DrillWell

DRILLING AND WELL CENTRE
FOR IMPROVED RECOVERY

ANNUAL REPORT 2016

IRIS

SINTEF

Universitetet i Stavanger

NTNU

Centre for Research-based Innovation

The Research Council of Norway

DrillWell

DRILLING AND WELL CENTRE
FOR IMPROVED RECOVERY

About DrillWell

DrillWell (The Drilling and Well Centre for Improved Recovery) was appointed the status as a Centre for Research Based Innovation (SFI) by the Research Council of Norway in 2011. IRIS is the host, with SINTEF, UiS and NTNU as research partners. The Centre has four industrial partners; Statoil, Wintershall, ConocoPhillips and Aker BP. Lundin was a partner until December 31, 2016. DrillWell is an industry-driven collaboration and innovation environment. The industrial partners prioritize and direct the R&D effort towards particular challenges. The Centre is living proof of Stavanger and Trondheim joining forces together with the international oil and gas industry.

The annual budget for 2016 was approximately NOK 47 million. NOK 10 million was granted from the Research Council of Norway, and the industry partners contributed with a total of NOK 25 million. In addition, NOK 12 million was funded by the Research Council for three PETROMAKS2 projects together with industry funding from DrillWell. One international partnership project (INTPART) with US partners in Texas was also funded by the Research Council.

A total of fifty researchers, ten professors and associate professors, twelve PhD candidates, two Post Docs and twenty graduated MSc students have contributed to the Centre activities in 2016. This has resulted in 20 journal papers and 40 additional publications plus several keynote speeches and popular publications. Prototype software for drilling process optimization has been tested by participating oil companies. The Centre organizes one large seminar annually and distributes the DrillWell Newsletter quarterly.

CONTENT

DRILLWELL 2016

Within the objective of improving drilling and well technology, DrillWell contributes with new knowledge and innovative technology for implementation in field developments and operations. In the second phase of the DrillWell history, which started in 2016, the efforts are focused on drilling process optimisation, well control, cement integrity, and plugging and abandonment of wells. High level scientific work is being combined with development and testing of prototype software and tools aiming to unlock petroleum resources.

Cost reduction is essential for developing new prospects within a frame of low to medium oil price, and to keep mature fields in operation. Improving efficiency and securing safe and optimal use of existing technology is essential, but new innovations are needed to obtain large steps in cost reduction. As more wells can be drilled in a low-cost regime, increased recovery of oil and gas will follow.

Important results are presented at international conferences and in journal papers. In 2016, emphasis was placed on increasing the number of journal papers in the second phase, with good success. Kanokwan Kullawan, Fatemeh Moeinikia and Mahmoud Khalifeh defended their PhD thesis successfully this year. Twenty master students contributed through their thesis work. Three PhD students will defend their thesis before the summer of 2017, and seven PhD students and three Post Docs have started their work in this second phase.

Our international cooperation has been expanded to involve eight universities, including four in Texas, two in Canada and two in France. The NorTex Data Science Cluster, with INTPART funding from the Research Council of Norway, has turned out to be important for the cooperation with the universities in Texas and enabled successful seminars to be held in Houston within digitalisation and integrated operation, and plugging and abandonment of wells.

At the annual seminar at Sola in September, recent results were presented and discussed. Service companies were invited to present innovative technology that relates to the DrillWell research and development. For the first time, the seminar was opened to participation from companies and institutions outside of the DrillWell partners. This proved to be very successful, as it gave an additional momentum to the seminar, supplementing the presentations from the researchers and representatives from the oil companies. Key results have also been presented and discussed in mini-seminars at the oil company offices.

Prototype software for drilling process optimisation has been installed at oil company offices for testing and application. There is a dialogue with service companies for implementation and commercialisation of useful models and knowledge.

Including the three Petromaks2 funded spin-off projects, the total centre budget is around NOK 45 million per year in the second phase which will last until summer 2019.

Sigmund Stokka
DrillWell Manager, IRIS

DrillWell
DRILLING AND WELL CENTRE
FOR IMPROVED RECOVERY

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Drilling and Well Centre for Improved Recovery

VISION

Unlock petroleum resources through better drilling and well technology.

OBJECTIVE

Improve drilling and well technology providing improved safety for people and the environment and value creation through better resource development, improved efficiency in operations and reduced cost.

Cost reduction
Innovative drilling and well technology is needed to reduce exploration and development costs, as well as well plugging and abandonment.

Improved recovery
Improved wells at lower cost will imply higher recovery of oil and gas by increasing the number of wells and their productivity.

Efficient field development
Improved wells at lower cost will imply cost-efficient field development. Today wells represent 50-60% of the field development cost.

PEOPLE IN DRILLWELL

BOARD

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SCIENTIFIC ADVISORY COMMITTEE

In 2015 DrillWell established a Scientific Advisory Committee (SAC). The Committee comprises international experts within drilling and well technology that cover the scope of work carried out in DrillWell.

- *The main task of the SAC is to advise and evaluate the scientific performance of DrillWell in relation to the Centre's vision, objective and research plans including PhD projects. The SAC will meet with the Centre's Management Team and Project Leaders once a year. Between meetings, the Centre Director is encouraged to seek advice from the SAC on important decisions relating to the scientific performance of DrillWell, especially for PhD projects.*

Representatives from SAC attended the DrillWell seminar in September 2016 and contributed with very interesting presentations. Kitt A. Ravnkilde gave the keynote speech on the second day of the seminar. Her presentation "Drilling and well experiences from Danish fields" described the development of the Halfdan field operated by Maersk. John Thorogood presented "Operational performance measures in drilling" where he talked about the research paper "Business Models and KPIs as Drivers for Drilling Automation". He and his co-writers believe that a change is required in business models and the way of measuring success in order to speed up the uptake of drilling automation technologies.

SAC had their annual meeting on September 28 in Stavanger. Scientific progress, scientific production and plans for 2017 were on the agenda. SAC gave valuable advice regarding priorities and direction for DrillWell. In addition to the members of SAC, the management team, the project leaders and the management of IRIS attended the meeting.

The following international experts are members of SAC:

JOHN THOROGOOD
DRILLING ENGINEERING ADVISOR AT DRILLING GLOBAL CONSULTANT LLP

Following 34 years with BP, now an independent consultant with 44 years industrial experience in drilling engineering and operations. Activities include advisory roles to operators on management systems, frontier exploration projects in deep water and remote areas, shale gas operations, process safety, well control and forensic reviews of operational problems, development and implementation of new technology and R&D programme management.

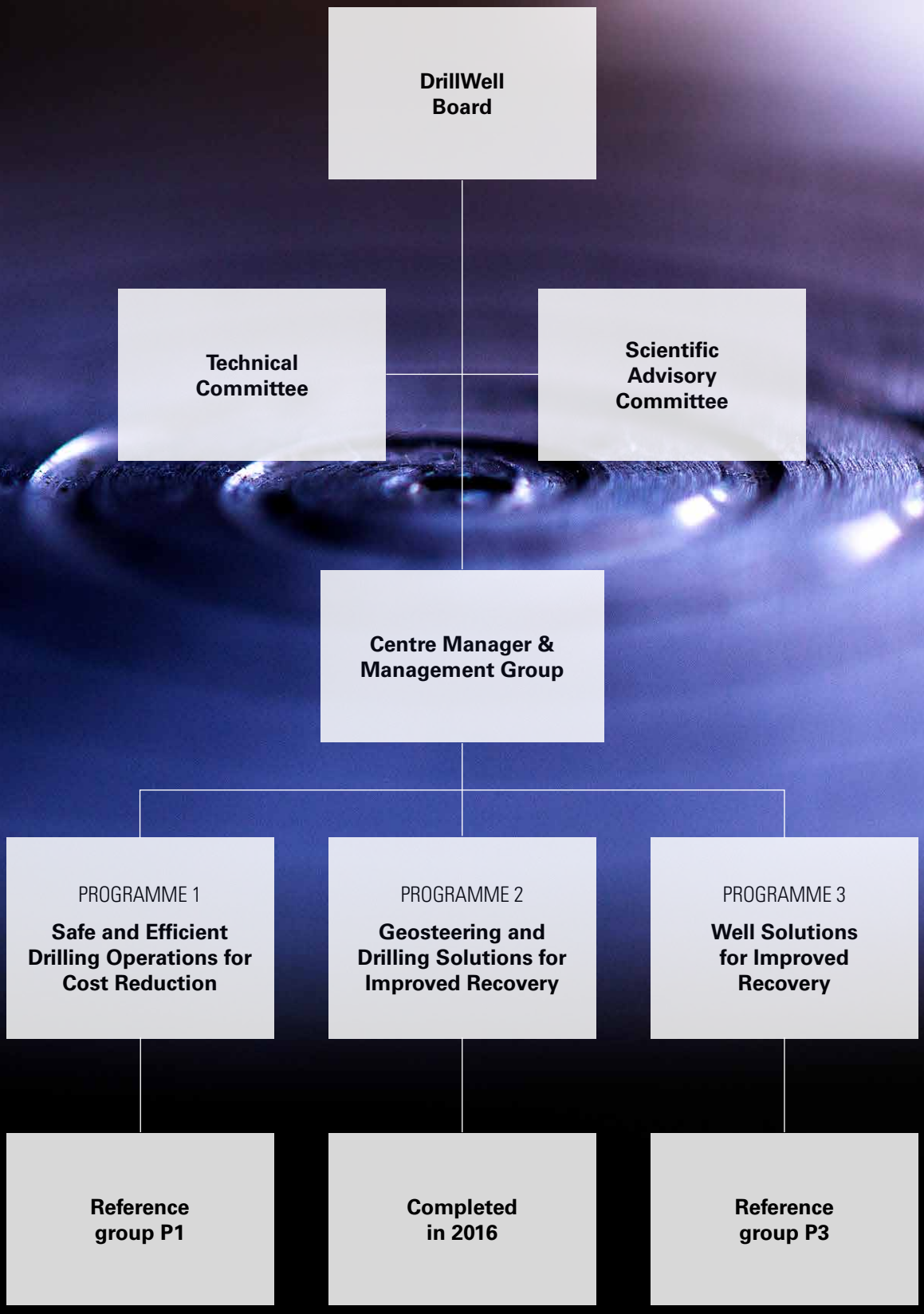
KITT ANITA RAVNKILDE
PRINCIPAL PROGRAMME MANAGER, DANISH HYDROCARBON RESEARCH & TECHNOLOGY CENTRE, DTU

Started her engineering career with Maersk Oil and later DONG E&P holding various positions related to Drilling and Production Technology over a period of 25 years. In April 2015, she joined the research centre DHTRC at DTU. The work involves building up a framework for international research and to lay the foundations for relevant, research-based study programmes with the potential to support interdisciplinary and interdepartmental research programmes. The overarching purpose is to identify new technological and conceptual solutions that boost oil and gas extraction in the Danish section of the North Sea.

ANDREW K. WOJTANOWICZ
TEXACO ENVIRONMENTAL CHAIR AND PROFESSOR IN THE CRAFT AND HAWKINS PETROLEUM ENGINEERING DEPARTMENT AT THE LOUISIANA STATE UNIVERSITY:

Has held faculty positions at the New Mexico Institute of Mining and Technology and the AGH University of Science and Technology in Krakow, Poland. He is a UN expert in drilling engineering and has worked for the oil industry as a drilling engineer, drilling supervisor, and drilling fluids technologist in Europe and Africa. His studies have been reported in 206 publications and eight books. He was Conoco Environmental Fellow 1990-91, served as Editor-in Chief of ASME Transactions Journal of Energy Resources Technology from 2000 to 2011, was SPE Distinguished Lecturer 2003-04, and received several awards from SPE and ASME.

DRILLWELL ORGANISATION



INDUSTRY PARTNER PERSPECTIVES

Stein Børre Torp Statoil

The results from the DrillWell SFI have contributed to improved drilling process quality and reduced field development investments. Prototype tools for assisting the operational drilling process control developed during the first phase of the programme, have been tested and implemented in existing systems used by the industry partners. Through industrialization and commercialization of the applications, the results of the SFI work is made available for the industry in general. For Phase 2 of the programme this will become even more important. The main challenge for the last years of the programme however, is to ensure that the scientific communities of DrillWell will remain strong and be able to serve the Norwegian oil and gas industry beyond the duration of the progamme. As an industry partner, we both recognize our responsibility, and appreciate the opportunity to influence the scientific direction of the programme.

Rune Woie ConocoPhillips

The DrillWell programmes are moving ahead and several of the activities are moving into validation testing to make sure that the new developments give the added value that is anticipated and prognosed. Validation has high priority also to test theory versus reality. This is a challenging task and also assumes available resources from both the researchers and the operator. From the operator point of view it is essential that value is documented throughout the project phase not only waiting for the final results. This will also help to guide the project in the right direction. New technologies and methods that simplify operations are needed to keep continued improved HSE, risks, efficiency and cost.

Terje Andre Pedersen Aker BP

The DrillWell programme has contributed positively towards minimizing the drilling cost of conventional wells and by increasing the probability of reaching drilling targets in a safe way. Within technology for Plug and Abandonment (P&A) of wells in particular, the DrillWell programme has presented significant potential improvements. The projects have improved the knowledge of cement durability and creation of micro-annuli. Some of the test methods within these enterprises have also been considered by service companies to be used to improve their performance. Also, the research programme has focused upon understanding gas loading and solubility of gas into oil based drilling fluids. The solubility is different for different base oils. This understanding is expected to increase the safety of drilling operations; especially while drilling HPHT wells.

Torgeir Larsen Wintershall

The R&D program in DrillWell addresses some key challenges within drilling and well technology. It is a strong consortium between the main operators on the NCS and the R&D partners IRIS, SINTEF, NTNU and UiS. For Wintershall it is important that DrillWell produces results and solutions that are useful for the industry. We want to see new solutions that can reduce operational cost and the cost of P&A significantly. The centre has over the last period produced promising results enabling more efficient and predictable operations.

INDUSTRY PARTNERS

Statoil ConocoPhillips AkerBP wintershall

Increasing international impact

DrillWell´s potential as an international research centre has grown significantly in 2016, as groundbreaking results emerge in scientific journals and new technology has been demonstrated successfully in the field. The Centre's visibility on the international research arena has been improved greatly through several events organized by the recently established NorTex Data Science Cluster.

BUILDING A STRONG DRILLWELL BRAND

The year 2016 marks a preliminary high point in DrillWell´s output of new knowledge, scientific publications and collaboration with the industry. Previous project investments into the main target areas of P&A and drilling optimization start to yield results, thereby confirming the vision of DrillWell: To create better drilling and well technology for the global industry.

DrillWell´s retiring chairman Stein Børre Torp from Statoil has been a strong promoter of international collaboration, institutional identity and tangible results as drivers of DrillWell´s future success.

The incoming chairman Fredrik Varpe follows the same tracks and specifies an agenda to strengthen DrillWell´s brand through relevant technological output and illumination of achievements made by the centre´s researchers. Varpe believes the well-balanced scientific and industrial interests in DrillWell´s portfolio make up an overall success story as well as specific stories from the research. The future of DrillWell is invariably depending on the public awareness of the centre´s contribution to the industry. One technology of particular interest is the advanced prediction of cuttings transport that has been commercially available in 2016 and which potentially can generate large cost savings.

«As several projects shortly start translating their results into industry technologies, we should make sure the success stories highlight the origin of the new knowledge. A strong DrillWell brand will be crucial, no matter what shape and color DrillWell takes on after the summer of 2019», Varpe concludes.

SUCCESSFUL FIRST YEAR OF THE NORTEX DATA SCIENCE CLUSTER

One important factor to strengthen DrillWell as a brand is through international partnerships and visibility on the international technology scene for plug & abandonment and drilling optimization. A major contribution in this direction is the successful first year of the NorTex Data Science Cluster, hosted by IRIS and managed by DrillWell. The grant was given at the end of 2015, and will run throughout 2018. The project is part of INTPART, International Partnerships for Excellent Education and Research. Scientists from DrillWell, SFI Offshore Mechatronics and GCE Node, together with the University of Texas at Austin and Rice University in Houston have now established a formal network. The goal is to create a larger cluster of academic institutions and industry partners with interests in digitalization. Drilling and Well technology has been targeted as the first strategic area.

«Cluster activities in 2016 include well-attended workshops at the OTC conference in Houston and later at the ONS conference in Stavanger, both regarding digitalization of drilling, as well as P&A», states senior research scientist Jan Einar Gravdal at DrillWell.

As the specific research activities currently develop in the NorTex cluster, Gravdal and his fellow researchers establish an increasingly formal network conducive to education, research and innovation.

INCREASED PUBLICATION

2016 has differed from previous years in particular when it comes to PhD headway. As several doctoral fellows achieve maturity in their research projects on DrillWell fields, a rising number of publications are submitted for peer-review and editorial check towards journal publication.

In specific numbers, DrillWell´s publication rate in peer-reviewed journals rose from six articles in 2015 to 20 in 2016. In addition, a respectable number of conference papers and other scientific formats were produced and disseminated. The distribution of scientific communication is a dedicated aspect of DrillWell´s strategy to sustain the research centre for the future.

During the mid-term evaluation performed by the Research Council of Norway in 2015, a panel of international experts evaluated DrillWell. As a result, the year 2016 has been guided by new standards throughout the organization. Board member in DrillWell and Senior Vice President of IRIS Energy Kristin Margrethe Flornes represents IRIS in the DrillWell board. She had an overall responsibility for the effectuation of new guidelines and confirms some significant results in 2016.

«Industrial relevance has always been a strong quality in DrillWell, but after the evaluation we have intensified our publication efforts towards peer-reviewed journals. The intention is to improve the academic impact of our research, and our world-leading scientists within drilling have been able to increase the number of publications sharply», states Flornes.

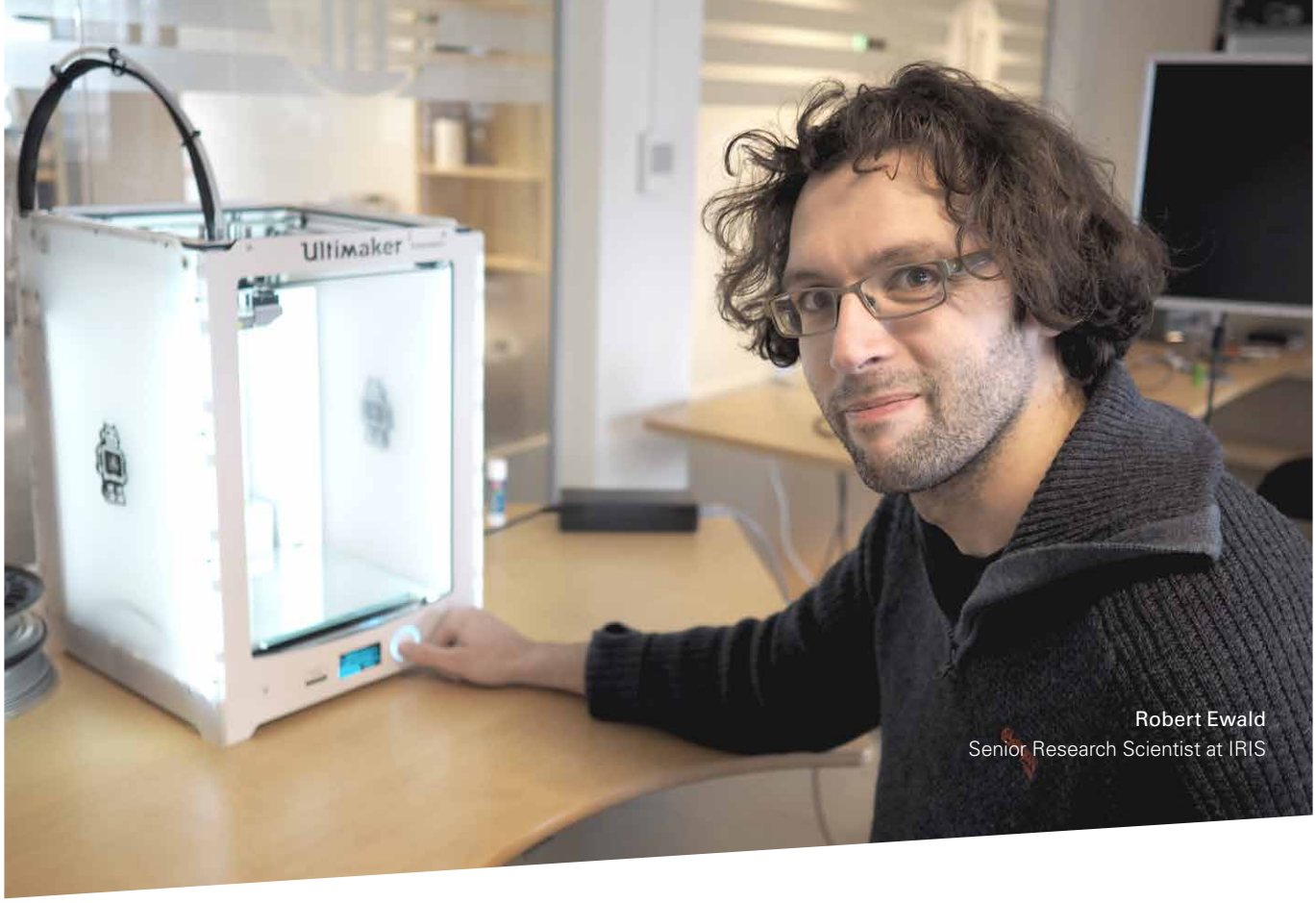
STRENGTHENING ITS IMPACT

The research plan for phase 2 which has been effectuated in 2016 maintains and sharpens DrillWell´s focus on plug & abandonment and drilling optimization as the main priority areas. Along with this, the DrillWell Scientific Advisory Committee comprising international expertise has started to act their role as quality promoters across DrillWell´s academic and scientific ventures.

During 2016 DrillWell has secured its position as an internationally recognized research centre with the highly competent industrial partners Aker BP, ConocoPhillips, Statoil and Wintershall. The setup also qualifies for public funding schemes requiring partial industrial funding, as well as for pure research and innovation programmes. From 2016, DrillWell runs three spin-off projects funded by the Research Council of Norway´s PETROMAKS2 programme. The possibility to create spin-off projects on top of the ordinary DrillWell activities strengthens international collaboration and contributes to build DrillWell's brand and increasing its impact.

Fredrik Varpe,
Chairman of the Board

Kristin Margrethe Flornes,
Board Member



Robert Ewald
Senior Research Scientist at IRIS

Jan Einar Gravdal,
Programme Manager

PROGRAMME 1:

Safe and Efficient Drilling Operations for Cost Reduction

In a time when digitalization is receiving considerable attention, DrillWell's programme on Safe and Efficient Drilling Operations for Cost Reduction is extremely relevant by targeting sensors, distribution of drilling data and data analytics.

Cost reduction is of major importance to make new oil and gas fields profitable and to increase oil recovery from existing fields. Half of the total cost for a field development in the North Sea consists of drilling and completion costs (Source: Petoro). This research programme aims to deliver technology to improve drilling safety and performance as well as avoiding drilling related problems. The programme has a broad variation of research topics, from new sensor technologies, to acquisition and distribution of real-time drilling data, to advanced analytics software.

In 2016, DrillWell has delivered software that is now being used in commercial businesses to reduce drilling costs. The transient cuttings transport model which is now commercialized by Sekal has been demonstrated to contribute to large cost savings for the operators. The potential benefit by using this software is both improved performance during drilling and to avoid expensive side-tracks.

This software is an example of technology that originates from fundamental research in DrillWell Phase I and which is being matured and tested in the ongoing Phase II. In addition, experimental work in the research partners' laboratories in Stavanger, Bergen and Trondheim has continued in 2016 and both the cuttings transport model and other models are being further developed.

Four projects have been run within this programme in 2016:

- Drilling Process Optimization (project manager: Eric Cayeux)
- Determining Changes in Oil-based Mud during Well Control Situations (project manager: Harald Linga)
- Well Control Simulator (project manager: Knut S. Bjørkevoll)
- Pressure Ahead - Pressure Prediction Ahead of Bit With Uncertainties (project manager: Ane Lothe)

Meet Solveig Riisøen, researcher at IRIS

Solveig just started her PhD project, related to DrillWell programme 1. Let's find out what switching from a reservoir engineer to a full-time researcher has been like.

PROGRAMME 1

Name: Solveig Riisøen

Age: 29

Education: MSc in Reservoir Technology from the University of Bergen

Department: IRIS Energy - Drilling and Well Modelling

What is the topic of your PhD Thesis?

The title of the PhD project is A study on the accuracy of the modelled frictional pressure loss based on rheological characterization of the drilling fluid.

What is the main contribution to the research field?

The overall objective of this project is to investigate the accuracy of the modelled frictional pressure loss of a typical drilling fluid, using a rheology curve produced by a Couette type rheometer and later look at the effect of solids particles on the predictability of frictional pressure loss.

You have a background in Reservoir Engineering. What is it about drilling engineering and your PhD study that you find interesting?

When working as a reservoir engineer it's important to understand the reservoir and how the fluids are behaving in the porous media. In drilling engineering, it is also of great importance to understand the behavior of the fluids in the well to improve the process and get better control of the well operations. It's the same laws of physics and chemistry that can be applied in both fields, and I find it exciting to be working in a new field and more towards drilling engineering. I have always been fascinated about drilling engineering and the energetic and dynamic environment.

I find the topic interesting because there are a lot of uncertainties related to calculating the frictional pressure loss and there are different aspects to the mitigation of these uncertainties to investigate. Aspects to look further into may be measurement methods, equipment, procedures, and different flow geometries to mention some.

I find the topic interesting because there are a lot of uncertainties related to calculating the frictional pressure loss and there are different aspects to the mitigation of these uncertainties to investigate.

Where do you see yourself after finishing the PhD dissertation?

There's a good working environment at IRIS Bergen and the people here are very friendly and welcoming. I hope to be able to continue working here, and hopefully continue in the Drilling and Well Modelling group on exciting new projects.

Eric Cayeux
Chief Scientist at IRIS
and project manager
of Drilling Process
Optimization

PROGRAMME 1

Drilling process optimization

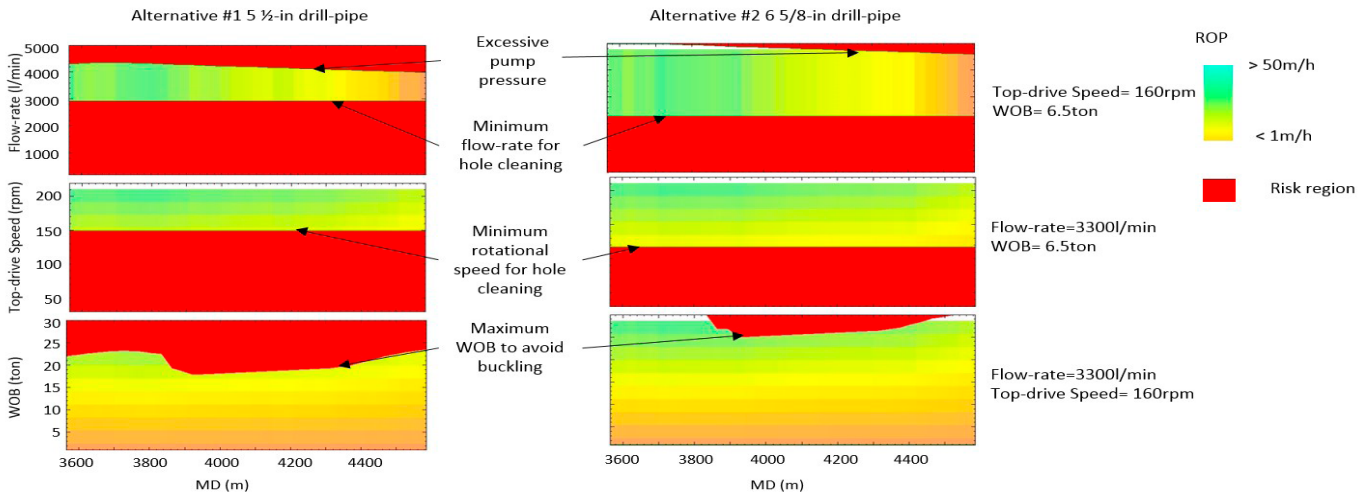
Underground conditions are uncertain and suffer from very limited downhole instrumentation. Drilling operations are therefore often confronted with incidents which, at the minimum cost, reduce the overall efficiency. In the worst case, drilling anomalies can escalate into more serious situations, where the borehole may be lost, or the safety onboard the rig can be jeopardized.

From the project start in 2011 this project has focused on providing mathematical models that can help better understand the downhole drilling conditions during the drilling operation. However, there is a complementary approach that consists in determining the embedded risk levels inside the drilling programme.

By describing the likely variations of the input parameters of a drilling operation plan, a quantitative risk evaluation method is now being used to estimate the probability of occurrence of various drilling incidents like pack-offs, stuck-pipe, formation collapse, formation fluid influx or formation fracturing, just to mention a few. Equipped with this quantitative risk estimation tool, it has been possible to compare different alternative plans and choose the one with the best compromise between safety and performance.

By the end of 2016 this methodology has been applied to a dozen drilling programmes where drilling incidents had occurred during the well construction. In each case, the software prototype detected and quantified potential risks from the operational plan, and these have shown to be prevailing during the drilling phase.

For more information about the method, see Cayeux et al. (SPE 181018, 2016) and Daireaux et al. (IADC/SPE 184693, 2017).



Comparison of the risks involved in the drilling of a 12 ¼ x 13 ½-in section of a long well when utilizing a drill-string made of a single drill-pipe size (5 ½-in) and another solution where both 5 ½-in and 6 5/8-in drill-pipe are used. One can notice that the second alternative provides better operational margins than the first.

PROGRAMME 1

Gas in oil based mud

Presence of formation gas in the drilling muds, either dissolved or entrained, represents a potential risk toward safe well operations and the avoidance of severe gas kicks. For HPHT drilling, oil-based muds (OBM) are preferred before water-based muds (WBM) due to their beneficial properties related to lubrication, shale stability and HPHT tolerance. On the other hand, OBMs reveal a significantly higher capability for physically absorbing natural gas compared to WBMs. This makes topside detection of bottom hole gas influx into the OBM more difficult during stationary operations such as flow checks or during continuous operation, circulating the mud towards the topside.

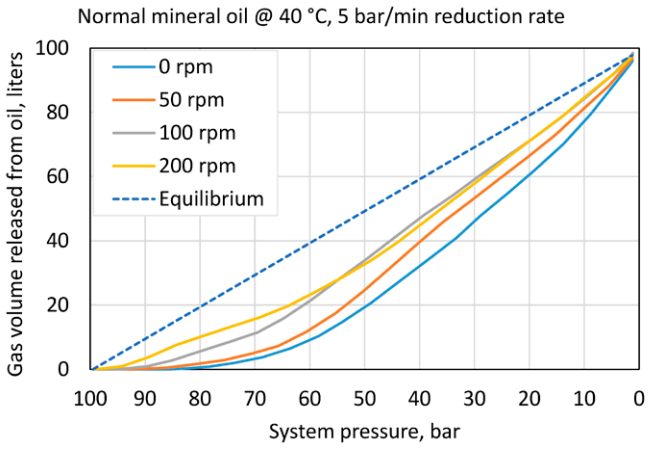
In this study, the response of gas-loaded OBM in terms of the gas release rate during depressurisation of the OBM is investigated. In particular, it is studied how the drill string rotation, the selection of base oil and temperature influences the gas release rate. The experimental depressurisation rate imposed corresponds to the typical pressure drop of the fluid volume when propagating towards topside facilities.

Initially the OBM is exposed by methane until the OBM is fully loaded with the gas at a constant elevated pressure. The pressurised, gas saturated liquid, located in a vertical annulus surrounding the drill string, is depressurized at a constant rate and the gas volume released is measured.

The gas loading capacity of OBM is governed by the gas loading capacity of the base oil, and the loading capacity is shown to be proportional to the pressure (Henry's law). Thus at any pressure during the depressurisation sequence the equilibrium loading and the corresponding gas volume is known.

It was observed that the gas release rate is very slow initially, at the higher pressures. This is more pronounced the slower the drilling rotation. It is also seen that the gas release rate is accelerated by elevating OBM temperature. The experiments are run with base oils, rather than mud, so the rheology impact from the gas release rate is not covered. It is however believed that the temperature effects seen indicate that a slower gas release rate would be observed by the OBM compared to the corresponding base oil, featuring lower viscosity and more attractive conditions for gas nuclei propagation and generation.

The results clearly demonstrate the non-equilibrium performance of gas release from gas loaded OBM, a feature which is not included in today`s commercial software for OBM hydraulic flow models.



Gas volume released vs. actual pressure for initially methane saturated normal mineral base oil, frequently used for HPHT drilling operations, during the constant depressurisation rate of 5 bar/min.

It is observed that for all drill string rotational speeds tested, from 0 (no rotation) to 200 rpm (rotations per minute), the gas release rate is very slow initially and far from what results from instant equilibrium (dashed line).

Well Control Simulator

Understanding the interaction between hydrocarbons from the reservoir and drilling fluid is of key concern for safer drilling operations. Supported by recent experimental studies in DrillWell, the impact from natural gas absorbed within drilling fluid is demonstrated. This knowledge can be particularly useful in planning and drilling High Pressure High Temperature-wells, using oil-based drilling fluids.

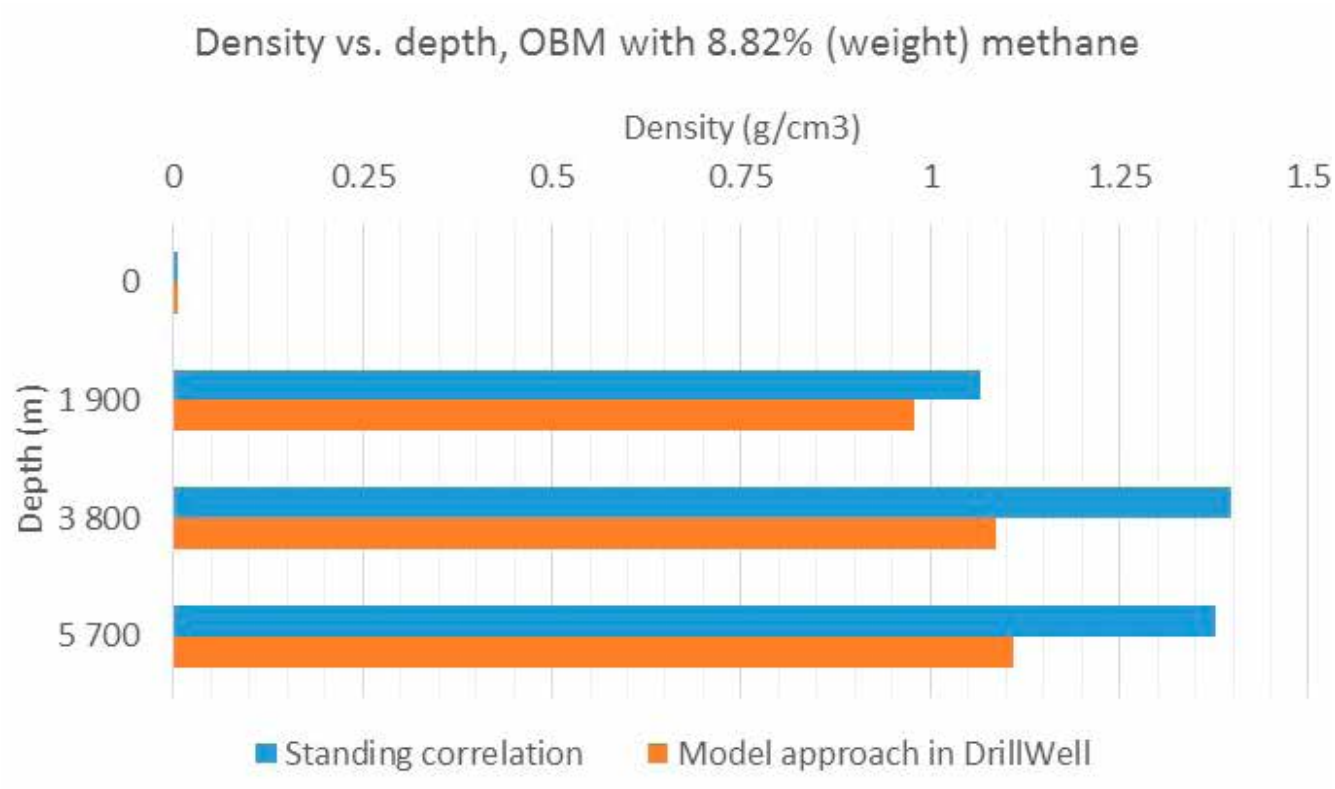
Improved calculation of gas-fluid interaction is of great importance for accurate gas kick predictions. These predictions can be applied in planning and execution of drilling operations. Current well control models suffer from simplified calculations of gas mass transfer in drilling fluid.

In order to detect kicks as early as possible and run well-control operations safer, recent knowledge from studies within DrillWell is taken further and reflected in improved procedures and software tools. The objective is to develop improved calculation algorithms for mixing and flow of reservoir and drilling fluids. Special emphasis is put on predicting effects that influence how kicks are taken and mixes with drilling fluid during static periods (closed well).

Improved modelling of the phase envelope (phase of the fluid) and density calculations of mixtures of drilling fluid and natural gas has been a key target. Modelling the dense phase is relevant for many deep wells, especially for cases where the well has been static for longer periods of time. Calculations show how gas absorption never levels out in the dense phase, even in overbalance situations.

Particularly important is the time dependency of the gas diffusion from the reservoir, the oil-gas kinetics in the well, and the numerical scheme applied for describing the gas mass transport in non-Newtonian fluids under drilling conditions.

As an example, the figure below illustrates the importance of improving density calculations. Furthermore, work done so far shows that even when using state-of-art density models, robust calibration routines supported by relevant density data are required to obtain reliable results. For more details, see SPE papers 180053, 184710, 184686, and OMAE papers 54293 and 61391.



PressureAhead – Using real time data to reduce number of well control events

Wells have been drilled on the Norwegian Continental Shelf (NCS) for half a century. Some parts of the shelf contain high and unpredictable overpressures that can lead to several problems and well control incidents. The PressureAhead project introduces new methods to reduce the uncertainties involved when dealing with these troublesome zones.

Mud is used during drilling operations to contain the pressure in the well. Choosing the correct mud weight depends on the anticipated pressure in the well and is difficult to predict ahead of the drill bit. Wrong assumptions regarding pressure and mud weight, may lead to non-productive time due to mud loss, stuck pipe and well control incidents.

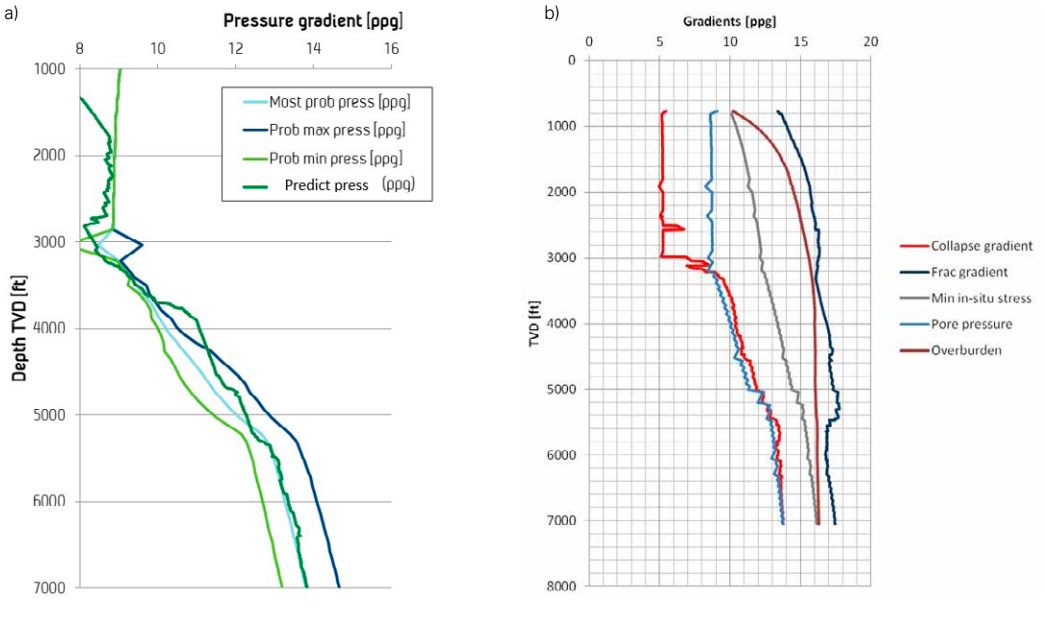
Currently in the industry, different methods are used to calculate the overpressure and mud weight window (interval in safe well mud pressure), with no unified use of input parameters. Only occasionally is an uncertainty evaluation of pressure and stress prognosis carried out prior to drilling campaigns.

In this project the objective is to reduce the uncertainty in predictions of overpressures and mud window ahead of bit. The project introduces new methods and a tighter connection between existing methods. Prior to drilling campaigns, a model is set up using interpreted seismic horizons – a 3D "picture" presenting the variation in sandstones, shales and other rocks in the study area. Since the input data is uncertain and our understanding of the processes are limited, thousands of simulations are carried out to simulate the most likely pressure profile (Fig. 1a). Thereafter, the most likely mud weight window along the planned well path is generated (Fig 1b). Through this project, we aim to update pressure prognosis and mud window by using available real time drilling data to improve predictions ahead of the drilling bit.

The new methods proposed in this project and tighter integration between software tools, can result in a reduced number of well control events by using aforementioned real time data available to the drilling team.

The project started in 2016. During the first year of the project, our focus has been addressing uncertainties in the modelling of the pore pressure and mud window, and selecting the data that can be used to update the models while drilling. For more information, please read Dupuy & Romdhane (2007), Suter et al. (2017) and Lothe et al. (2017).

As an example, the figure below illustrates the importance of improving density calculations. Furthermore, work done so far shows that even when using state-of-art density models, robust calibration routines supported by relevant density data are required to obtain reliable results. For more details, see SPE papers 180053, 184710, 184686, and OMAE papers 54293 and 61391.



a) Simulated pressure gradient (ppg) versus depth (ft) showing most probable pressure, maximum and minimum pressure curves using Pressim for a North Sea well.

b) Simulated mud window using PSI, with the most probable pressure gradient from Pressim as input. From Lothe et al. (2017).

Anouar Romdhane,
Programme Manager

PROGRAMME 2:

Geosteering and Drilling Solutions for Improved Recovery

On the Norwegian continental shelf (NCS), the costs for drilling wells are high and the remaining hydrocarbons are often located in complex reservoirs.

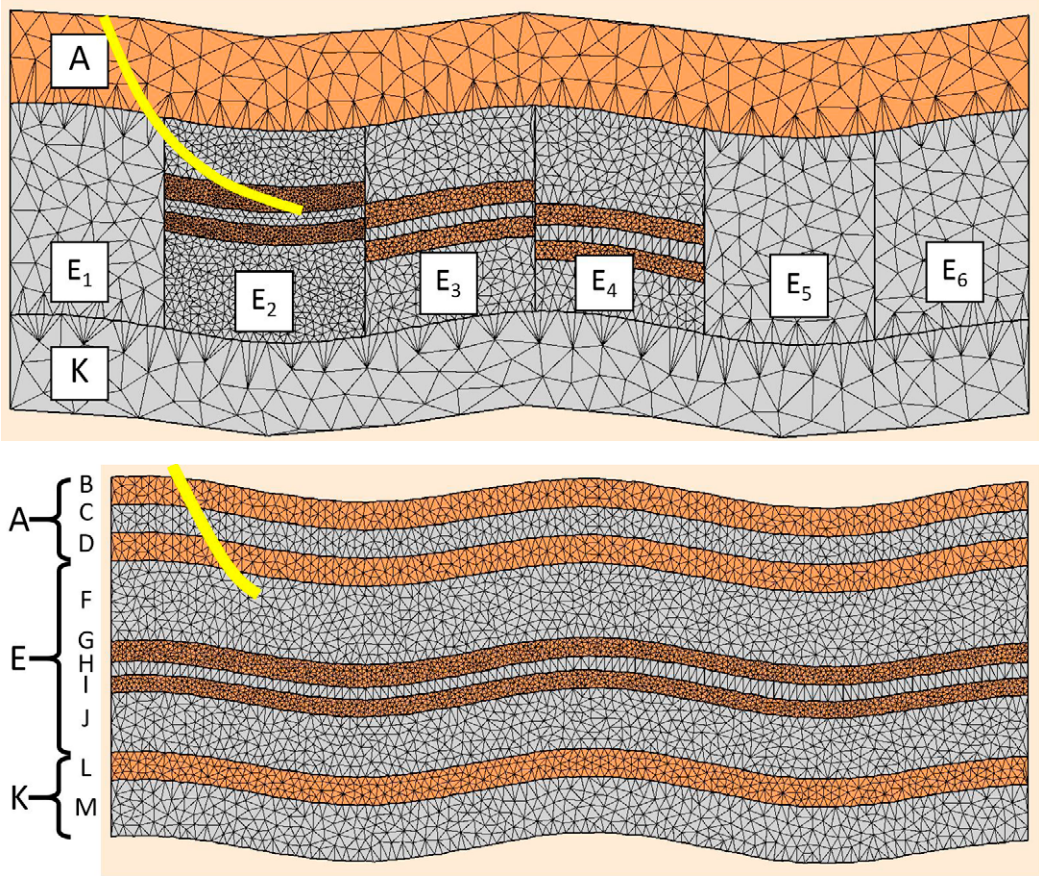
The research objective in this programme has been to develop a new methodology for geosteering where the geomodel is continuously updated based on measurements acquired during drilling.

The main focus in 2016 has been the public dissemination of the results obtained in the programme.

Decision analytics under uncertainty: figure from a case study on decision-oriented geosteering and the value of look-ahead information. The case study evaluated optimization for sequential decision making while drilling, using the Dynamic Programming method (DSDP) where the aim is to reach an optimal combination of sequential decisions. The method has been successfully applied in various industries.

Case	Description	Net Value Increase	Impact of DSDP
Base case	Small faults, medium thickness	Upto 31%	High
1	Thin reservoir, small faults	Upto 24%	High
2	Thick reservoir, large faults	Upto 10%	Low to Moderate
3	Thin reservoir, dip angle changes	Upto 56%	High
4	Flat reservoir, medium thickness	< 1%	Low

The table shows average improvement in the net value of the well in different types of reservoir. Details are available in the paper SPE-184392 and other articles by Kullawan et al.

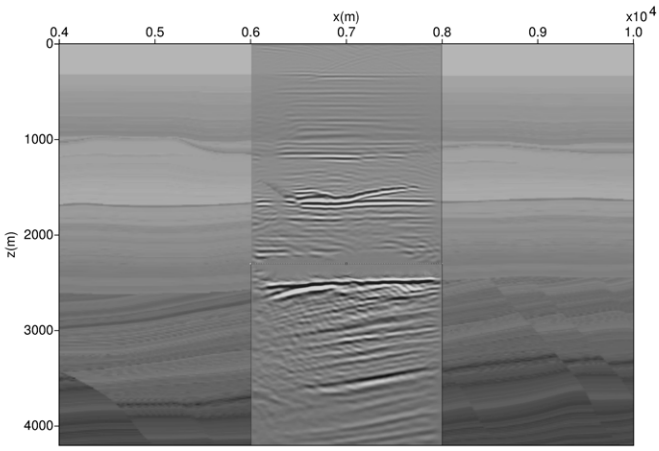


The figures show the results from a software prototype for a new earth modelling method for real-time decision support while drilling.

Flexible Earth Model: A novel software prototype aims to enable a) effective local updates of the connectivity in the geological structure and of the petrophysical properties in a populated earth model grid, b) multi-resolution control of both the geological structure and the grid, and c) local scale uncertainty modelling around and ahead of the bit including the geological structure and the properties.

In the figures above, the well being drilled is shown in yellow. Properties can be interpolated into the grid from dedicated property functions that are managed separately from the geological structure and grid (not shown here). The figures indicate how the earth model structure can be locally updated ahead of bit (new vertical faults are inserted). They also indicate how the stratigraphic resolution is coarsened away from the bit (the layers A+K above and below the reservoir, the reservoir layers E in the fault blocks E1, E5, E6). The grid is refined around the bit (fault block E2) to allow capturing of fine-scaled reservoir heterogeneities that are important for placing the well optimally. The resolution of the populated grid can be effectively updated as a local operation. The aim is to develop an earth modelling strategy where the model is never fixed, always updated with the most recent measurements and interpretations, and always at an optimal resolution. The method is described in Suter et al. (2017) and in the paper SPE-182687.

Seismic interferometry and beyond: The main research topic within this part of the programme has been to develop data-driven methods for robust target-oriented seismic imaging near boreholes. Several applications of the method include imaging using the drill-bit energy, imaging deep area of the subsurface with velocity uncertainties, better imaging that accounts for internal multiples reflections, separation of time-lapse traveltime changes in the overburden and the reservoir, and up-down wavefield decomposition in boreholes using only pressure data. The developed method requires no prior information of the subsurface, and single-component seismic data suffices. See the articles by Liu et al. for further details.



The figure indicates how the seismic image near a borehole can be improved using a newly developed method.

Torbjørn Vrålstad,
Programme Manager

PROGRAMME 3:
Well Solutions for Improved Recovery

Finding good solutions for improved well integrity is always important in order to increase recovery by prolonging well lifetime and to minimize leakages to the environment during production and after well abandonment.

All projects in Programme 3 address cement integrity and/or plug & abandonment (P&A), however with different approaches and with different angles such that all projects complement each other. The programme as a whole therefore provides a comprehensive research contribution to improved well integrity, with a special emphasis on maintaining the sealing ability of plugged and abandoned wells.

A trademark of Programme 3 is the good cooperation among the four research partners and in particular the collaborative and constructive dialogue with the industry partners, as well as with service companies. This good dialogue ensures that the deliverables from the projects are relevant and have potential value for the industry.

Two important events during 2016 were the successful PhD defenses of Mahmoud Khalifeh and Fatemeh Moeinikia at UiS. New PhD students and Post. Docs have now started and they will continue this good work by providing valuable contributions to the projects.

There are now five ongoing projects in Programme 3: three main DrillWell projects and two additional KPN projects with funding from PETROMAKS2. Most of these projects have an experimental focus where high quality results from lab-scale, medium-scale and full-scale experiments are obtained. It will be interesting to continue to follow these projects and to ensure even better synergies between them.

Projects in Programme 3:

- P3.2 Life cycle cement integrity
  (Project manager: Torbjørn Vrålstad)
- P3.3 Improved plug and abandonment
  (Project manager: Torbjørn Vrålstad)
- P3.5 KPN Cementing irregular wellbore geometries
  (Project manager: Hans Joakim Skadsem)
- P3.6 Technologies for barrier evaluation and P&A
  (Project manager: Dave Gardner)
- P3.7 KPN Leakage risk assessment for plugged and abandoned oil and gas wells
  (Project manager: Øystein Arild)

Meet Jan David Ytrehus, researcher at SINTEF

At SINTEF's petroleum laboratory in Trondheim, hidden behind cement samples and advanced testing equipment, we find Jan David, a mechanical engineer.

PROGRAMME 3

Name: Jan David Ytrehus

Age: 40

Education: MSc in Mechanical Engineering

Department: Drilling and Well, SINTEF

Hi Jan David, what are you working on right now?

I am working on fluid displacement in irregular wellbore annuli through the DrillWell project Cementing Irregular Wellbores. We have performed several medium-scale experiments in a relevant setup and this has provided many interesting results. Currently we are working on understanding our findings better and explaining what they may imply for modelling and field applications.

So, what is it that you find interesting about this topic?

It is very interesting to observe the effects of the parameters tested. Only minor adjustments can change the dominating physical effect significantly. Explaining the likely causes of these observations is challenging and exciting. It is especially nice to evaluate findings with respect to expected behaviour in a field operation.

In what way, would you say your research can contribute to the oil and gas industry?

Cementing is a crucial operation in the drilling process since you basically get only one chance to do it properly. Increasing the understanding of what happens in the annulus can be used to improve the models used also in field operations. In addition, providing a good and realistic visualization of the displacement process through videos and graphical explanation is a good base for discussing improvements to the cementing process.

Is cementing irregular wellbores what you will be working with in the future as well?

My plan is to continue doing applied research in close cooperation with service companies and operators, much like I do today. I believe there is a lot more to be done within cement displacement of complex geometries and hope to contribute with this. I also expect to work more with hole cleaning and mechanical friction issues during drilling and completion. In addition, I am involved with several topics within P&A and it's likely I will continue with this for a long time.

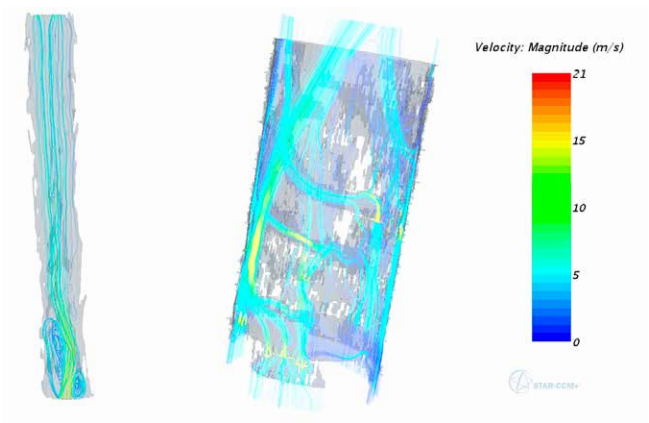
PROGRAMME 3

Life-cycle cement integrity

Cement is one of the most important barrier materials in the well, both during production and after abandonment. The aim of this project is to study degradation mechanisms and sealing ability of both cement sheaths and cement plugs. Such an improved understanding of cement integrity will lead to fewer well integrity problems and less leakage to the environment.

A tailor-made laboratory set-up has been built in this project to study cement sheath integrity during thermal cycling, where the formation of microannuli and cracks in the cement is monitored in 3D by X-ray Computed Tomography (CT). The obtained CT data is imported into a Computational Fluid Dynamics (CFD) simulation tool in order to visualize and quantify fluid flow through the created leak paths. An interesting finding so far is that fluid flow patterns and flow rates are different in cracks and partial microannuli as opposed to full, uniform microannuli.

Furthermore, the integrity of cement plugs is studied in a dedicated experimental set-up, where different cement systems are tested at relevant well conditions. The sealing ability of the plugs are determined by measuring gas flow through or around the plug for different pressure differences. Findings from this work could potentially provide important research-based input to improved barrier acceptance criteria for cement plugs.



CFD simulations of fluid flow through cracks and microannuli in degraded cement sheaths

Laboratory set-up for experimental tests of cement plug integrity

PROGRAMME 3

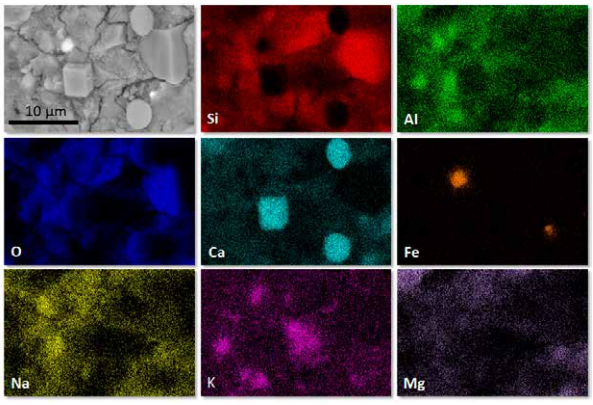
Improved plug and abandonment

Thousands of wells need to be plugged and abandoned at the NCS in the next few decades, which will be both time-consuming and costly. As most plug and abandonment (P&A) operations currently require dedicated drilling rigs, it is important to find more cost-effective methods for P&A operations that also ensure well integrity after abandonment.

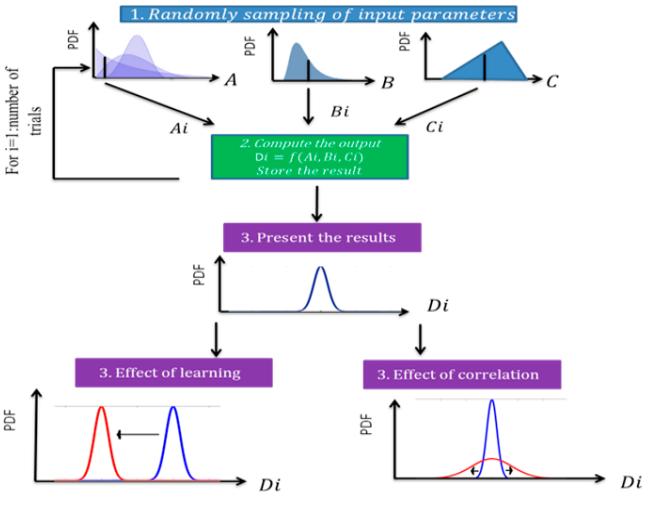
For long-term integrity of cement plugs, it is important that material properties such as mechanical strength and sealing ability do not change significantly over time after the plug has been placed in the well. In this project, ageing tests have been performed where several plugging materials have been exposed to different downhole chemicals at elevated temperature and pressure. The results show that the materials are affected by most of the chemical environments, but in different ways.

Determination of long-term integrity of cement samples

Additionally, two PhD students were also involved in the project. One PhD student was preparing and testing different types of rock-like materials known as "geopolymers" as potential plugging materials. Properties such as mechanical strength, pumpability and long-term integrity have been determined, and the obtained results indicate that geopolymers can be a suitable alternative to the more commonly used Portland cement.

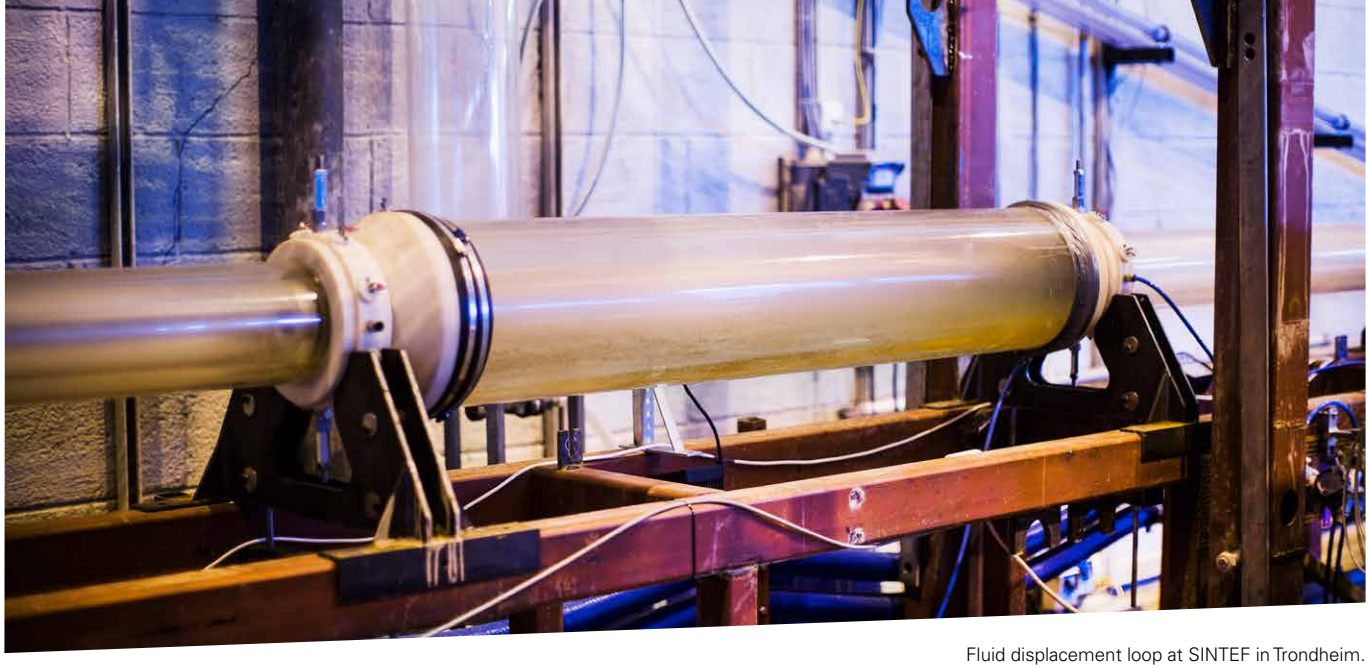


SEM image of geopolymer sample with EDX elemental composition that reveals the rock-like nature of geopolymers



Schematic illustration of Monte Carlo simulation approach during probabilistic cost and time estimation of subsea multi-well P&A campaigns

The other PhD student has developed a probabilistic method for cost and time estimation of subsea multi-well P&A campaigns. The method incorporates use of drilling rigs vs light vessels, new technologies, learning effects and other correlations, and can be used as a potential planning tool to optimize time consumption during P&A operations.



Fluid displacement loop at SINTEF in Trondheim.

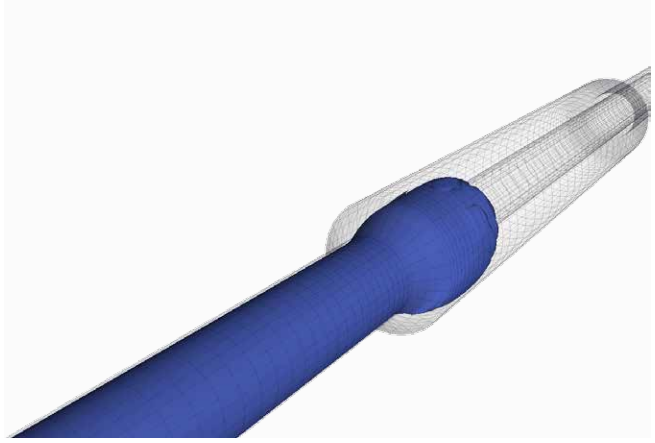
PROGRAMME 3

Cementing Irregular Wellbore Geometries

Primary cementing is among the most critical operations during well construction and one that affects the entire life cycle of a well. Quality of the cementing operation is critical for zonal isolation and productivity of the well, for well control and for P&A operations. The objective of this project is to improve the understanding of fluid displacement and cementing in irregular wellbores geometries through experiments and numerical simulations.

Fluid displacement experiments have been performed in a medium-scale flow loop, where part of the annulus contains an overgauge section representing a washout. Two experiment campaigns with non-hardening fluids have been performed, with an emphasis on determining the effects of casing eccentricity, casing rotation and wellbore inclination on fluid displacement. The displacement front is tracked along the axis of the flow loop and at the outlet during experiments, and these results are compared with numerical simulations in an OpenFOAM model of the same annular geometry.

Major findings so far show that the washout section has a significant effect on the displacement front. Furthermore, it is seen that eccentricity and inclination have pronounced effects on the displacement in the regular section as well. The large washout section slows down the displacement front, and depending on inclination and eccentricity, simulations show that different parts of the washout section becomes harder to mobilize and displace. These results can be significant building blocks toward better understanding the effects and consequences of irregular sections in the well, both locally and downstream the irregular section.



The open source software OpenFOAM is used to study fluid displacement mechanics in the proximity of irregular wellbore sections.

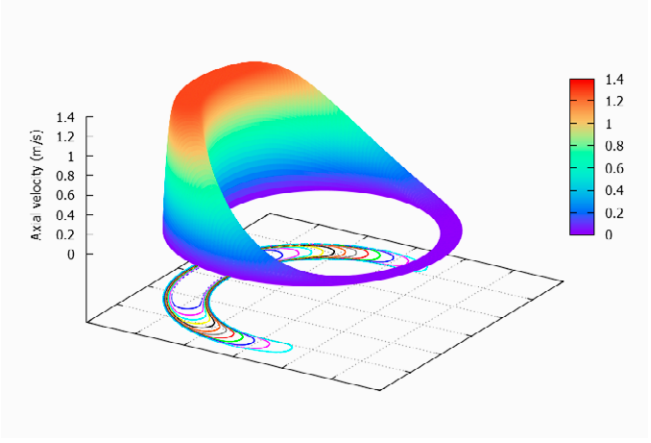


Illustration of the fully developed laminar axial velocity profile of a yield pseudoplastic fluid in an eccentric annulus with unyielded regions of fluid in the wide and in the narrow side of the annulus.

PROGRAMME 3

Technologies for barrier evaluation and P&A

To design an optimal P&A operation the barrier quality of the cemented casing(s) must be assessed. Borehole cement evaluation logs are used to map the cement placement and identify defects that might compromise the annular seal quality. A driver for the industry is to develop techniques to log the cemented casing without removing the production tubing first.

To design an optimal P&A operation the barrier quality of the cemented casing(s) must be assessed. Borehole cement evaluation logs are used to map the cement placement and identify defects that might compromise the annular seal quality. A driver for the industry is to develop techniques to log the cemented casing without removing the production tubing first.

Logging survey inside a cement reference cell with drilled defects.

The objective of this project is to establish reference conditions for cement (barrier) logging to investigate the performance of barrier evaluation technologies. Full-scale reference cells are being constructed to evaluate commercial and emerging logging technologies.

Different cell configurations can be quickly assembled using quick unions and rigged up in a horizontal or vertical configuration. The tubing and annulus pressures (max. 2000 psi) and fluids can be varied according to the experimental objectives.

A pilot phase has been executed re-using the test fixtures constructed for the "tubing left in hole" experiments. These sections represent a high-quality start point for producing reference cells with known properties. Precisely defined defects have been introduced in the cement based on studies of gas and mud channels.

Reference cells available include:

1. Uncemented casing
2. Cemented eccentered casing
3. Cement with drilled holes
4. Embedded control line
5. Micro-annulus
6. "Free pipe" for attaching cable clamps etc.

The first logging experiment utilizing the reference cells has been executed by Baker Hughes and planning is in progress with other service and technology companies.

Pressure testing a barrier logging reference cell

Leakage risk assessment for plugged and abandoned oil & gas wells

P&A barrier design is predominantly prescriptive today. An alternative approach is a fit-for-purpose approach, where the resulting P&A design to a larger degree captures the attributes of the well and its surroundings, for example by using a risk-based approach.

A prescriptive approach to P&A design implies that the same approach is applied to all wells, and does not take into account large individual differences between wells, such as reservoir pressure and permeability. In many cases, the resulting P&A design from a fit-for-purpose approach will differ from a P&A design using a prescriptive approach, and a justification for the fit-for-purpose design will be needed. Such a justification can be achieved by introducing a measure of goodness or quality of any P&A design, such as leakage risk.

Leakage risk consists of two main components: the probability of P&A barrier system failure in a given time interval and the corresponding consequences in terms of leakage rate. The main focus area in this project is to quantify the leakage risk by using probabilistic methods in combination with physical modelling.

In this project, a software tool for leakage rate calculation for P&A barrier failure is developed. In the first version, a selected sub-set of leakage paths through the well barriers has been included; i) leakage through bulk cement, ii) leakage through cracks and fractures and iii) leakage through micro-annuli. Subsequently, the software tool will be tested on real wells.

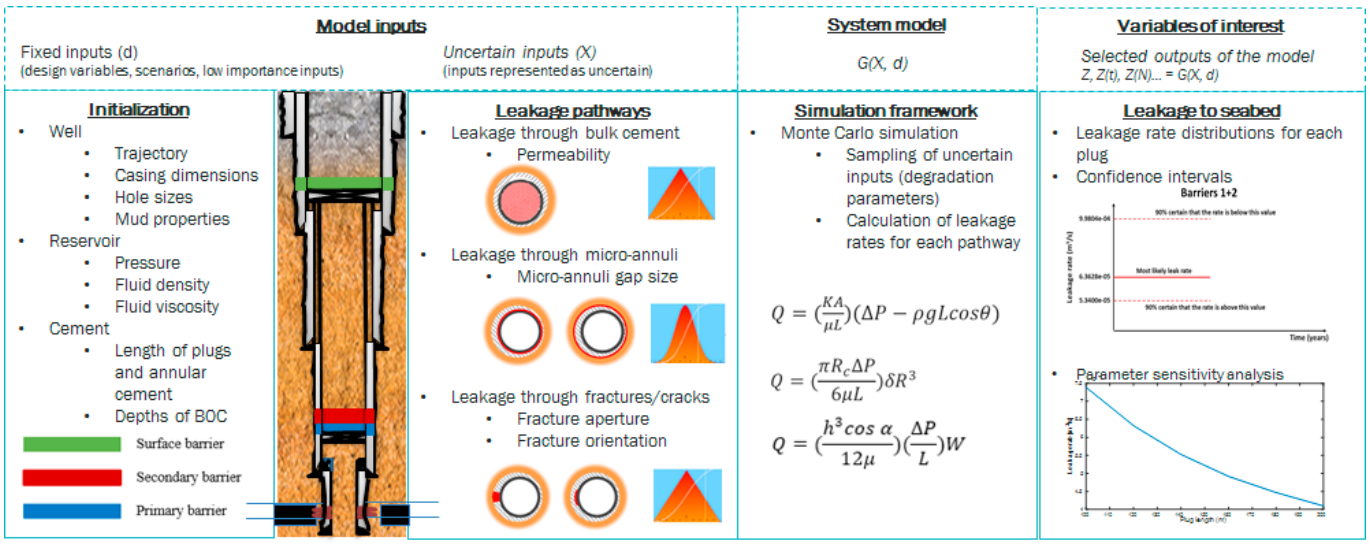


Illustration of proposed leakage calculator structure and components

OUR INNOVATIONS

Creating innovation, values and academic results for industry partners are paramount for research institutes. Compared to academic results that are measured by number of publications, innovation is difficult to measure.

Helga Gjeraldstveit, Research Director at IRIS, explains that DrillWell has delivered several results that resonate well with the six first KPI's.

One way of doing it is using Key Performance Indicators (KPI's);

1. Take into use new/improved models in e.g. studies or pilots
2. Take into use new/improved methods
3. Development of new facilities offering services to the industry
4. Demonstration of new technology
5. Patents
6. Co-authored publications with industry
7. Prototype/product (related to TRL level)
8. Technology transfer

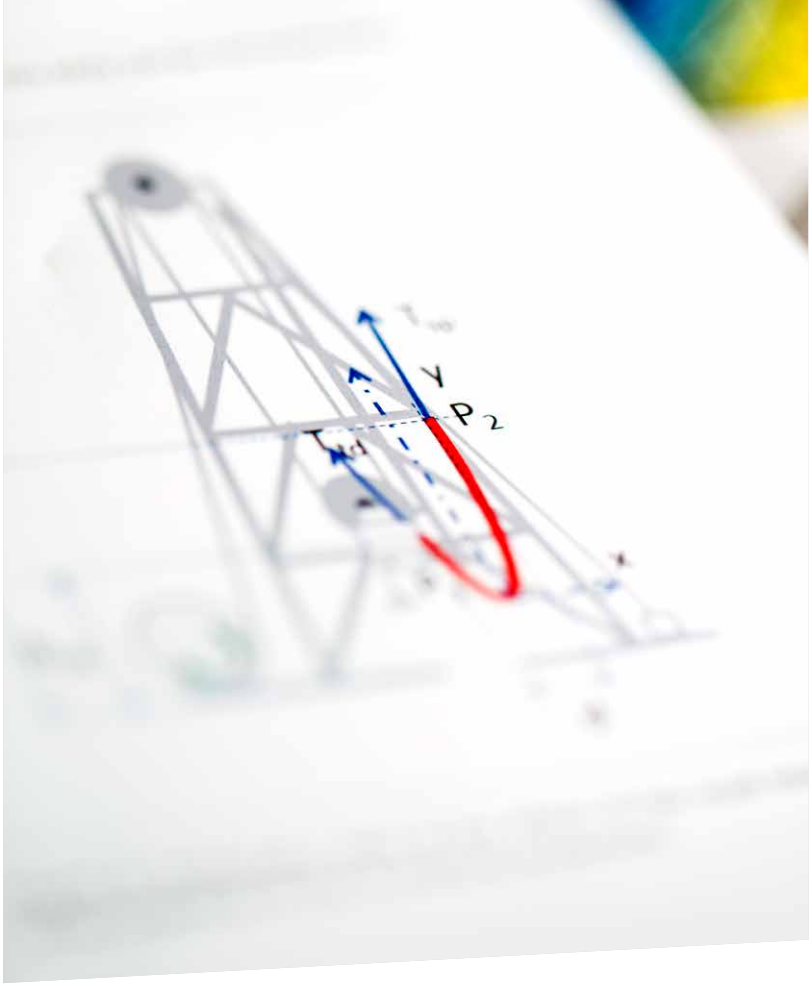
"We have executed several studies of great value for our industry partners, and the studies are also valuable for validation of our models. New facilities and procedures are established. Determining cement integrity during thermal cycling is one example. New technology such as "tubing left in hole" was demonstrated at Ullrigg and we have approval for three patents. New applications are also coming."

Helga mentions that development of technology at a higher readiness level is challenging within the SFI-framework. Especially considering the last two groups of KPI's. The SFI itself should not support product development, but it can support prototypes at the lower end of the TRL (Technology Readiness Level) scale. It is challenging for the industry partners in DrillWell to validate advanced software at early stages in development, because user-friendliness and industrialization are lacking in many instances.

Technology transfer could represent an easier way of making our research available as products. For instance, Sekal has incorporated an advanced model for simulation of cuttings transport, developed in DrillWell project P1.3 "Drilling Process Optimization", into one of their commercially available products. On one occasion this resulted in savings of nearly 50% for Sekal's client when they compared planned versus actual drilling time spent on the well.

Value for industry partners

Statoil has decided to extend DrillTronics with a new function for managing the rate of penetration (ROP). The new functionality will minimize the overall drilling duration and risk of drilling incidents.



Statoil is currently funding a spin-off project (from "P1.3 Drilling Process Optimization") called DrillTronics Smart ROP. Statoil's project leader, Mohsen Karimi Balov, is happy to see that the DrillWell centre is working as intended.

> Relevant research is performed within the centre and Statoil now intends to take the research into use through this spin-off project that fits into Statoil's portfolio.

DrillTronics, which is commercialized by Sekal, has been running on Statfjord C since late 2014, and new installations are under way.

DRILLTRONICS SMART ROP BUILDS ON FIVE CONCEPTS FROM P1.3

Transient cuttings transport model, hook-load correction, transient torque and drag model, uncertainty evaluations and risk assessment are all elements from P1.3 that will be incorporated in this new project. Project leader, Eric Cayeux explains.

> Managing drilling advancement is a question of balancing performance and risk. If there are little cuttings under transport, in some instances, more aggressive drilling parameters can be applied. While on the contrary, if there is an overload of cuttings in the wellbore, it may be wise to reduce cuttings-production to avoid occurrence of drilling incidents such as pack-offs.

ROP is mainly controlled using the surface WOB. Surface WOB is derived from hook-load measurements that are well-known to be biased and of poor quality. A new model provides a way to improve upon accuracy of the measurements. This is useful both for controlling the ROP and for a more accurate interpretation of friction tests that are an important source of information for determining if the downhole drilling conditions are deteriorating.

Another aspect of ROP management is related to drill-string vibrations. A transient torque and drag model has been developed in P1.3. This model runs in real-time and indicates whether some forms of vibration takes place and where. By running the operation with minimum vibration, damage on both BHA components and drill-string are minimized.

Finally, this new project also makes use of elements from uncertainty evaluations and risk assessment. Because the properties of formation rocks are uncertain and because the hydro-mechanical system used to drill is very elastic, and at the same time sparsely instrumented, there is always a large part of uncertainty in the estimations that are made during a drilling operation. With the inherent inaccuracy of the measurements and estimations, managing the ROP performance can be translated into a question of managing risk.

It will be exciting to follow this project further and see the different models developed in P1.3 applied in real operations. The new DrillTronics functionality will be available to the rest of the drilling community (through Sekal) when it is finished.

DrillWell
DRILLING AND WELL CENTRE
FOR IMPROVED RECOVERY

PhD students

MARIUS STAAHL NILSEN

Department: Department of Geoscience and Petroleum NTNU

Main topic of PhD Thesis: Gas influx in drilling fluid

Main contribution to the research field: Investigate the potential of gas diffusion in oil-based mud while overbalanced through mathematical modelling and lab experiments. The key performance to be measured is the mass transfer rate of gas with respect to gas type and drilling fluid composition, rheology, filter cake properties, pressure and temperature.

ANISA NOOR CORINA

Department: Department of Geoscience and Petroleum NTNU

Main topic of PhD Thesis: Cement plug integrity within plug & abandonment phase

Main contribution to the research field: The objective of this project is to study the sealing ability of cement plug throughout the life-cycle of the well, especially during the well P&A phase. The tasks will focus on determining the sealing ability of cement plugs at different conditions, such as effect of additives (with an emphasis on expandable cement), presence of mud, plug length, etc.

JACOPO PAGLIA

Department: Department of mathematical sciences NTNU

Main topic of PhD Thesis: Statistical models for pore pressure prediction and drilling window.

Main contribution to the research field: Build statistical models for the pore pressure over a spatial domain and linking this variable to measurements made in wells. The key goal is to predict the pore pressure (with uncertainties) at various depths, ahead of the drill-bit, before the well is drilled to that depth. Pore pressure prediction will be connected with the mud-weight window characteristics.

TURAL HUSEYNOV

Department: Department of Geoscience and Petroleum NTNU

Main topic of PhD Thesis: Influence of Thermal Cycling on Cement Sheath Integrity

Main contribution to the research field: The overall objective of this project is to reveal the influence of the thermal cycling on annular cement sheath and identify its severity at different well conditions as well as determine a risk of the zonal isolation loss.

SOLVEIG RIISØEN

Department: IRIS Energy - Drilling and Well Modelling

Main topic of PhD Thesis: A study on the accuracy of the modelled frictional pressure loss based on rheological characterization of the drilling fluid.

Main contribution to the research field: The overall objective of this project is to investigate the accuracy of the modelled frictional pressure loss of a typical drilling fluid, using a rheology curve produced by a Couette type rheometer and later look at the effect of solids particles on the predictability of frictional pressure loss.

SHREYANSH DIVYANKAR

Department: Petroleum Engineering, University of Stavanger

Main topic of PhD Thesis: Cementing irregular wellbore geometries

Main contribution to the research field: The research work aims to study velocity profiles in irregular (washouts and eccentricity) wellbore geometries and gain a better understanding of displacement efficiency during primary cementing.

DALILA DE SOUSA GOMES

Department: Petroleum Engineering, University of Stavanger

Main topic of PhD Thesis: Improved dynamic modelling of two phase flow in well control operations

Main contribution to the research field: The thesis work is about how we can improve transient flow models for better prediction of well control scenarios with focus on oil based muds. The plan is to also integrate new PVT sub-models under development in DrillWell. Improved models can be used for increased knowledge about safety critical issues, training as well as providing input to procedures. Improved models can be used for developing tools that can be used in an operational environment

DrillWell Post Docs

Name: Ulf Jakob Flø Aarsnes

Department: IRIS Energy – Drilling and Well Modelling

Main topic of post doc thesis: Interaction of drill string vibrations, cuttings transport and well hydraulics

Work on extending the analysis of drill string vibrations, as caused by bit-rock interaction and drill string-wellbore interaction, from simplified lumped models to more realistic distributed models. This is needed to extend the current knowledge and existing mitigation techniques to include drill string behaviour in long and deviated wells.

The variation of the drill-string rotational velocities will also affect the transport of cuttings, which in turn will affect not only the pressure losses but also the mechanical friction. These variations can result in complex wave patterns both for the fluid and the drill-string, potentially with standing waves within sub-sections of the well. The goal of the present research is to develop a combined model that accounts for the cross interactions between drill-string, fluid and cuttings motions.

Name: Fatemeh Moeinikia

Department: Department of Petroleum Engineering, UiS/ Risk management and well construction group, IRIS Energy

Main topic of post doc thesis: Leakage risk assessment for plugged and abandoned oil & gas wells

In the coming decades, thousands of wells will have to be plugged and abandoned (P&A) on the Norwegian Continental Shelf (NCS). P&A well design performed on the NCS today follows a best practice approach. Such an approach does not say anything about the quality of a P&A solution in terms of its hydrocarbon sealing capabilities in the long-term, thus making it challenging to introduce alternative P&A well design and technologies.

This KPN project aims to enable the operators to put a quality measure on any given P&A well design. The primary objective of this project is to develop a methodology for evaluating the quality of the barrier system of a permanently plugged and abandoned well by expressing the quality of the barrier system in terms of leakage probability and potential future leakage rates.

2016 DrillWell PhD dissertations

Three PhD students defended their thesis in DrillWell during 2016; Mahmoud Khalifeh, Fatemeh Moeinikia and Kanokwan Kullawan.

On May 20, **Mahmoud Khalifeh** successfully defended his thesis

"MATERIALS FOR OPTIMIZED P&A PERFORMANCE – POTENTIAL UTILIZATION OF GEOPOLYMERS" AT THE UNIVERSITY OF STAVANGER.

During Khalifeh's PhD work two new geopolymeric materials were produced and investigated regarding their usability for P&A and zonal isolation. These produced materials are environmental-friendly and have the potential to be used for civil engineering applications.

Acting as opponents were Associate Professor Runar Nygaard from Missouri University of Science and Technology (US), professor Olafur Haralds Wallevik, Reykjavik University (Iceland) and associate professor Jan Aage Aasen from the University of Stavanger.

Khalifeh´s supervisors have been Professor Helge Hodne and Professor II Arild Saasen from the University of Stavanger, and PhD Torbjørn Vrålstad from SINTEF.

On August 10, **Fatemeh Moeinikia** successfully defended her thesis

"RIGLESS P&A TECHNOLOGY AVAILABILITY AND COST EFFECTIVENESS OF RIGLESS P&A OPERATIONS" AT THE UNIVERSITY OF STAVANGER.

Moeinikia's project reviews potentials of light well intervention vessels (LWIV) for subsea well P&A. Correct estimation of cost and time is important for budgetary planning of well abandonment. In her thesis, she discusses how to structure the probabilistic modelling in line with Oil and Gas UK Guideline for cost and time estimation of P&A operation.

Acting as opponents were Dr. Antonio Lage from Petrobras (Brazil), Dr. Eng. Malene Sandøy from ConocoPhillips (Stavanger) and Associate Professor Jan Aage Aasen from the University of Stavanger.

Moeinikia's supervisors have been Professor Kjell Kåre Fjelde (University of Stavanger), Professor II Arild Saasen (University of Stavanger) and Dr. Torbjørn Vrålstad (SINTEF).

On August 31, **Kanokwan Kullawan** successfully defended her thesis

"A BAYESIAN FRAMEWORK FOR REAL-TIME OPTIMIZATION OF WELL PLACEMENT" AT THE UNIVERSITY OF STAVANGER.

The overall objective of Kullawan's project is to improve the decision quality of geosteering processes by introducing a decision analytics framework for geosteering operations. Having a well-established decision process will enable the team to better incorporate a large amount of real-time data, experiences, and expertise to achieve high quality decisions faster.

Acting as opponents were Dr. John Thorogood (Drilling Global Consultant LLP), Dr. Tor Inge Waag (Teknova AS) and Associate Professor Dan Sui (University of Stavanger (administrator)).

Kullawan has been supervised by Professor Reidar Brumer Bratvold (University of Stavanger) and Professor Kjell Kåre Fjelde (University of Stavanger).

At Eindhoven University of Technology. From left Ulf Jakob F. Aarsnes (IRIS) and Prof. Florent di Meglio (Mines ParisTech).

International collaboration

THE NORTEX DATA SCIENCE CLUSTER

The grant from The Research Council of Norway's INTPART programme, for the establishment of the NorTex Data Science Centre, has enabled closer collaboration between DrillWell and its established research partners, as well as new collaboration partners. Rice University in Houston, and University of Texas at Austin are collaborating U.S. partners in NorTex. In Norway, the project is managed by IRIS, with University of Agder and GCE NODE as Norwegian partners.

The objective is to initiate and expand collaboration on education and research within data analytics and energy research between universities and industry in Norway and Texas. During 2016, the activities in this cluster have included several workshops and seminars during OTC in Houston in May and during ONS in Stavanger in August. The collaboration has resulted in several applications both to Petromaks II and to INTPART, and contributed to scientific publications together with international renowned universities.

Visiting researchers in 2016:

Researchers from UT Austin and University of British Columbia have visited IRIS and SINTEF during the year. In addition researchers from DrillWell have stayed at both UT Austin, Rice University, University of Calgary, Mines ParisTech and Eindhoven University of Technology. Collaborating universities during 2016 are listed below:

- Rice University
- University of Texas at Austin
- University of Houston
- Oklahoma State University
- University of British Columbia
- Mines ParisTech
- Eindhoven University of Technology
- Ecole des Ponts ParisTech
- University of Calgary

TWO NEW EU PROJECTS IN GEOTHERMAL ENERGY

The competence in DrillWell enabled two EU projects granted in the Horizon 2020 programme in 2015, and the projects started in 2016. During the year, the GeoWell and Descramble projects have been well established, increasing collaboration with a broad network in Europe (Iceland, Germany, The Netherlands, France and Italy).

Communication and dissemination activities

DrillWell has improved it's visibility, and 2016 has been a year with focus on dissemination of results in conferences, and hosting workshops and seminars with programmes of high relevance for the industry and academia.

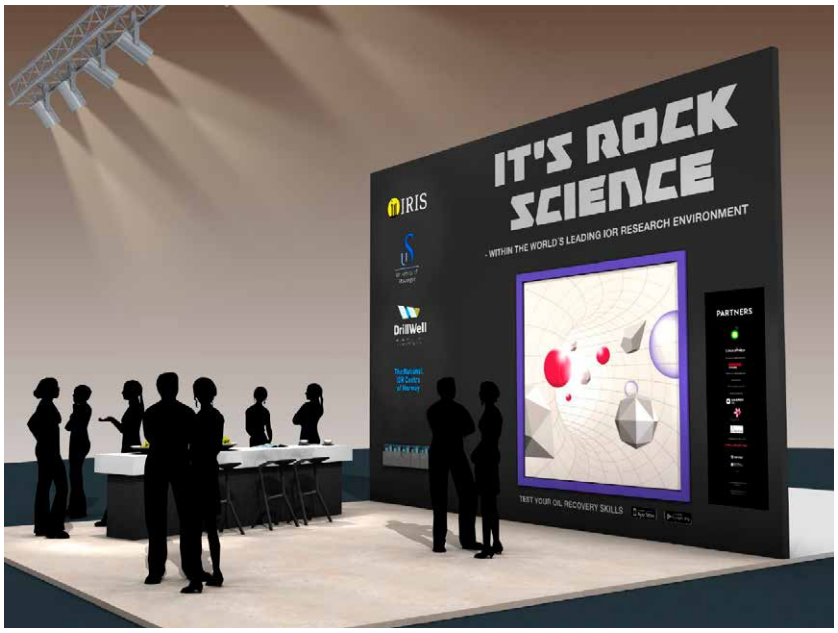
DrillWell received very good exposure during OTC in Houston with two full-day workshops arranged by DrillWell in collaboration with GCE NODE. The main topics for the workshops were drilling data analytics and plug & abandonment, two of the most important research topics to address in the years to come.

During ONS in Stavanger, DrillWell was visible both on the exhibition and with specialized workshops. One of the highlights in 2016 was the nomination of DrillWell for the "Best stand award" during ONS in Stavanger.

DrillWell has managed to achieve a strong and visible position in the shift towards automated drilling. The knowledge and experience from more than 15 years of technology development and field implementation of software for automated drilling has put DrillWell on the scene as one of the leading contributors to research within the area.

The mini-seminars for the industry partners have continued in 2016, disseminating relevant information on ongoing work and achieved results. The mini seminars also generates fruitful discussions with the industry experts and end-users, and have been very well received by the industry partners.

STAND **ONS 2016**



DrillWell, together with University of Stavanger, The National IOR Centre and IRIS, was nominated for Best Stand Award during ONS 2016.

DRILLWELL.NO
posts centre news on a regular basis

NEWSLETTERS
are distributed every three months

DrillWell is active on LinkedIn, follow us!

The Annual DrillWell seminar

The annual DrillWell seminar at Sola Strand Hotel gathered more than 80 participants, making it the largest seminar since the start of DrillWell.

Manager of DrillWell, Sigmund Stokka, welcomed researchers, clients and cooperating partners as well as associated partners. For the first time, participants from outside DrillWell were invited to the seminar.

DAY 1

The first day of the seminar was filled with presentations on Cementing and Plug & Abandonment (P&A), moderated by Kristin Flornes, Senior Vice President of IRIS Energy.

Helga Gjeraldstveit, Research Director at IRIS, gave a presentation on innovation from DrillWell and asked what is needed to be the best, before Chairman of the DrillWell board, Stein Børre Torp from Statoil, held the key note speech "R&D – Need for innovations in well construction".

The seminar proceeded with Lars Hovda from ConocoPhillips, who presented "Qualifying shale as a barrier".

"Results from displacement experiments in irregular annulus geometries" was the title of the presentation given by Bjørnar Lund from SINTEF, whereas Ian Frigaard from University of British Columbia talked about "Modelling of cement displacement". He showed the theory called "The yield stress miracle".

Jip van Eijden from Shell Global Solutions presented "Development of qualification set-up and procedure for testing zonal isolation and well abandonment materials", while Dave Gardner from IRIS's topic was "Test facilities for cement evaluation".

"P&A challenges from a service company perspective" was the title of the presentation from Per Arild Boganes from Halliburton. Will Orwell and Scott Ingram from Baker Hughes presented "Well barrier logging testing", and showed results from their DrillWell testing project at IRIS Ullrigg. Amit Govil from Schlumberger presented "Cement evaluation PWC

John Thorogood talked about the research paper "Business Models and KPIs as Drivers for Drilling Automation".

(Perforate Wash & Cement)" and Hans-Erik Olsen from Wintershall presented the experiences from Wintershall´s P&A campaign on the Murchison field. The last presentation of the day was held by Johannes Sæstad from Island Offshore, who talked about "Subsea wells, P&A operations using lighter vessels".

DAY 2

The second day of the annual DrillWell technical seminar focused on drilling technology.

Kitt A. Ravnkilde, member of the DrillWell Scientific Advisory Committee, started the list of presenters and gave a very good keynote speech. Ravnkilde represents the Danish Hydrocarbon Research and Technology Centre at DTU (DHRTC), and her presentation "Drilling and well experiences from Danish fields" showed the development of the Halfdan field operated by Maersk.

Other presenters were Eric Cayeux, IRIS - "Cutting Transport and Drilling Optimization" with results from the project P1.3 in DrillWell (Drilling Process Optimization), Alv-Arne Grimstad, SINTEF: "Gas release from drilling fluid during depressurization", Sigve Hovda from Statoil had a more practical perspective in his speech on Drilling Process Optimization seen from a Statoil perspective, while "Data quality – use of real time data" was the title of Tor Inge Waag's, Teknova, presentation.

John Thorogood from Drilling GC, and also a member of the Scientific Advisory Committee, presented "Operational performance measures in drilling" and talked about the research paper "Business Models and KPIs as Drivers for Drilling Automation".

DRILLWELL RESEARCHERS

Helga Gjeraldstveit	IRIS	Drilling and well technology
Jan Einar Gravdal	IRIS	Drilling physics
Fionn Iversen	IRIS	Drilling physics
Erich Suter	IRIS	Computer modelling
Sergey Alyaev	IRIS	Computer modelling
Jostein Sørbø	IRIS	Drilling technology
Dave Gardner	IRIS	Drilling and well technology
Dimitrios Hatzignatiou	IRIS	Reservoir engineering
Arne Stavland	IRIS	Reservoir physics
Eric Cayeux	IRIS	Computer modelling
Benoit Daireaux	IRIS	Computer modelling
Erik Dvergsnes	IRIS	Drilling physics
Steinar Kragset	IRIS	Computer modelling
Hans Joakim Skadsem	IRIS	Computer modelling
Gunnstein Sælevik	IRIS	Drilling physics
Johnny Petersen	IRIS	Drilling physics
Erlend Randeberg	IRIS	Drilling and well technology
Hans Petter Lohne	IRIS	Drilling and well technology
Xiadong Luo	IRIS	Reservoir modelling
Øystein Arild	IRIS	Risk analysis
Liv Carlsen	IRIS	Drilling physics
Kjell Kåre Fjelde	UiS	Drilling physics
Reidar Bratvold	UiS	Reservoir technology
Terje Kårstad	UiS	Computer science
Dan Sui	UiS	Computer modelling
Mahmoud Khalifeh	UiS	Well integrity
Helge Hodne	UiS	Fluid mechanics
Rune W. Time	UiS	Fluid physics
Bård Bjørkvik	SINTEF	Reservoir physics
Knut Steinar Bjørkevoll	SINTEF	Well flow modelling
Anja Torsvik	SINTEF	Fluid rheology
Jan Ole Skogestad	SINTEF	Thermodynamics
Alv-Arne Grimstad	SINTEF	Reservoir physics
Idar Larsen	SINTEF	Reservoir physics
Torbjørn Vrålstad	SINTEF	Well integrity
Ragnhild Skorpa	SINTEF	Well integrity
Bjørnar Lund	SINTEF	Drilling physics
Harald Linga	SINTEF	Drilling physics
Nils Opedal	SINTEF	Drilling physics
Jelena Todorovic	SINTEF	Drilling physics
Ane Lothe	SINTEF	Basin modellig
Johnny Frøyen	SINTEF	Numerics and software development
Anouar Romdhane	SINTEF	Seismics
Jan David Ytrehus	SINTEF	Drilling and well technology
Ali Taghipour	SINTEF	Drilling and well technology
Børge Arntsen	NTNU	Applied geophysics
Sigbjørn Sangesland	NTNU	Drilling engineering
Pål Skalle	NTNU	Drilling engineering
Sigve Hovda	NTNU	Drilling engineering

DRILLWELL PUBLICATIONS

JOURNAL

Aarsnes, U.J.F., Acikmese, B., Ambrus, A. and Aamo, O.M. 2016. ''Robust Controller Design for Automated Kick Handling in Managed Pressure Drilling''. Journal of Process Control, vol 47, November, pp46-57.

Aarsnes, U.J.F., Ambrus, A., Di Meglio, F., Vajargah, A.K., Aamo, O.M., van Oort, E. 2016. ''A Simplified Two-Phase Flow Model using a Quasi-Equilibrium Momentum Balance''. International Journal of Multiphase Flow, Vol.83, pp 77-85.

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Gelyani, A.M., Selvik, J.T., Abrahamsen, E.B. 2014. ''Decision criteria for updating test intervals for well barriers''. Journal of risk research.

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Abrahamsen, E.B., Selvik, J.T. 2013. ''A framework for selection of inspection intervals for well barriers''. ESREL conference, London, 29 September-2 October.

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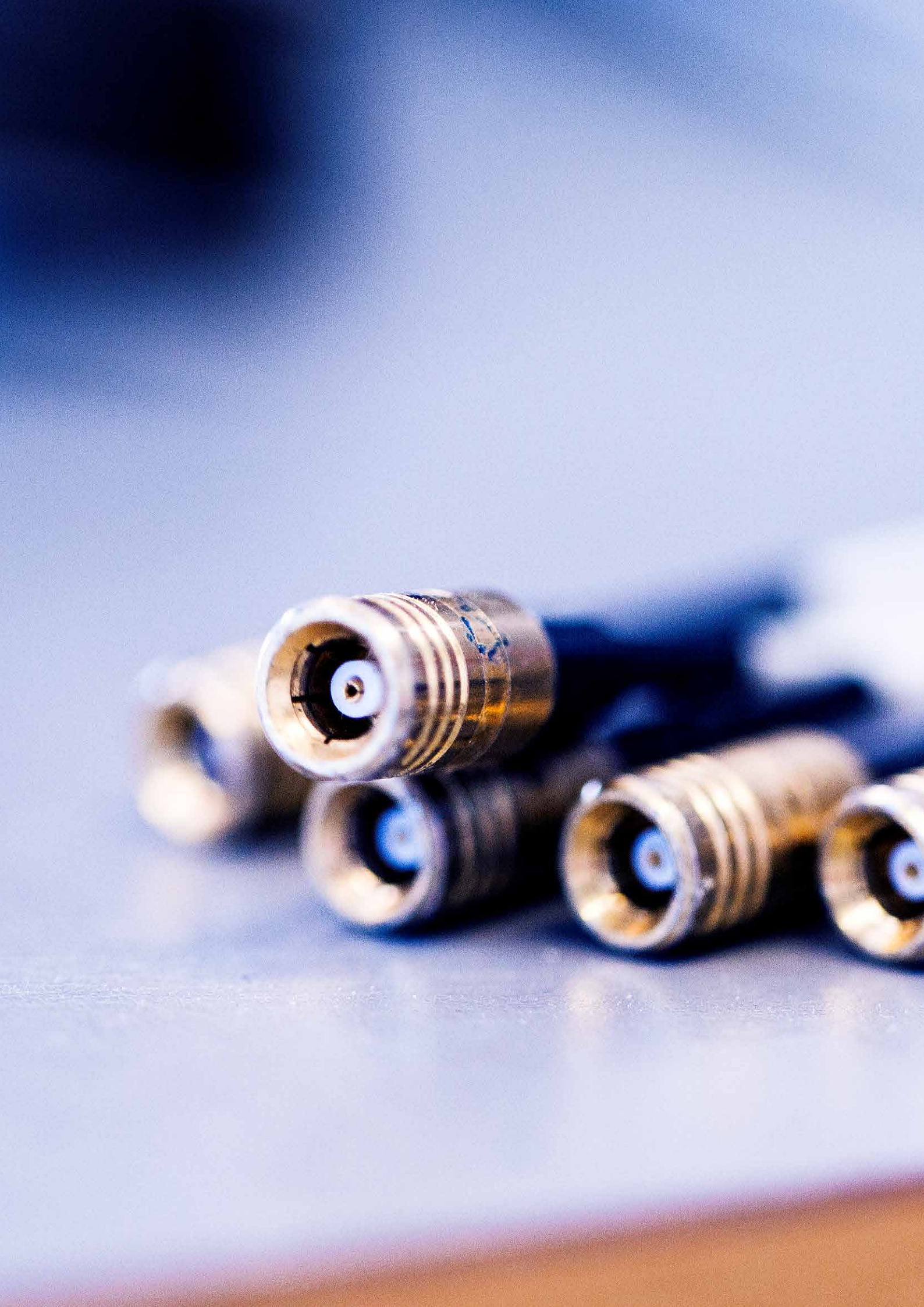

DrillWell

DRILLING AND WELL CENTRE
FOR IMPROVED RECOVERY

Drilling and Well Centre for Improved Recovery

VISION

Unlock petroleum resources through better drilling and well technology.

OBJECTIVE

Improve drilling and well technology providing improved safety for people and the environment and value creation through better resource development, improved efficiency in operations and reduced cost.

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