner, is also participating in this project. MELODIC will enable data-intensive applications to run within defined security, cost, and performance boundaries seamlessly on geographically distributed and federated cloud infrastructures. Serving the user's needs and constraints, MELODIC will realise the potential of Cloud computing for big data and data-intensive applications by transparently taking advantage of distinct characteristics of available private and public clouds, dynamically optimise resource utilisation, consider data locality, conform to the user's privacy needs and service requirements, and counter vendor lock-in.

These benefits are achieved by integrating and extending the results and the open source platforms available from three major European Cloud projects with the Hadoop and Spark big data frameworks: The PaaSAGE platform will be used for intelligent and autonomic cross-cloud deployment and is extended with data aware modelling and deployment configuration reasoning; the CACTOS platform is extended with support for Hadoop and Spark in cross-Cloud application deployment and management; with added support for unified data security and cross-Cloud privacy.

MELODIC will integrate with the existing open source development teams for these platforms and the contributions will be released back to the used platforms as open source. The integrated MELODIC platform will be maintained and exploited by a professional software house, and the results in the MELODIC project will be coordinated with the Scalable Computing strand in SIRIUS and will be available for use in the SIRIUS laboratory.

Numascale Hardware and Software

Numascale, one of the SIRIUS partners, builds hardware and software to implement a cache-coherent shared-memory cluster system for high-performance computing. This allows clusters to share memory, making the adaptation of legacy software to multiprocessing easier. Facilitated by the Scalable Computing strand, the SIRIUS laboratory will be using the Numascale PRACE machine at the University of Oslo for experiments in the Knowledge Representation and Execution Modelling & Analysis strands. A program of collaboration with the Database strand is also planned for 2017.

Dolphin Interconnect Solutions produces a series of low-latency switches for connecting processors and storage in clusters.

Dolphin Hardware

Dolphin Interconnect Solutions produces a series of low-latency switches for connecting processors and storage in clusters. This approach promises to be useful for improving the performance of data access procedures and analytic calculations for dataset exceeding the memory capacity of the cluster. Dolphin's interconnect technologies will be integrated with the SIRIUS laboratory testbed by the Scalable Computing strand during 2017. Effort in 2016 was used to define requirements for the cluster and prepare the hardware for the laboratory installation.

Statoil Reservoir Simulation

During spring 2016, a feasibility activity was run with Statoil and Simula to define a collaborative research project on improving high-performance computing for reservoir simulation. The project's primary objective is to enable extreme-scale reservoir simulations by using modern numerical strategies and high-performance computing (HPC) techniques, while being ready to embrace the latest and upcoming developments of HPC hardware and middleware. As secondary objectives, the project aims to improve the reservoir simulation capabilities of Statoil, as well as showcasing relevant HPC & scalable data access techniques and solutions for other partners within the SIRIUS Centre.

This project will investigate parallel programming frameworks and performance optimisation and techniques for efficient use of computing platforms that are based on cutting-edge multicore CPUs and interconnects; adaptation and extension of modern numerical strategies for reservoir simulation, in order to match with the latest supercomputing hardware; and Investigation of heterogeneous CPU-accelerator computing for reservoir simulations.

Geir Horn

Dr. Geir Horn is Head of European ICT Research at the Faculty of Mathematics and Natural Sciences, and represents the Faculty on the SIRIUS strategic board and leads the SIRIUS Scalable Computing strand.

Geir holds a Cand. Scient. degree in cybernetics and a PhD in computer science on mathematical learning in combinatorial optimisation problems, both from the University of Oslo. He started his career at the Centre for Industrial Research in Oslo working on embedded software and fieldbus sensor systems, leading him on to distributed and parallel computing. Geir's current research interest is on stochastic combinatorial optimisation and how to handle complexity and services choreography for large-scale distributed applications through adaptation, autonomic decisions, self-awareness, and emergence.

Geir has previously held positions as senior scientist and research director at SINTEF in Oslo, before spending 4 years in more basic research at the SIMULA Research Laboratory. He has been working with European research for 20 years and has been coordinating 16 European collaborative projects ranging from coordination and support actions to large integrated projects. Geir has participated in multiple proposal evaluations for IST/ICT in FP5, FP6 and FP7 and has also been on the scientific review panel for several ICT projects within the areas of Cloud, communication technofixes, and Internet of Things.

Data Science

DataScience@UiO

During 2016, the SIRIUS and Big Insight centres collaborated to set up an innovation cluster called DataScience@UiO. Gunnhild M. Haugnes wrote about this in Titan (https://titan.uio.no/node/2025).

"Finally, four projects and four researchers are in place. All that remains, is to start", says an optimistic Ingrid Glad. The professor of statistics is talking about a brand-new innovation cluster in science and technology at the University of Oslo. The cluster, which Glad leads, is called DataScience@UiO and will work with two new Centres for Research-based Innovation: SIRIUS and BigInsight.

- SIRIUS' aim is to solve one of the data age's toughest challenges: to find and collect data in a world where the amount and complexity of data is growing by the day.
- BigInsight will improve the generation of value in society by developing new statistical methods and tools for handling and analysing large and complex sets of data.

Glad believes that SIRIUS and BigInsight represent two central groupings who are working with important challenges in the knowledge society. By connecting these skills, we can advance further and faster.

DataScience@UiO

- Lay the foundation for a new interdisciplinary research group and a new study programme in Data Science, covering both data access and analysis. The Departments of Informatics and Mathematics are central participants.
- Collaborate with two SFIs (SIRIUS and BigInsight).
- Work with partners from industry and the public sector.
- Inven2 will assist with start-up companies and commercialisation of innovations.

It is exciting to work in these different subject areas and connect knowledge together

DataScience@UiO has identified four areas that the new doctoral students will work with. Each of the students has received a four-year stipend, including a year that shall be used to create innovation based on the research results.

Smart grid communication and operation

Andreas Nakkerud is one of the young researchers who have been hired. He will work with data from the energy sector.

Energy supply has become more and more complex, with new energy sources and transmission methods. A better and more intelligent IT infrastructure is needed to drive effectiveness while ensuring environmentally responsible supply.

Nakkerud will work with so-called Smart Grid technology. Smart Grid is a term for a new-generation power grid, which uses new communications technologies to allow better use of energy infrastructure. In practice, this means combining the power net and the Internet.

He says that we will use the latest developments in data analysis, optimisation, statistics and logic to develop new algorithms that make electricity smarter and less expensive. He hopes to contribute to practical improvements for both the energy producers and consumers. The work is being done in collaboration with several companies in the energy sector. He believes that his background in physics, IT and statistics will help in the task. It is exciting to work in these different subject areas and connect knowledge together.

Decisions about product and system development and troubleshooting are dependent on data sets that are incomplete.

Recommendation systems for highly incomplete data

The media industry is changing rapidly. How a user clicks on news items and net shops says a lot about their preferences. This is data that occurs in many parts of the digital world.

Researchers at the University of Oslo have developed a new statistical method for learning preferences from this type of data. However, often such data is incomplete and incoherent. Current research promises to make models that can determine preferences from this incomplete data. Telenor and NRK are partners in the project, which will include work on developing personally-adapted TV. This means that the individual TV viewer receives recommendations on programs based on what he or she has viewed previously. At the same time, a wider range of programmes can be offered so that the sender does not only confirm and narrow the programmes offered to the viewer.

Glad points to the on-line bookshop Amazon as an example of a retailer that proposes new products based in previous purchases. NRK has a different approach, where recommendations shall not only satisfy the individual viewer, while maintaining NRK's societal role.

Addressing challenges in the oil and gas sector

The other two projects address problems in the oil and gas sector. One of these looks at the problem of missing and inconsistent data in corporate and technical database systems. Decisions about product and system development and troubleshooting are dependent on data sets that are incomplete. This project will examine ways of intelligently detecting and correcting these inconsistencies.

The second project will focus on use of semantic modelling and machine learning to address the challenges the oil industry faces in understanding, navigating and analysing the massive amounts of data generated in exploration and operations.

DataScience@UiO at the start line. In front Ingrid Glad, at the back from the left Evgenij Thorstensen, Carlo Mannino, Ida Scheel, Qinghua Liu, Anders Nakkerud and David Cameron

Drop-in-Data Science for Researchers

The cluster is planning a range of activities, including six-monthly meetings with industrial partners in collaboration with the University of Lancaster. Development of interdisciplinary courses is also planned. In addition, each researcher will be given a four-month placement at a relevant industrial partner.

Glad also believes that the community will value the setting up of a drop-in Data Science advisory service for researchers. This service is designed for researchers in the natural science and technology who need support in data science. She concludes "We want to obtain new knowledge that is useful for society, for research at the University of Oslo and for our partners in the private and public sectors. And obviously, the projects can result in new start-up companies."

What is Data Science?

Data Science is learning from data and integrates methods for statistics (probability, inference and machine learning) and computer science (algorithms, visualisation, databases) with a focus on handling large and/or unstructured data sources.

The SIRIUS Consortium

SIRIUS Partners cover the scalable data access supply chain

The SIRIUS consortium consists of a good mix of operating companies, service companies, information technology vendors, specialized software suppliers and researchers. Together, the consortium covers the supply chain for IT in the oil and gas industry.

Tom Erling Henriksen, Director for Oil and Energy, Evry. ***"SIRIUS will be exciting. We hope that the results will be practically useful, because we really need to get more out the data that is stored in DISKOS"***. Computerworld Norway, 27th February 2017.

In conjunction with the opening of the SIRIUS centre, IBM, as one of the partners in the project, invited Lisa Armini, Director for R&D in Cognitive Computing, one of the world's leading researchers in artificial intelligence, to Oslo. ***"To analyse large amounts of data you need a machine that understands big data. The oil and gas industry has often struggled with excessive risk and uncertainty. This is not just due to the oil price, but also applies when they want to find oil. What lies under the surface and what is the best way to recover it? Here is where big data and artificial intelligence can help."*** digi.no. https://www.digi.no/artikler/sann-skal-kunstig-intelligens-hjelpe-norge-med-a-finne-olje/347929

Country General Manager Arne Norheim of IBM Norway says that ***"SIRIUS is possibly the most important research initiative in Big Data for Oil & Gas today. This initiative demonstrates the potential in exploiting the large quantities of data within this industry sector. As a leading player in Big Data and advanced data analytics, IBM believes that new technology will contribute to addressing societal challenges and ensuring better resource utilization"***, he states.

"We are very pleased with this collaboration between research communities in academia and industry. One of the challenges we face is access to and use of the valuable information that is found in our massive volumes of data. We therefore see SIRIUS as good way to facilitate digitalisation and strengthen innovation based on our data." Åshild Hanne Larsen, Senior Vice President for IT and CIO in Statoil.

"We see that the technology has an enormous growth potential", says Hugo Kohman, CEO of Dolphin Interconnect Solutions. The company develops rapid network solutions. Contributing to SIRIUS gives Dolphin crucial access to academic resources and end-users, which will enable the further development of high-quality innovations relevant to Big Data problems.

Numascale, a company that delivers technology for connecting servers in order to build very large shared memory systems, will also be a part of SIRIUS. Getting into an international market with disruptive products is a huge challenge for a small company. SIRIUS gives Numascale a solid foundation in important local research and industry sectors as well as the necessary feedback in order to develop optimal products for end-users. ***"The Centre's focus towards the Oil & Gas domain, as well as other sectors with large quantities of data, creates an ideal arena for Numascale to conduct research, development, and innovation"***, says Kåre Løchsen, founder of Numascale.

Partner	Role in SIRIUS	In-kind contribution
Statoil	Provider of use cases and targets for pilots	Chairman of centre General Assembly. Work package manager for Exploration. Scoping, road-mapping and project feasibility projects. Financial support
Computas	Knowledge of real-world deployments and system integration. Facilitating pilots.	Led road-mapping activity for cloud computing. Scoping, road-mapping and project feasibility projects. Provides CODIO collaboration and operations software to laboratory.
Kadme	Provision of leading search and retrieval technology, cross-segment oil and gas data integration and information management domain knowledge.	Contribution of WHEREOIL software to laboratory. Coordination of SIRIUS' work with ECIM. Scoping, road-mapping and project feasibility projects.
IBM	Provider of cloud-based software infrastructure. Contributions from leading R&D centres in USA and Brazil.	Leadership of road-mapping activity on Language Technologies. Scoping work with IBM Research in USA and Brazil. Contribution of BlueMix and cloud to laboratory,
DNV-GL	Expertise in implementation of semantic solutions in oil, gas, health and maritime sectors.	Participation in feasibility projects for BIGMED and next generation operations. Piloting of Optique data access in hospital.
Schlumberger Information Solutiions	Leading expertise in software systems for the oil and gas sector. Contributions from leading R&D teams.	Course for PhD students. Access to Schlumberger Oilfield Glossary. Participation in Scoping activities for Exploration work packages and all strands.
fluidOperations AG	Contributes leading semantic technology platform and know-how in its deployment.	Participation in next generation operations feasibility activity, road-mapping and scoping activities. Contribution of Information Workbench software to laboratory.
Evry	Contributes technology and know-how related to hosting of large-scale oil and gas data sets.	Project leader for road-mapping activity. Supplied collaboration Sharepoint site for centre. Contributes access to Petroportal cloud environment to laboratory.
OSIsoft	Contributes leading technology platform for historians and know-how in its deployment.	Course for SIRIUS personnel. Participation in feasibility and scoping activities. Contributing PI database to laboratory.
Numascale	High-performance computing for big data technologies, with special focus on scalable memory.	Access to Numascale hardware in laboratory. Participation in feasibility, scoping and road-mapping activities.
Dolphin Interconnect Solutions	High-performance interconnect hardware for reduced latency in big data processing.	Tailoring of hardware for delivery to laboratory in 2017. Participation in scoping and road-mapping activities.

The SIRIUS Centre

SIRIUS Space

The SIRIUS centre ls located on the eighth and ninth floors of the Informatics Building (Ole-Johan Dahls Hus) at the University of Oslo. The centre has been renovated and redecorated to reflect the centre´s identity and provide a pleasant and productive working environment.

The SIRIUS place provides:

- Space for all University of Oslo researchers.
- Space for visiting researchers from partners and collaborating institutions.
- Facilities and décor that establishes a centre identity.

The aim of the SIRIUS space is to create an attractive forum for industrial informatics in South-East Norway.

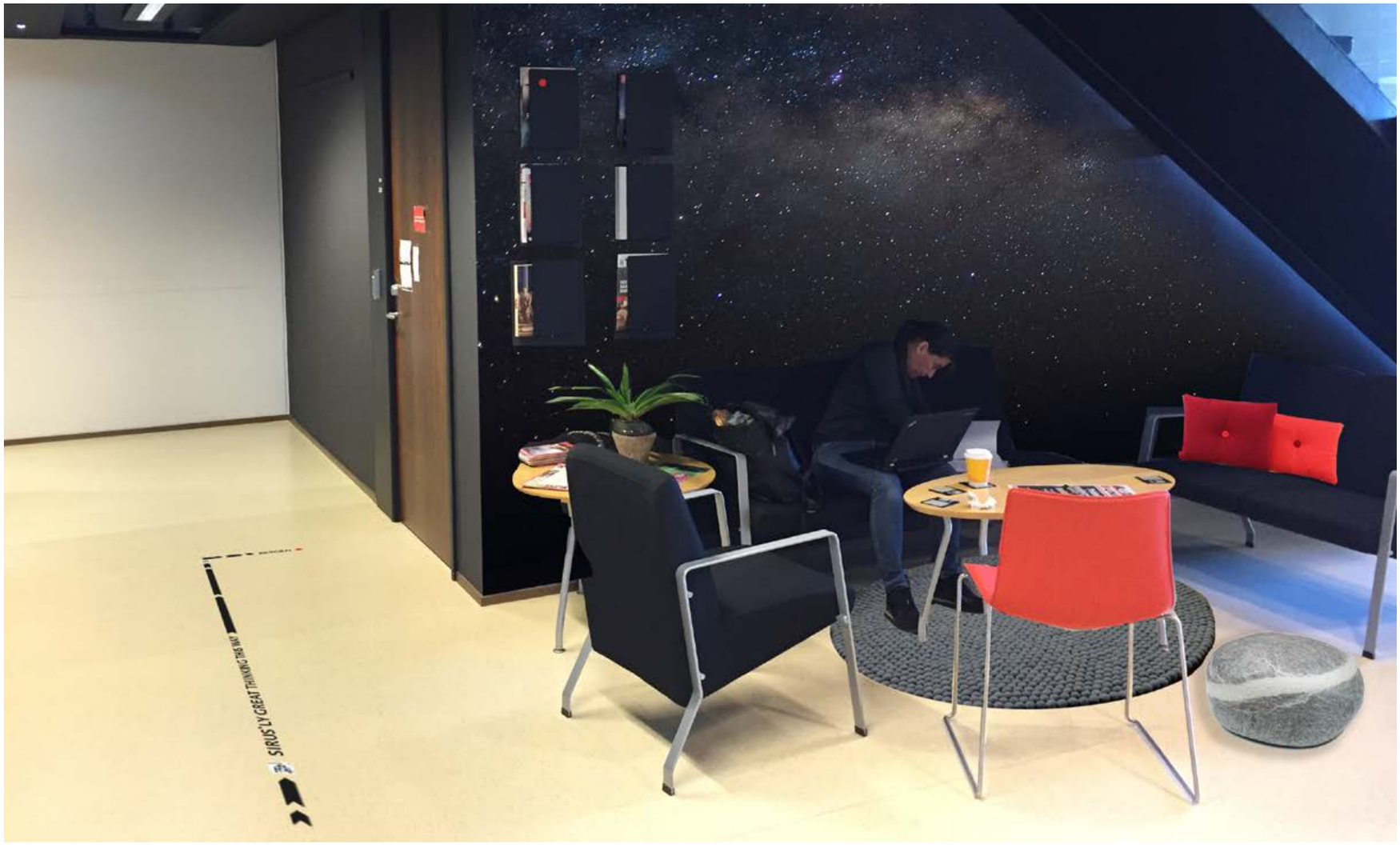
The SIRIUS centre is a highly international environment. We therefore finance the cost of Norwegian language training for our workers. We also provide access to quality newspapers: Dagens Næringsliv, Morgenbladet and The Economist and relevant business and oil and gas journals: World Oil, GEOExpro, Harvard Business Review and Journal of Petroluem Technology.

Lise Reang

Lise Reang has a varied background within administration, coordination and service. She worked nine years for the Kongsberg Group, first as a service coordinator for collaboration environments, then as a Site Manager/conference coordinator and finally as management assistant for executive management in Oil & Gas. Lise worked for AS Vinmonopolet for six years where she established, managed and built the internal IT helpdesk. Lise's main tasks in the center are to facilitate collaboration between colleagues and contribute to a stimulating work environment and good communications. She assists and guides in administrative questions and also helps to plan and run different kinds of events.

SIRIUS Lunches and Seminars

The SIRIUS centre consists of students and researchers from three groups at the University of Oslo. Building a common team identity has been prioritised in 2016. One of the mechanisms for this has been regular lunch seminars. Partners have also been invited to and attended these lunches. They have been successful and will be continued, with a frequency of around two per quarter in 2017.


SIRIUS-LY GREAT THINKING THIS WAY


SIRIUS


WE ARE SIRIUS

Kick-off and Autumn General Assembly

Formal Opening of the Centre

SIRIUS' formal kick-off was held on 19th and 20th May 2016. Bjarne Røsjø covered the formal part of the program for Titan, the University of Oslo publication. This is an edited translation of his article[1].

Participants at the formal opening of the two new Centres for Research-based Innovation, SIRIUS and Big Insight, on Thursday 19th May received a clear message on the way to lunch: Data is the new natural resource, which we must be better at exploiting. The centres will contribute to this in their own way: SIRIUS by making it easier to get access to the right data and BigInsight by analysing the date and developing new solutions for the knowledge economy.

It had been planned for Trade and Industry Minister, Monica Mæland, to have formally opened SIRIUS and BigInsight, but at the last moment the minister had to answer questions in parliament. The role thus delegated to state secretary Dilek Ayhan. Ayhan is trained as a data engineer from Oslo University College and she was very pleased to have the chance of opening two SFI centres that work in a discipline that is near to her heart.

Ayhan described Norway as a land that had overflowed with oil and honey. We have lived well for a long time using the natural resources of oil. Now, however, it is time to look for new possibilities. "Our future welfare depends on continued growth. However, in the last few years this growth has slowed. We therefore need to find something new, like strengthening the collaboration between different industrial sectors and developing new and smart technology".

[1] https://titan.uio.no/node/1601

Optique works with Big Data, i.e. development of systems that give access to the right information in enormous databases.

Professor Knut Liestøl, Head of the Department of Informatics, opened the ceremony by noting that data science is a rapidly growing area of research. He believes that the setting up of the two centres increases the probability of Oslo becoming a focal centre for European and global data science. He then challenged the audience: "if you have a daughter of the right age, encourage her to become a data scientist. Norway needs more of these".

The SIRIUS research program builds on the Optique EU project, which started in 2012 and ended in autumn 2016. Optique works with Big Data, i.e. development of systems that give access to the right information in enormous databases. David Cameron, centre coordinator for SIRIUS noted that oil engineers can use up to 70 percent of their time finding and collating he data from various sources that they need to do their job. SIRIUS will contribute to reducing this time by developing methods that give expert easier access to the information they need, without unnecessary pain.

The head of the Research Council of Norway (RCN), Arvid Hallén, noted that both SIRIUS and BigInsight are part of the third generation of centres for research-based innovation financed by the RCN. The first 14 centres were set up in 2006 and have delivered their concluding reports, while seven more SFI-II centres started in 2010 and are now at their mid-term review.

Dilek Ayhan

Plaque Presentaton

About 90 percent of the data that exists today was generated in only the last two years.

Hallén recommended that we study these concluding reports and evaluations, so that we can avoid some of the errors made by our predecessors. He also congratulated both the Norwegian Computing Centre and the University of Oslo and all participants in SIRIUS and BigInsight. He is sure that there is much hard work that awaits us. He then presented the two SFI plaques to Professor and SIRIUS Director Arild Waaler and Kjersti Aas from the Norwegian Computing Centre, who is co-director in BigInsight.

Arne Norheim, Managing Director of IBM Norway, spoke on behalf of one of the industrial partners in SIRIUS. He emphasised that we are entering a world defined by the Internet of Things and more and more cognitive technology. IBM's Watson system is a good example of this in that it can read and understand natural sentences. When Watson is asked a question, it forms and evaluates hypotheses for rapidly locating relevant data for the case. The more one uses Watson, the smarter the system becomes.

He noted that the world needs this new technology because the amount of data that is collected from sensors and the Internet of Things is growing exponentially. About 90 percent of the data that exists today was generated in only the last two years. Furthermore, 80 percent of all the world's data is unstructured and thereby invisible to computers. The new centres can contribute to meeting the challenges we face in the journey to cognitive data processing.

Senior management from Statoil, Schlumberger and Oracle also presented their views of the challenges of big data in the oil and gas domain. Speakers were Elisabeth Kvalheim, Research Director for Statoil, Torjer Halle, Chairman of Schlumberger Norway and Tore Bjelland, Managing Director of Oracle Norway. Pro-Rector Ragnhild Hennum spoke on behalf of the University administration.

Morten Dæhlen, Dean of the Faculty for Mathematics and Natural Sciences, opened by quoting Martin Luther King´s famous "I have a dream". About ten years ago, Dæhlen, who was at the time Head of the Department of Informatics, was contacted by a young and perceptive professor of informatics who didn´t so much have a dream but a plan. A plan was something that could be realised. The young professor was none other than Arild Waaler, who had already seen the need for a centre like SIRIUS.

Arne Norheim

Morten Dæhlen

Arild Waaler

Ian Horrocks

Dæhlen then gave the floor to Professor Waaler, who explained that access to data has become an enormous bottleneck for business. There is a lot of data, and huge analytical capacity, but it is difficult to get the data that should be analyses. Consider, for example, all the old research reports that only exist as PDF documents. This is a treasure chest that is waiting to be opened. SIRIUS will focus on developing and demonstrating new technology that can be used to structure data so that they are made more available.

The formal opening concluded with a keynote address by Professor Ian Horrocks from the University of Oxford. He is Scientific Coordinator in SIRIUS. The presentation dealt with Scalable Semantic Data Access and gave an introduction to the topic, explained the theoretical basis for the Optique platform and highlighted current research challenges.

Spring General Assembly

SIRIUS' spring General Assembly was held on 19th and 20th May, after the formal opening of the centre. The aim of the meeting was to discuss the expectations of all partners and further the dialogue between the industrial partners and the academic researchers. A celebratory dinner was also held on the evening of the 19th.

Autumn General Assembly

SIRIUS held its Autumn General Assembly in Oslo on Thursday 17th November 2016. This was a business meeting and had two purposes:

1. Review the progress of the Centre since start-up in November 2015
2. Discuss and approve the work plan for 2017 and later years.

Knut Sebastian Tungland's chairman's address is printed on pages 8 - 10. Arild Waaler and David Cameron presented the status report and the draft work plan, while Einar Broch Johnsen led a discussion on how a geographically spread centre like SIRIUS can build up a common spirit, good communication and effective work practices.

A planned highlight for next year is the SIRIUS Mentoring programme. This will be a structured programme in which mentors from SIRIUS partner companies will work with post-doctoral researchers and Ph.D. students in the SIRIUS centre to discuss career and personal development. The programme promises to be beneficial both to mentors and mentees. Ingrid Chieh Yu, who is leading the programme, gave an introductory presentation about it.

Partners at Kickoff

Recruitment, Education, Mentoring and Equal Opportunity

Mentoring Program

SIRIUS' Mentoring Program is a one-on-one program where a mentor facilitates the development of a mentee. The program contributes to the professional and personal development of both mentees and mentors and has the following overall objectives:

- Offer individual SIRIUS researchers a *personal* development strategy and to train future research leaders in academia or industry.
- Shape SIRIUS *center identity* by exchanging expertise, values, skills, perspectives, attitudes, and through networking.
- Increase *mutual understanding* between SIRIUS industries and academia to foster collaboration, engagement, and build career competence on *both* sides of the mentoring relationship.
- Promote and harness the full potential of *diversity* in SIRIUS: culture, age, gender, and expertise aspects.

This formal program targets SIRIUS researchers, post-doctoral researchers and PhD students and provides training and support with the following program structure:

- Each mentor and mentee relationship lasts for 9-12 months
- The mentoring program will match mentors and mentees based on their profiles
- During the mentoring period, mentors and mentees are expected to meet 1-2 times a month in their individual learning progress
- The mentoring program runs:
- Mentor master class for mentors
- Mentor program Kick-off for new pairs.
- Seminars with topics that facilitate personal and career development. These meetings also provide arenas for networking and social interactions between all pairs to share knowledge and expertise.
- A common closing event

Mentors are Industry leaders from SIRIUS partners who are motivated to support the career development of a SIRIUS researcher. The first mentoring program 2017/2018 has enrolled in total 10 mentor- and mentee pairs.

The 10 mentors are top leaders from Statoil, Schlumberger, IBM, Evry, and Numascale. Mentees are from the University of Oslo and NTNU. The Program will have its kick-off in May 2017.

Education

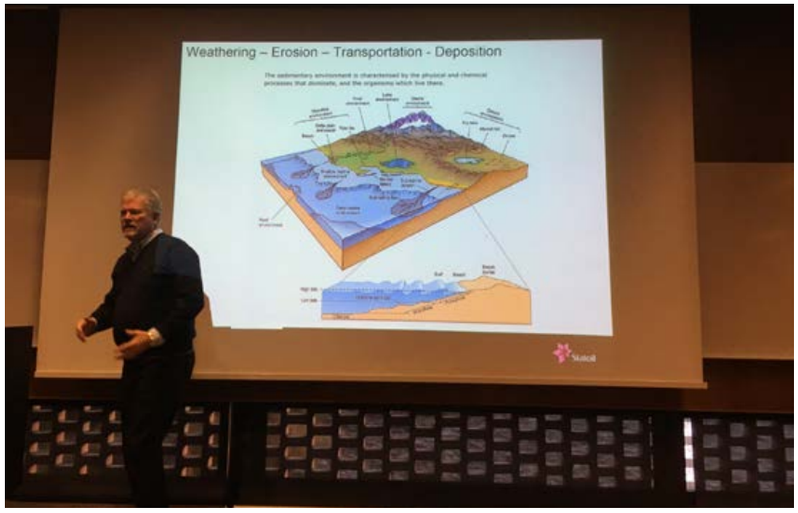
Three doctoral students, two from Oslo (Vidar Klungre and Farhad Nooralazadeh), one from Oxford (Alessandro Ronca) spent a week on Pau in October learning about oil and gas from Schlumberger NeXT. During

this hands-on course, the students learned the life cycle of the oil and gas industry, the functions of companies involved throughout the cycle and their roles and responsibilities. They got an overview of technologies, workflows and processes that enable the oil and gas industry to explore, appraise, develop and produce oil and gas. Throughout the course, we learnt the risks and rewards associated with the industry along with their social, environmental and financial impacts. The OilSim simulator was used to play the roles of oil and gas companies and authorities, and was used for exploration tasks and making decisions in a virtual, realistic environment. The participants also had one day field visit to an oil rig to see and touch a piece of what was learnt during the course.

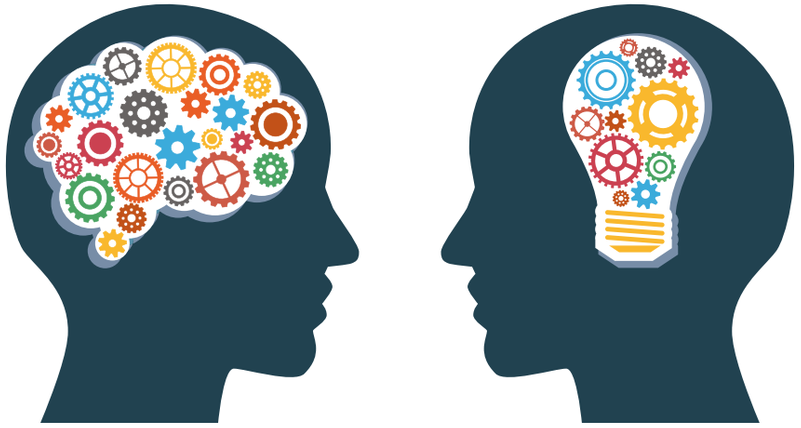
Peter Nielsen from Statoil started off the Christmas celebrations with a lecture entitled: "Introduction to Exploration geology for non-geoscientists".

Equal Opportunity

The mentor program is a vehicle for promoting and training future female research leaders. In particular, the 2017/2018 mentoring program has 60% female mentees. In addition, the SIRIUS mentor program has established collaboration with the female IT network, Oda-Nettverk, Norway's leading network for women working in IT. This will enable woman in SIRIUS to have access to a wider female network. In 2016, SIRIUS woman participated at the Inspiration Day event with the theme "Lead the Change". The event is based on the three pillars of the conference –inspiration, technology and management.



We hope that a good onboarding process will help new researchers to be well adjusted and that they experience an inclusive working environment.



Onboarding

The SIRIUS onboarding program is designed to help new employees to adjust to the center's culture and work environment. We hope that a good onboarding process will help new researchers to be well adjusted and that they experience an inclusive working environment. The practice is structured with a written onboarding plan that is consistently implemented. All new hires will be assigned a buddy, typically a post doc or a PhD student. The buddy helps the new employee during his/her first 3 months of employment. The primarily responsibility of a buddy is to offer guidance and support regarding the day-to-day aspects of working at SIRIUS plus some culture and connection to help the employee understand SIRIUS organizational structure, the department, mentoring and educational programs, introduce co-workers and partners, and information sources. We believe this will strengthen and contribute to the SIRIUS culture and social working environment.

International Collaboration

It is exciting to work in these different subject areas and connect knowledge together

European Projects

During 2016, SIRIUS personnel have been involved in the following EU projects.

- Optique, FP7, as coordinator.
- Envisage, FP7, as coordinator.
- HyVar, Horizon 2020, as participant.
- PaaSAGE, FP7, as participant.
- Melodic, Horizon 2020, awarded in 2016, as coordinator.

The Optique FP7 project is described in detail in the section on the Knowledge Representation strand on page 32.

The Envisage FP7 project is described in detail in the section on the Execution Modelling & Analysis strand on page 43.

The HyVar Horizon 2020 project is described in detail in the section on the Execution Modelling & Analysis strand on page 44.

The Melodic Horizon 2020 project is described in detail in the section on the Scalable Computing strand on page 50.

Alan Turing Institute

The Alan Turing Institute, the United Kingdom's national research centre for data science, has now been set up is in operation from its new facilities in the British Library in London. Professor Ian Horrocks, SIRIUS' Scientific Co-ordinator is a Fellow of the institute and acts as SIRIUS' point of contact for the institutes work.

Kush Wadhwa, BYTE's project manager, presenting the BYTE project summary at the BDVA Summit in Valencia

SIRIUS researchers participated in a joint workshop on the interface of semantic technologies and data science.

BYTE Project

The BYTE Project, funded by the European Commission under FP7, ended with a workshop in London in February 2017. Guillermo Vega-Gorgojo has been the main project participant from SIRIUS. David Cameron also held a presentation on the implications of and possibilities for scalable data access in environmental monitoring and assessment.

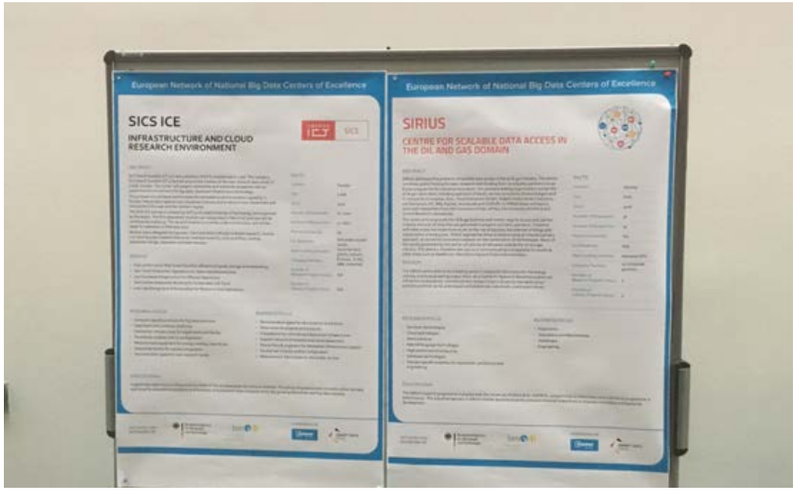
The aim of BYTE was to develop, in collaboration with expert stakeholders, a vision for big data and its societal implications in 2020. In 2017, the project will be transformed into a voluntary community for big data: a cross-disciplinary platform that will assist people in adopting big data and using it responsibly. SIRIUS will be full member of this community and will contribute effort to running it.

BDV BIG DATA VALUE ASSOCIATION

Full Member

Big Data Value Association

The Big Data Value Association (BDVA) is a private-public partnership organization established by the European Union. Its purpose is to provide the EU with input for developing the work programmes for Horizon 2020. SIRIUS finances full membership for the University of Oslo. This has allowed us to participate in the activities of the association. We are particularly interested in applications in manufacturing industry.



European Network of National Big Data Centres of Excellence

SIRIUS is a member of the European Network of Big Data Centres of Excellence. This organisation was set up in October 2016 in Graz at the initiative of the German and Austrian governments, through their ministries for Trade and Industry. The purpose of the network is to bring together European research institutions to share experience, develop European project collaboration and provide feedback on research and education policy to the European Commission.

Delegation to Brazil

SIRIUS participated in a seminar on Energy for the Future, held in São Paulo and hosted by FAPESP, the research council for São Paulo state in collaboration with the Research Council of Norway. We participated in the session on Integrated Operations, together with speakers from Petrobras, Statoil and NTNU. Our message was that scalable data access is essential for better decisions and higher productivity in natural resources. We are part of a delegation of 60 Norwegian academics and university leaders accompanying the Norwegian minister of Education. Meetings were also held with IBM's research team for oil and gas applications and with the big data team at Petrobras´ CENPES Research Centre.

National Collaboration

Gemini

SIRIUS, SINTEF and NTNU were awarded a Gemini Centre for Big Data in for three years from 2016 to 2018. Through this centre, we will work with colleagues in SINTEF Digital and NTNU in Trondheim and Gjøvik to share information on projects, broke collaborative research and build up common resources, courses and data sets.

Subsea Valley

SIRIUS has worked with the Subsea Valley cluster of engineering and service companies in the Oslo Area to promote awareness of and adoption of best practice in scalable data access, data science and industrial digitalisation. A master class in big data was held at the 2016 Subsea Valley conference. Around forty participants were given a tutorial introduction to big data and a practical presentation of the Optique platform for access to big data.

NORWEP

SIRIUS funds the University of Oslo's partnership in Norwegian Energy Partners (NORWEP), formerly INTSOK. NORWEP's aim is to be an effective vehicle for promoting the Norwegian offshore and energy industry's capabilities to key clients in overseas markets and providing market information to its partners. Our aim in membership is twofold: NORWEP gives us access to market information and assistance in communicating with oil and gas businesses outside Norway. In addition, SIRIUS can interact with the NORWEP partner companies to build a better understanding of the digitalisation of the oil and gas supply chain. SIRIUS personnel contributed to the preparation of NORWEP's catalogue of digital services.

SIRIUS also contributed to the joint activities of the French-Norwegian Chamber of Commerce. They held a seminar on Digitalisation as part of the annual French-Norwegian Day in Oslo on 13th October. SIRIUS participated in the organising committee for a workshop on the implications of Industry 4.0 to the oil and gas sector.

Oslo Industrial Ontology Seminar

The Oslo Industrial Ontology Seminar is run by SIRIUS and is a regular meeting place for academic researchers and industrial practitioners in the area of Knowledge Representation. Participants in the seminar come from SIRIUS partner companies and other companies outside the consortium. New members are welcome.

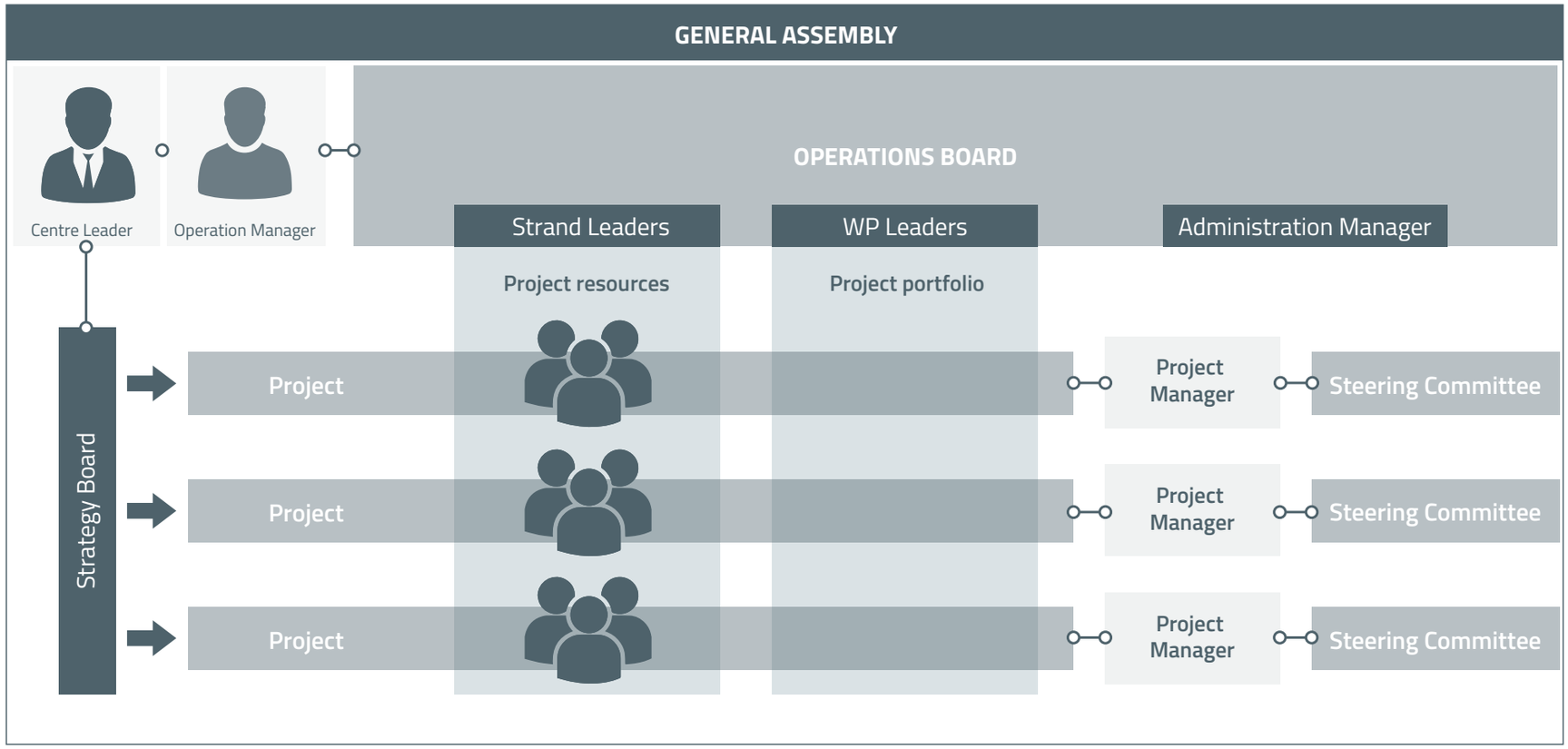
The Fine Print

General Assembly

The General Assembly is the body that makes final decisions in the centre. It consists of one high-level representative from each partner. It meets physically twice a year, with video meetings as otherwise needed. The spring General Assembly focuses on the strategy of the centre, whereas the autumn meeting approves the centre's work plan. Two meetings were held in 2016, both in Oslo.

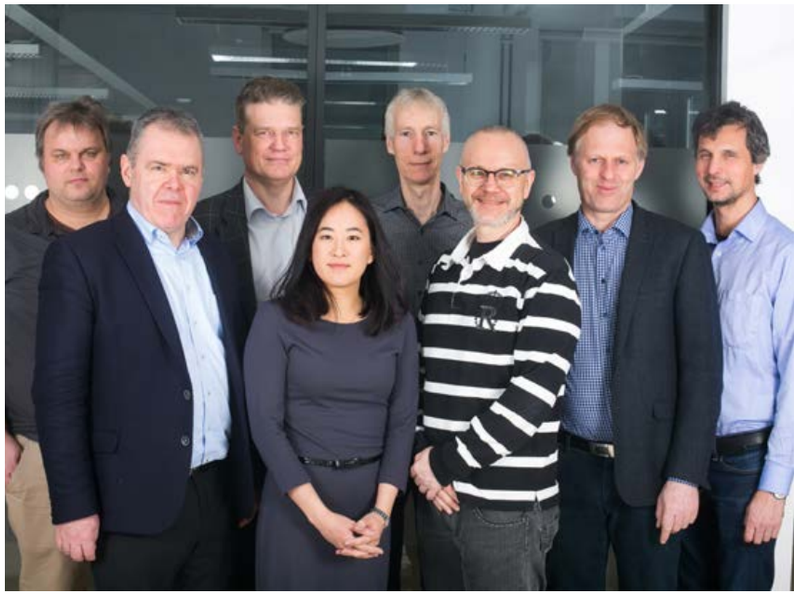
Strategy Board

The Strategy Board defines the strategic plans for the SIRIUS centre and for approving the projects in the SIRIUS project portfolio. It is chaired by the Centre Leader and consists of the Scientific Coordinator, Intellectual Property Manager, Pilot Strategy Coordinator, the Faculty Research Strategist and the leader of the Strategy Work-package (WP5).



Operations Board / Centre Management

The Operations Board (or Centre Management team) is responsible for day-to-day operation of the centre and the definition of work plan that implements the decisions of the Strategy Board. It is chaired by the Operations Manager and consists of the Centre Leader, Administration Manager, Mentor and Education Coordinator, Work Package Leaders and Strand Leaders.



The strategy board and its observers: Einar Broch Johnsen, David Cameron, Geir Horn, Ingrid Chieh Yu, Ian Horrocks, Knut Sebastian Tungland, Arild Waaler and Eric Monteiro.

Role	Name	Affiliation
Chairman of General Assembly	Knut Sebastian Tungland	Statoil ASA
Centre Leader	Arild Waaler	University of Oslo
Deputy Centre Leader	Einar Broch Johnsen	University of Oslo
Operations Manager	David Cameron	University of Oslo
Scientific Coordinator	Ian Horrocks	University of Oxford
Administration Manager	Lise Reang	University of Oslo
Finance Manager	Geir Ulvestad	University of Oslo
Intellectual Property Manager	Jarl Magnusson	DNV-GL
Mentor & Education Coordinator	Ingrid Chieh Yu	University of Oslo
Pilot Strategy Coordinator	Eric Monteiro	NTNU
Faculty Research Strategist	Geir Horn	University of Oslo
WP1 Exploration	Jens Grimsgaard	Statoil ASA
WP2 Operations	David Cameron (acting)	University of Oslo
WP3 Cross-Domain Applications	Laura Slaughter	University of Oslo
WP4 Supporting Technologies	Ian Horrocks	University of Oxford
WP5 Strategy and Outreach	Einar Broch Johnsen	University of Oslo
S1 Knowledge Representation	Martin Giese	University of Oslo
S2 Language Technologies	Lilja Øvrelid	University of Oslo
S3 Databases	Boris Motik	University of Oxford
S4 Execution Modelling & Analysis	Ingrid Chieh Yu	University of Oslo
S5 Scalable Computing	Geir Horn	University of Oslo
S6 Work Practices	Thomas Østerlie	NTNU

Visibility and Dissemination

Publications

Ahmet Soylu, Martin Giese, Ernesto Jimenez-Ruiz, Evgeny Kharlamov, Rudolf Schlatte, Christian Neuenstadt, Özgür Lütfü Özcep, Hallstein Lie, Sebastian Brandt and Ian Horrocks. *Ontology-based Visual Querying with OptiqueVQS Statoil and Siemens Cases*, Norwegian Big Data Symposium (NOBIDS), 2016

Ahmet Soylu, Martin Giese, Rudolf Schlatte, Ernesto Jimenez-Ruiz, Ozgur Ozcep and Sebastian Brandt. *Domain Experts Surfing on StreamSensor Data over Ontologies.* Proceedings of the 1st Workshop on Semantic Web Technologies for Mobile and Pervasive Environments (SEMPER@ESWC 2016).

Ahmet Soylu, Martin Giese, Rudolf Schlatte, Ernesto Jiménez-Ruiz, Özgur L. Özçep, and Sebastian Brandt. *A Visual Query System for Stream Data Access over Ontologies.* ESWC Satellite Events. LNCS 9989, 2016.

Crystal Chang Din, Silvia Lizeth Tapia Tarifa, Reiner Hähnle, Einar Broch Johnsen *History-Based Specification and Verification of Scalable Concurrent and Distributed Systems.* 17th International Conference on Formal Engineering Methods (ICFEM). LNCS 9407, 2015.

Dag Hovland, Davide Lanti, Martin Rezk and Guohui Xiao. *OBDA Constraints for Effective Query Answering.* 10th International Symposium on Rule Technologies Research, Tools and Applications (RuleML). LNCS 9718, 2016.

Dmitriy Zheleznyakov, Evgeny Kharlamov, Vidar Klungre, Martin G. Skjæveland, Dag Hovland, Martin Giese, Ian Horrocks and Arild Waaler. *KeywDB: A System for Keyword-Driven Ontology-to-RDB Mapping Construction.* ISWC Posters & Demonstrations Track, 2016.

Eduard Kamburjan, Crystal Chang Din, Tzu-Chun Chen, *Session-Based Compositional Analysis for Actor-Based Languages Using Futures*, International Conference on Formal Engineering Methods (ICFEM). LNCS 1009, 2016.

Einar Broch Johnsen, Jia-Chun Lin, Ingrid Chieh Yu, *Comparing AWS Deployments Using Model-Based Predictions*, 7th International Symposium on Leveraging Applications of Formal Methods, Verification and Validation: Discussion, Dissemination, Applications – (ISoLA). LNCS 9953, 2016.

Einar Broch Johnsen, Ka I Pun, Martin Steffen, Silvia Lizeth Tapia Tarifa, Ingrid Chieh Yu, *Meeting Deadlines, Elastically,* From Action Systems to Distributed Systems, Chapman and Hall/CRC Luigia Petre, Emil Sekerinski, Page 99-111 ISSN/ISBN 978-1-4987-0158-7, 2016.

Elena Giachino, Einar Broch Johnsen, Cosimo Laneve, Ka I Pun, *Time Complexity of Concurrent Programs - - A Technique Based on Behavioural Types*, 12th International Conference Formal Aspects of Component Software (FACS). LNCS 9539, 2016.

Eric Bodden, Ka I Pun, Martin Steffen, Volker Stolz, Anna-Katharina Wickert, *Information Flow Analysis for Go*, 7th International Symposium Leveraging Applications of Formal Methods, Verification and Validation: Foundational Techniques (ISoLA). LNCS 9952, 2016.

Erika Ábrahám, Florian Corzilius, Einar Broch Johnsen, Gereon Kremer, Jacopo Mauro, *Zephyrus2: On the Fly Deployment Optimization Using SMT and CP Technologies*, 2nd International Symposium Dependable Software Engineering: Theories, Tools, and Applications. LNCS 9984, 2016.

Erika Ábrahám, Marcello M. Bonsangue, Einar Broch Johnsen (eds), *Theory and Practice of Formal Methods - Essays Dedicated to Frank de Boer on the Occasion of His 60th Birthday*. LNCS 9660, ISSN/ISBN 0302-9743, 2016.

Evgeny Kharlamov, Sebastian Brandt, Martin Giese, Ernesto Jiménez-Ruiz, Yannis Kotidis, Steffen Lamparter, Theofilos Mailis, Christian Neuenstadt, Özgür L. Özçep, Christoph Pinkel, Ahmet Soylu, Christoforos Svingos, Dmitriy Zheleznyakov, Ian Horrocks, Yannis E. Ioannidis, Ralf Möller, and Arild Waaler,

Enabling semantic access to static and streaming distributed data with Optique: demo, 10th ACM International Conference on Distributed and Event-based Systems (DEBS), 2016.

Evgeny Kharlamov, Sebastian Brandt, Martin Giese, Ernesto Jiménez-Ruiz, Yannis Kotidis, Steffen Lamparter, Theofilos Mailis, Christian Neuenstadt, Özgür Lütfü Özçep, Christoph Pinkel, Ahmet Soylu, Christoforos Svingos, Dmitriy Zheleznyakov, Ian Horrocks, Yannis E. Ioannidis, Ralf Möller and Arild Waaler, *Scalable Semantic Access to Siemens Static and Streaming Distributed Data*. ISWC Posters & Demonstrations Track, 2016.

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Ferruccio Damiani, Christoph Seidl, Ingrid Chieh Yu, *Introduction to the Track on Variability Modeling for Scalable Software Evolution*, 7th International Symposium on Leveraging Applications of Formal Methods, Verification and Validation: Discussion, Dissemination, Applications (ISoLA). LNCS 9952, 2016.

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Jerry Gao, Martin Giese, Yifeng Zeng and Hong Zhu, Editors of the proceedings of *IEEE 2nd International Conference on Big Data Computing Service and Applications (BigDataService)*, IEEE Page 1-300, ISSN/ISBN 978-1-5090-2251-9, 2016.

Jia-Chun Lin, Ingrid Chieh Yu, Einar Broch Johnsen, Ming-Chang Lee, *ABS-YARN: A Formal Framework for Modeling Hadoop YARN Clusters*, 19th International Conference on Fundamental Approaches to Software Engineering The Netherlands, April 2-8. LNCS 9633, 2016.

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Maurizio Gabbrielli, Saverio Giallorenzo, Claudio Guidi, Jacopo Mauro, Fabrizio Montesi, *Self-Reconfiguring Microservices*. Theory and Practice of Formal Methods. LNCS 9660, 2016.

Michael Nieke, Jacopo Mauro, Christoph Seidl, Ingrid Chieh Yu, *User Profiles for Context-Aware Reconfiguration in Software Product Lines*, 7th International Symposium on Leveraging Applications of Formal Methods, Verification and Validation: Discussion, Dissemination, Applications (ISoLA). LNCS 9953, 2016.

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Davide Ancona, Viviana Bono, Mario Bravetti, Joana Campos, Giuseppe Castagna, Pierre-Malo Deniélou, Simon J. Gay, Nils Gesbert, Elena Giachino, Raymond Hu, Einar Broch Johnsen, Francisco Martins, Viviana Mascardi, Fabrizio Montesi, Rumyana Neykova, Nicholas Ng, Luca Padovani, Vasco T. Vasconcelos, Nobuko Yoshida, *Behavioral Types in Programming Languages*, Foundations and Trends in Programming Languages, Vol.32(2-3), 2016.

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Ivanova Angelina, Oepen Stephan, Dridan Rebecca, Flickinger Dan, Øvrelid Lilja & Lapponi Emanuele, *On different approaches to syntactic analysis into bi-lexical dependencies: An empirical comparison of direct, PCFG-based and HPSG-based parsers.* Journal of Language Modelling, Page 113-144, Vol.4(1), 2016.

Parmiggiani, E, Monteiro, E, A Measure of Environmental Happiness: *Infrastructuring Environmental Risk in Offshore Oil and Gas Operations*, Science & Technology Studies. Vol.29(1), 2016.

Parmiggiani, Elena; Monteiro, Eric; Østerlie, Thomas, *Synthetic Situations in the Internet of Things*, IFIP Advances in Information and Communication Technology. Page 215-228, Vol 489, 2016.

Richard Bubel, Ferruccio Damiani, Reiner Hähnle, Einar Broch Johnsen, Olaf Owe, Ina Schaefer, Ingrid Chieh Yu, Proof *Repositories for Compositional Verification of Evolving Software Systems – Managing Change When Proving Software Correct*, Transactions on Foundations for Mastering Change, Page 130-156, Vol.1, 2016.

Roberto Amadini, Maurizio Gabbrielli, Jacopo Mauro, *An Extensive Evaluation of Portfolio Approaches for Constraint Satisfaction Problems*, International Journal of Interactive Multimedia and Artificial Intelligence, Page 81-86, Vol.3(7), 2016.

Roberto Amadini, Maurizio Gabbrielli, Jacopo Mauro, *Portfolio approaches for constraint optimization problems*, Annals of Mathematics and Artificial Intelligence. Page 229-246, Vol.76(1-2), 2016.

Thomas Østerlie, *Some first steps towards a perspective on digitalization and the transformation of contemporary work and organizing*. 39th Information Systems Research Conference in Scandinavia (IRIS), 2016.

Presentations

Arild Waaler, Big Data. Oslo Innovation Week, October 2016, Oslo.

David Cameron, Masterclass on Big Data, Subsea Valley Conference, April 2016, Fornebu.

David Cameron, Optique: Simple, Oil & Gas-oriented Access to Big Data in Exploration. Paper at SPE Intelligent Energy, September 2016, Aberdeen.

David Cameron, Presentation of Center at EU H2020 Information Days, January 2016, Brussels.

David Cameron, Industry 4.0 for the Oil and Gas Sector, Research and Innovation Challenges and Mechanisms CCFN Digital Transformation, 13th October 2016, Oslo.

David Cameron, Analytics and scalable data access: the future of industrial information technology. Seminar for Petrobras CENPES September 2016, Rio de Janeiro.

David Cameron, Analytics and scalable data access: the future of industrial information technology. Presentation at FAPESP Norwegian-Brazilian Seminar on Energy, Septermber 2016, Sao Paulo.

David Cameron, Analytics and scalable data access: the future of industrial information technology. Presentation at Optique Summit September 2016, Oxford.

David Cameron, Analytics and scalable data access: the future of industrial information technology. Plenary lecture at EPIM conference September 2016, Haugesund.

David Cameron, Presentation of SIRIUS Centre at BDVA Activity Group, June 2016, Brussels.

Annual Accounts

Costs

All figures in 1000 NOK	**2015**	**2016**
Personnel and indirect costs	539	5188
Purchase of research services	-	600
Equipment	-	31
Other operational costs	62	9505
Total Sum	**601**	**15324**

Funding

All figures in 1000 NOK	**2015**	**2016**
Personnel and indirect costs	539	5188
Purchase of research services	-	600
Equipment	-	31
Other operational costs	62	9505
Total Sum	**601**	**15324**

Researchers and Projects

Doctoral Students

Name	Working title
Johanna Beate Stumpf	A Calculus for Resource Management
Farhad Nooralahzadeh	Domain adapted language technology for Oil & Gas
Lars Tveito	Rapid verification of concurrent and distributed specifications
Anastasia Gkolfi	Resource aware program analysis using abstractions
Daniel Lupp	Non-monotonic mappings and epistemic queries in ontology-based transformation.
Vidar Klungre	Improving the usability of ontology-based visual query formulation tools.
Leif Harald Karlsen	Qualitatively correct Bintrees - An efficient representation for qualitative spatial information
Shiji Bijo	Formal modeling of cache coherent multi-core architectures
Anthony Potter	Materialized-based query reasoning
Alessandro Ronca	Incremental reasoning for continuous queries
Daniel Bakkelund	Data science topic related to checking and compensating for missing and inconsistent data in complex sets of data.
Summaya Mumtaz	Data science topic related to application of machine learning and semantic technologies to an oil and gas use case.

Postdoctoral Fellows and Researchers

Name	Strand
Elena Parmiggiani	Working practices
Lizeth Tapia	Scalable computing
Violet Pun	Execution Modelling & Analysis
Jacopo Mauro	Execution Modelling & Analysis
Jia-Chun Lin	Execution Modelling & Analysis
Crystal Chang Din	Execution Modelling & Analysis
Martin Skjæveland	Knowledge Representation
Dag Hovland	Knowledge Representation
Evgenij Thorstensen	Knowledge Representation
Guillermo Vega-Gorgojo	Knowledge Representation
Ernesto Jiminez-Ruiz	Knowledge Representation

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