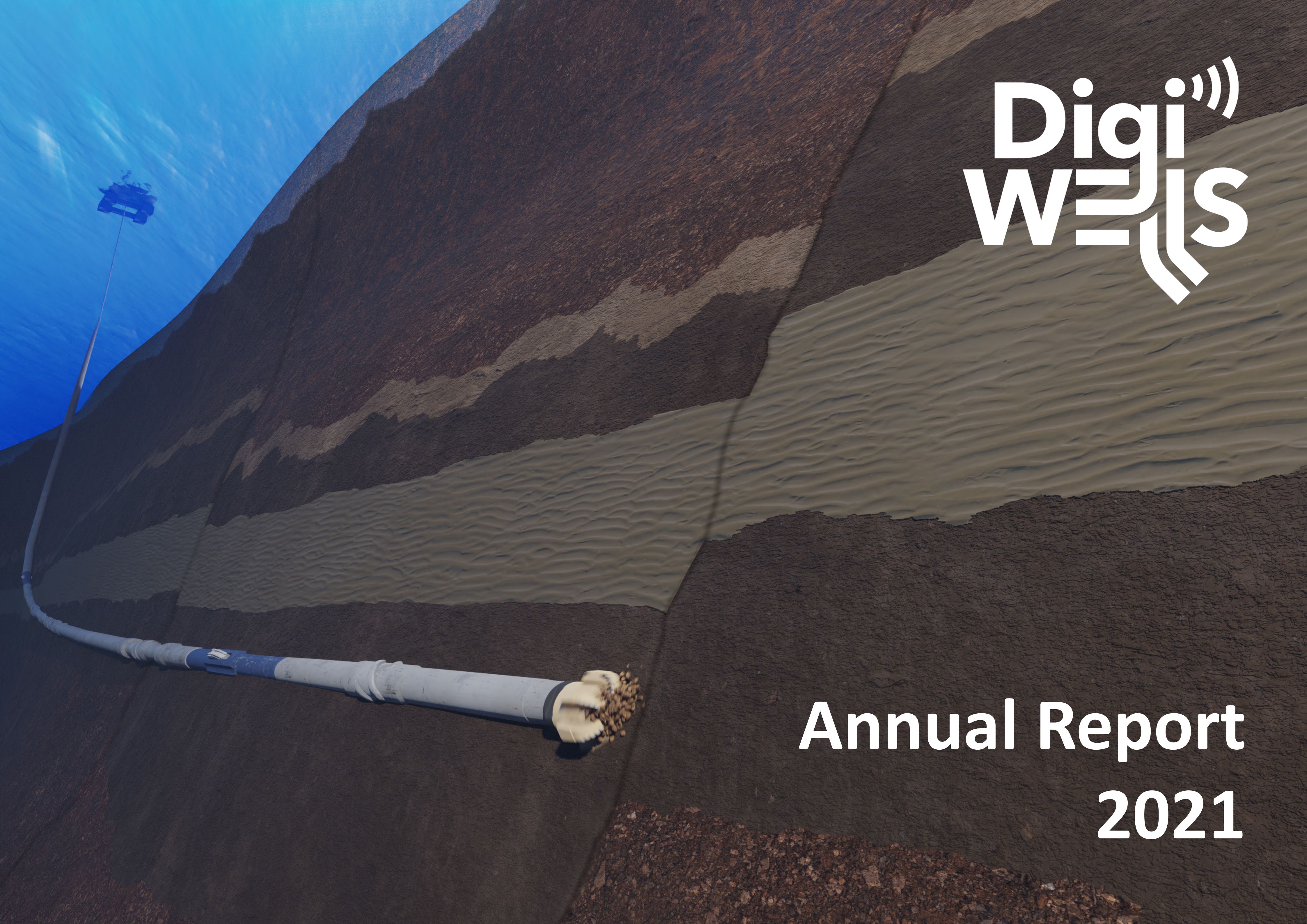


DigiWells

Annual Report 2021

Contents

Drone photo: Veronica Helle/NORCE

DigiWells:
Digital Well Center for Value Creation, Competitiveness and Minimum Environmental Footprint

VISION
Unlock petroleum resources through better drilling and well technology.

MAIN OBJECTIVE
DigiWells aims to develop new knowledge, methodologies and innovative solutions to optimize the well delivery process with special attention to challenges and possibilities at the Norwegian Continental shelf.

Subobjectives:
- Develop more efficient work process for planning the well delivery process by systematic workflows that addresses the uncertainties in a systematic way
- Develop techniques for fast modelling of the drilling and formation evaluation processes to enable optimization and improved decisions
- Investigate and develop solutions for automation and autonomous well delivery process
- Investigate and develop new measurement techniques that will improve process control
- Investigate and develop innovative hardware concepts to improved drilling performance based on in- depth understanding of the drilling process
- Support standardization and interoperability
- Strengthen collaboration between academic and industrial players
- Ensure industrial relevance and generate new ideas by performing casestudies in collaboration with end users


Mette S. Myhre, Sergey Alyaev, Erlend H. Vefring, Helga Gjeraldstveit and Rodica Mihai (photo: Rune Rolvsjord/NORCE)

Successful first operating year

The center was awarded by the Research Council of Norway in June 2020. The center has now been in operation for a little more than one year after start-up early 2021. We have been successful in attracting six operating companies representing the end users in the center. In addition, three service companies and three Norwegian universities are partners. Four international universities are connected to the centre.

For the first year 2021, four main activities have prioritized. The main activities have been automatic well engineering, deep learning, organizational interoperability and distributed drilling control. These activities were selected from several candidate activities. A total of four PhD students have also been recruited and have started.

Each of the four main activities have had two demonstrations, one before summer and one at the end of the year. This has been done to ensure efficient collaboration between involved partners, ensure progress and to be able to do adjustments of plans.

Due to the pandemic situation, the official opening was delayed until November 23rd and arranged in combination with the first annual seminar for the centre. Very inspiring opening statements were given from the Minister of Petroleum and Energy, CEO of the Research Council of Norway, CEO of Petoro and CEO of NORCE. Key-note presentations from Equinor and Total energies also emphasized the importance of the topics addressed in the center. At the annual seminar, technical presentations from NORCE personnel and partners were given. In addition, a physical demonstration of a new technology for vibration damping was given.

The publication from the center has been satisfactory with a total of 23 publications.

A highlight for international collaboration has been that Nazanin Jahani stayed at University of Texas at Austin for a period in 2021 for collaboration with the internationally recognized research team there within formation evaluation.

The DigiWells Innovation Committee is established, and processes are ongoing to start industrialization of results related to the center. The results include new work processes for drilling engineering, software developments which may become available as software as a service, new standard for organizational interoperability which will be made available to the industry and a new solution for vibration damping, for which a patent has been filed.

We look forward to more exciting research, development, innovation and collaboration in 2022.

Erlend H. Vefring, Centre Director, NORCE

Erlend H. Vefring (photo: Rune Rolvsjord/NORCE)

About DigiWells

Digitalization, new sensors, new high-speed telemetry solutions, automation, autonomy, and improved work processes has the potential to enable a step change of the well delivery process.

The centre will explore these possibilities by combining domain knowledge with fundamental research to accelerate the digital transformation of the well delivery process.

The centre aims to develop work processes for planning drilling and well operations, new sensors, solutions for interoperability, solutions for automated and autonomous drilling, and decision support systems for geosteering. New solutions will be demonstrated at the national research infrastructures OpenLab Drilling, Ullrigg and against field data from operators.

The centre will become a collaborative arena for operators, service industry, public authorities, research institutions and academia in Norway and internationally. Results from the centre's activity will enable innovation, business development, and value creation for the Norwegian society. Moreover, in collaboration with universities, the centre will educate the next generation of specialists who will help implement the achieved research results.

The DigiWells consortium connects the operators, service companies, and academic partners. It is the place where experts of different disciplines talk together.

Partners

Official opening of DigiWells

More efficient drilling - less emissions

DigiWells was officially opened in November 2021. The goal of the center is to develop new knowledge, methods, and innovative solutions to improve the well delivery process through the use of digitization, new sensors, high-speed telemetry, automation, and autonomy.

The center will use the national research infrastructures OpenLab Drilling and Ullrigg in Stavanger, for testing and developing ideas on a small scale, before being taken out in the field.

Photo: Veronica Helle/NORCE)

- In many ways, SFI DigiWells is a kinder egg, Marte Mjøs Persen, Minister of Petroleum and Energy, says.

- Through increased digitization and optimization you will help to optimize well production, reduce negative environmental impact, and increase value creation opportunities. I applaud this center!

- DigiWells will develop knowledge and digital solutions that will contribute to a competitive Norwegian continental shelf, increased profitability, and reduced emissions. Digital competence will be crucial in the years to come. We must build completely new industries on the shoulders of those we have. The knowledge you develop in DigiWells can also be applied for CO_2 storage underground and geothermal energy production. We look forward to following you in the years to come, Tveit says.

Kristin Kragseth, CEO of Petoro, believes a large part of the solution is to use new technology - further digitization.

- But digitalization takes time, and changing work processes is demanding. Now it's time to try out technological solutions and subsequently implement them as best practices on our rigs. I applaud your work! Kragseth says.

How we can contribute to UN's sustainable development goals

SFI DigiWells can play an important role in reducing carbon footprint in the petroleum sector and the developed methods and knowledge can be transferred to other industries. We hope to achieve significant contributions especially to UN's goals number 7 and 9.

Today's unstable political situation has put the focus on especially stable gas deliveries to Europe. To ensure access to sufficient energy, it is very likely that the petroleum sector will be part of the energy mix for many years. Thus, we need to continue to work for reduced carbon emissions from this sector.

The potential for reduced CO_2 emission from automated drilling technology

NORCE has since 2008 had automated drilling as one of the target areas. Solutions for automated drilling has been commercialized by Sekal. A report made by Rystad Energy assesses the potential effects on costs and emissions from implementation of Sekal's technology:

"Two clear initiatives have been identified for Sekal, both expected to decrease drilling expenditures and reduce drilling emissions from ultimately reducing the total rig demand and length of rig contracts. The first initiative is directed at the reduction of technical sidetracks and the second is decreasing drilling time through automatization of the drilling operations. Full global adoption of Sekal's DrillExpect and DrillScene software has the potentials of reducing CO_2 emission by 2.1 million tons and cost by 13 billion USD annually. If the automation software DrillTronics is fully adopted in addition the CO_2 emission reduction increase to 2.9 million tons, and costs can be reduced by 17 billion per annum."

Work in SFI DigiWells

In DigiWells we build on this knowledge, and the ongoing research has the potential to further decrease the CO_2 emission. DigiWells focuses on developing automation and autonomous well delivery process, new measurement techniques important for closed-loop control and support standardization and interoperability. All these can contribute to reduce failures, costs, and energy consumption in a safe way. We have done it before and strongly believe that we with DigiWells will continue along this path and make results with large potential for reduced carbon footprint available for the industry.

We also see many possibilities to transfer methods developed in DigiWells to other sectors and has several ongoing initiatives. Efficient well delivery is important for CO_2 storage and geothermal energy production also.

Industry perspectives

From the first year of its inception in January 2021, SFI DigiWells consortium has already been active in demonstrating its value through the research in various topics with focus on digital transformation of the Oil and Gas industry.

We see epics addressed in SFI DigiWells not only relevant for advancements of technology in the Norwegian Continental Shelf, but also helping the entire industry to move forward towards safe, more efficient and sustainable operations while minimizing the environmental footprint of our Upstream activities.

SFI DigiWells has proven to be an industry leading initiative, which targets digitized work processes for planning and execution of well delivery, using technologies like machine learning for prediction of drilling efficiency and stratigraphy ahead of the drilling bit, helping to solve the interoperability challenges in the multidisciplinary sense.

Four 2021 epics demonstrated some high quality tangible results that were achieved in a relatively short time span. Furthermore, ideas generated in SFI DigiWells give opportunities for spin-offs projects, and having so many operators, research institution and universities working together creates an excellent eco-system where these ideas will eventually turn into real solutions implemented in the industry.

Anar Ismayilov, TotalEnergies

TotalEnergies

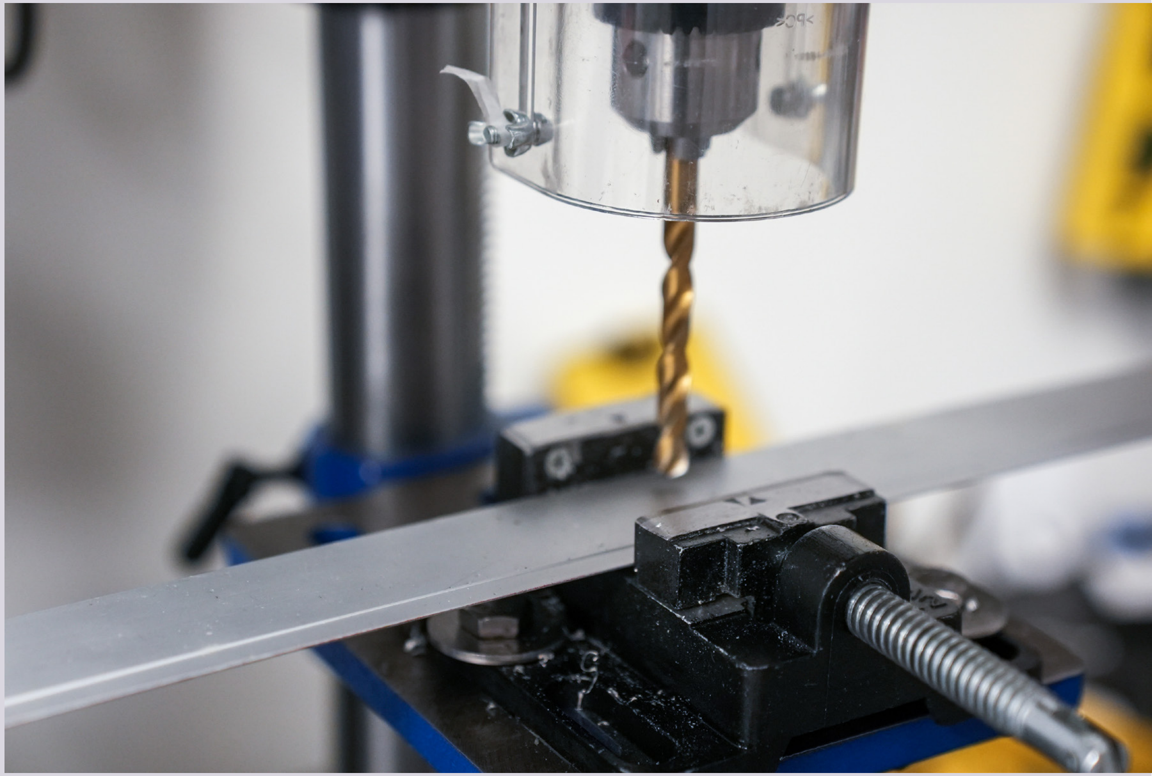


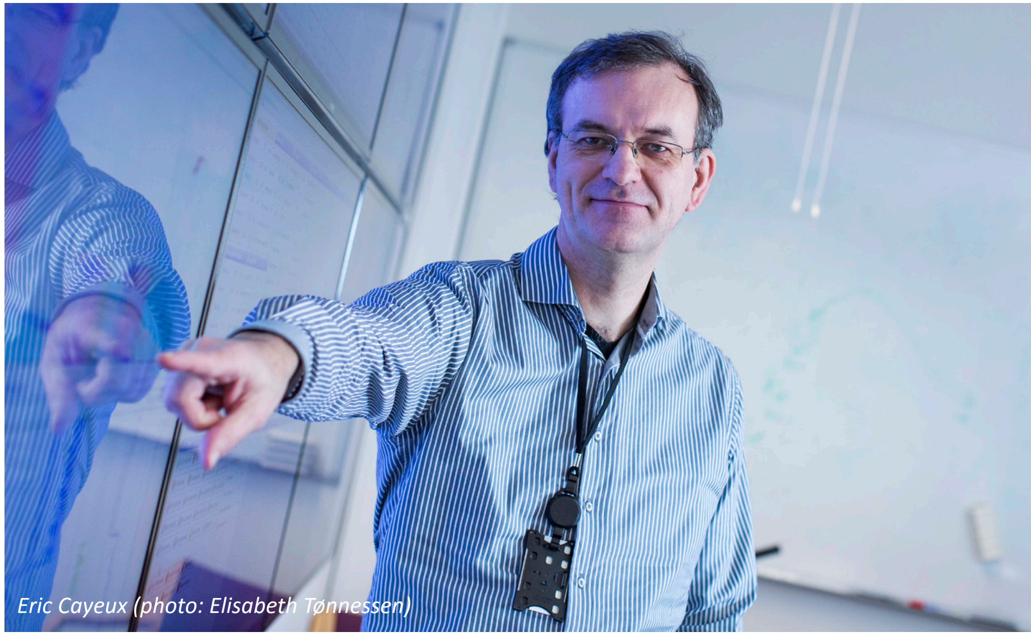
Photo: Lisa Ravna Rørmoen/Screen Story

EPICS

Photo: Lisa Ravna Rørmoen/Screen Story

Automatic Well Engineering

A digital drilling program consisting of an ensemble of possible drilling design using information from both the planning phase and the operational phase



Eric Cayeux (photo: Elisabeth Tønnessen)

Background

Drilling engineering and drilling operation are two steps of the well construction process that are treated sequentially and separately. The interface between those two steps is the drilling program, i.e., a unique solution that has been singled out and analyzed in detail during well planning. However, when an unexpected situation occurs during the drilling operation, the drilling program is of little use to take informed decisions as it does not contain any information about acceptable tolerances. In practice, the drilling operation needs to adapt to the actual drilling conditions, which often are different from the one expected at the planning stage. As the drilling program does not contain any information about the reasons why some design choices have been made nor acceptable tolerances for deviation from the plan, it is difficult to take informed decisions as the plan does not fit with the actual situation.

A digitalized drilling program

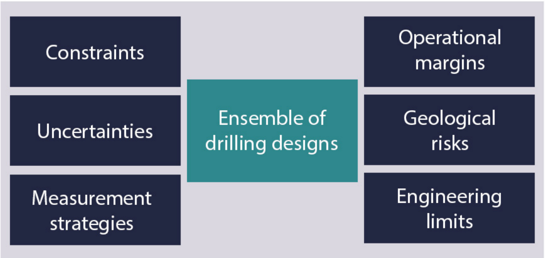
An alternate approach for passing information between the planning stage and the operational phase, could be an ensemble of drilling designs that account for:

- Uncertainties
- Design constraints
- Geological risks
- Engineering limits
- Operational margins
- Measurement strategies

From this point of view, the drilling program turns to be an ensemble of possible solutions, each of them associated with potential risk levels. In this context of an ensemble-based drilling program, engineering estimations are constraints that limit possibilities for the minimum rig capabilities, the planned well path, the directional surveying program, the top-side and downhole instrumentation, the BHAs and drill-stems, the fluids, operational parameters.

The workflow to produce the ensemble solutions consists in using multiple automatic generators for each of the possible elements of the drilling program, e.g., well path, surveying program and BHA. The calculations made in the directional drilling, mechanical and hydraulic engineering estimations are used to decide which combination fulfil all the requirements imposed by the proximity to neighboring wells, geo-pressure margins, etc. Solutions are within engineering safety criteria decided by the drilling engineering team.

Therefore, the digital drilling program can be considered as the collection of all the constraints and boundaries that need to be respected and an ensemble of solutions that satisfy these constraints.



A digital drilling program is the combination of constraints, uncertainties, measurement strategies, operational margins, geological risks, engineering limits that delineate an ensemble of possible drilling designs.

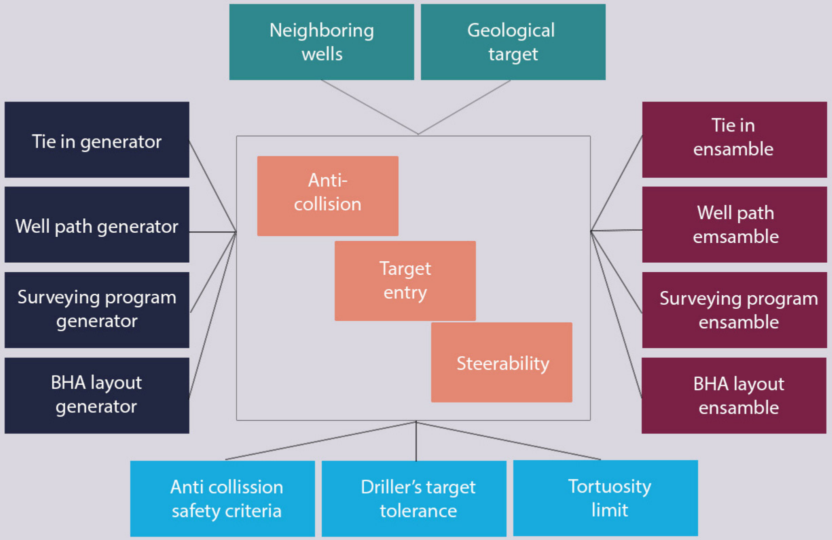


Illustration of the typical directional drilling engineering estimations and their associated constraints and engineering criteria

Anticollision

The complete realization of an ensemble-based drilling program is a huge task. This first year, the scope has been focused on directional drilling engineering estimations. In the context of directional drilling, there are at least three different estimations that need to be made:

- Is there any risk of collision with other wells?
- Is it possible to enter the geological target boundaries?
- Can we steer the trajectory properly?

The outcomes of these estimations are an ensemble of possibilities for the starting locations, i.e., tie-in positions, well paths, surveying programs and BHA layout in terms of directional drilling capabilities. The given constraints are the position of neighboring wells and the geological target(s) to be reached. The directional drilling engineering estimations are furthermore parametrized by anti-collision safety criteria, acceptable driller's target tolerances and maximum tortuosity limits. To estimate the ensemble of possibilities, we need automatic generators for tie-in points, well paths, survey programs and BHA layouts. The automatic generation of possibilities is recurrently based on other types of constraints which are more at a design and architecture level.

Main results

A generic method for ensemble-based drilling program taking into account uncertainties and constraints has been developed. In 2021 the focus has been on directional drilling and how the surveying program can automatically be generated to respect anticollision criteria with neighboring wells and acceptable driller's target dimensions.

The main outcome is a digitalized drilling program that generates surveying programs and their envelopes of well paths that respect a set of directional surveying constraints. The following capabilities are included:

- A fast algorithm for true 3D separation criteria between wellbore position uncertainty
- A fast algorithm to discover all potential trajectories that are at risk for collisions accounting for wellbore position uncertainty. The algorithm works at the earth scale and is not impacted by choice of cartographic projections.
- A model to analyze the impact of BHA directional tendencies on wellbore tortuosity
- A generic method to calculate well paths and target axes

Digitalized drilling programs with the above capabilities give the opportunity to do well-considered choices during the planning phase, e.g., by choosing a combination of wellpaths and surveying programs that gives a sufficient clearance to the constraints. At the operational stage, when unexpected situation occurs, acceptable margins are readily available allowing for deviating from plan in an informed way and without recourse to qualitative judgement.

More details about this work can be found in a paper that is going to be published at the SPE/IADC Drilling Conference 2022, SPE-208791_MS An Ensemble-based Solution for Automating Drilling Engineering: Application to Directional Surveying by Eric Cayeux, Erik W. Dvergsnes, Lia A. Carlsen and Rodica Miahai.

EPIC 2
Project leader:
Sergey Alyaev

Deep-learning models of drilling-process and subsurface prediction that estimate uncertainty

Deep-learning models of drilling-process and subsurface prediction that estimate uncertainty.

Optimization of the drilling and well placement process relies on the modeling of drilling processes. The models need to be fast to enable the real-time performance of optimization algorithms which often require thousands of model evaluations. Drilling speed, also known as Rate of Penetration (ROP) has a direct influence on the cost and energy footprint of a drilling operation. High-fidelity physics-based models are not sufficiently fast for real-time optimization. Data-driven and hybrid models enabled by machine learning give a fast performance while maintaining sufficient prediction quality. However, most of them rely on a large amount of data representative of the whole operation and yet do not account for uncertainty limiting their usage in the context of optimization. Focus has been on uncertainties related to drill-bit performance and geology/lithology of the drilled formations.

Transfer Learning for ROP Prediction

Many attempts have been made to predict the rate of penetration. Although with some success, traditional physics-based models require frequent recalibration depending on the auxiliary data such as facies types, bit design, and mud properties. This is problematic since the geological environment is among other things unknown prior to drilling and would require correlation to data from nearby (offset) wells. Machine-learning models use data to find correlations among many drilling variables which avoids some drawbacks of physics-based models. However, higher predictive capability comes at the cost of substantial data requirements, computational constraints during training, and generalization capability. These practical issues hinder ROP models for field deployment.

Transfer learning is an active research field in deep learning that involves reusing a model trained for a more general task for another more specific task. Reusing a pre-trained model for a target task allows better performance with less training, see Figure 1. Transfer learning techniques have been proven successful in many domains such as computer vision and natural language processing where data is expensive or hard to obtain.
We adapted transfer learning techniques to the ROP prediction during drilling. We first train base models using real or simulated data from previously drilled wells. Then, we reconfigure each model by freezing some parameters and retrain it using a small portion of the data from the well for which we perform the estimation. For four out of the five test wells considered in our study, the transfer-learning produced a better predictive model with lower mean absolute error than training an entirely new model or using the base model without retraining, see e.g. Figure 2. For the fifth case the results were on par, but required less computational time.

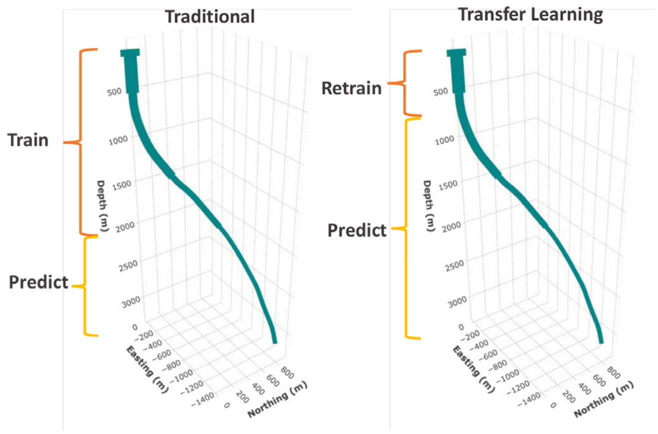


Figure 1: Data utilization for traditional versus transfer learning approaches for well data.

Five test cases with historical drilling data from two fields indicate that retraining the base model would produce

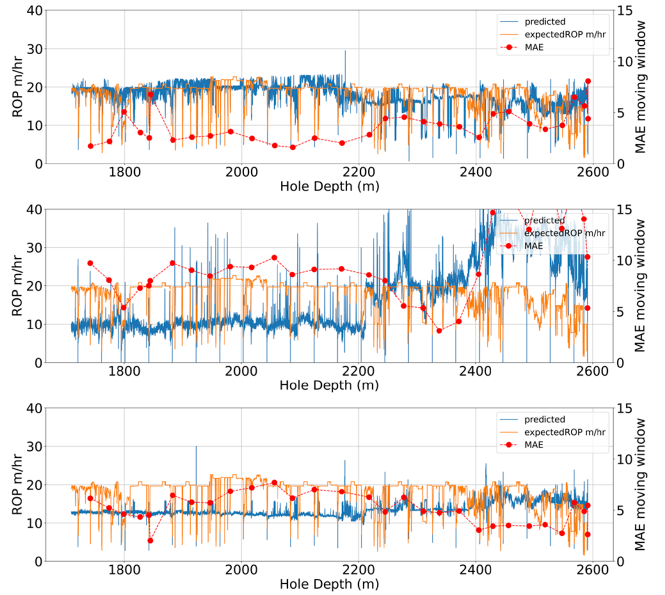


Figure 2. Fine-tuned model (top) gives better prediction than the base model (middle) and the newly trained model (bottom). The MAE curve shows Mean Absolute Error difference between the predicted and expected ROP.

a better model than training an entirely new model or using the base model without retraining. Transfer learning allowed to reduce the training data requirement from a typical 70 percent down to just 10 percent. In addition, transfer learning reduced computational costs and training time. Finally, results showed that simulated data could be used in the absence of real data or in combination with real data to train a model without trading off the model's predictive capability.

Probabilistic prediction to resolve drilling efficiency

Drilling is a highly uncertain process, and drilling efficiency can highly vary depending on whether the drill bit cutters are operating in the optimal mode and also on their wear and tear. To give reliable predictions of the ROP it is desirable to move from a possibly inaccurate deterministic prediction to a probabilistic prediction.

We developed a quantile regression deep neural network (DNN) that predicts ROP probabilistically for several time steps ahead. The DNN outputs the quantiles for the ROP: in addition to the expected median (P50), we also calculate lower and upper percentiles: P10 and P90. The DNN architecture is shown in Figure 3. The idea is that P10/P50/P90 give a more realistic range of values for the observed ROPs, yielding a highly robust predictive model which quantifies uncertainties.

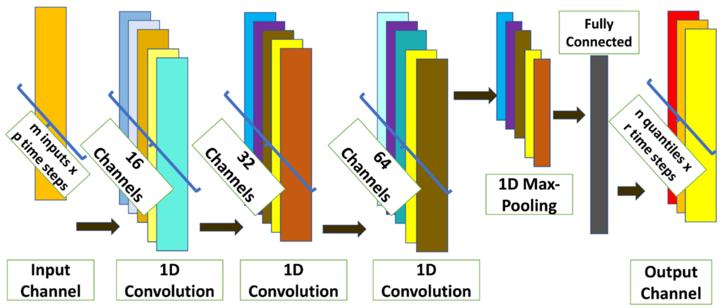


Figure 3. The architecture of the deep neural network for the quantile regression model.

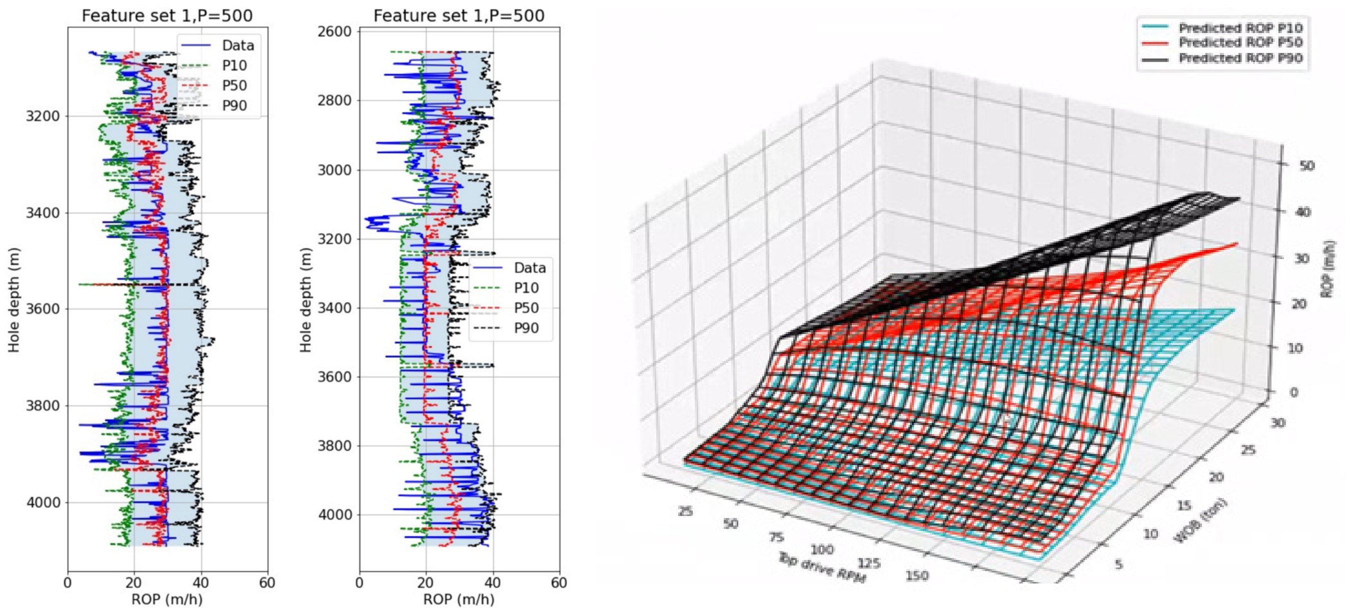


Figure 4. Left panel: P10, P50, and P90 estimates from the DNN for two well sections from the Volve field. Right panel: a map of estimated ROP versus top drive revolutions per minute (RPM) and weight on bit (WOB), generated with our deep neural network model.

The approach was tested on publicly available drilling data sets from the Volve field in the North Sea, wherein several wells were used for training the models and others for validation and testing. Results on the validation and test data sets show that the proposed approach can give accurate predictions of ROP in real operations while including the uncertainty due to variations in drilling efficiency.

The left side of Figure 4 illustrates the P10, P50, and P90 estimates from the deep neural network for two different well sections from the Volve field. The right side of Figure 4 depicts a map of estimated ROP versus two common drilling parameters, top drive revolutions per minute (RPM) and weight on bit (WOB), generated with our deep neural network model. Such maps can be used within ROP optimization algorithms where the prediction uncertainty can give insight on the variations in drilling efficiency, for instance, due to drill bit wear or other technical limitations.

Multi-modal stratigraphy prediction with deep learning

One of the main uncertainties that would influence the ROP prediction is the strength of the rocks that are being drilled. Understanding the rock types which are currently drilled requires fast interpretation of streamed geophysical measurements. As such interpretations are not unique, prediction of ROP can benefit from exploration of all likely interpretations and estimation of their probabilities.

We developed a mixture density deep neural network (MDN) that correlates the log of the drilled well with the corresponding log from an offset well and outputs a chosen number of interpretations of the geometry of geological layers and their probabilities. Moreover, by learning the likely configurations from the geological training data, it can predict stratigraphy ahead of the data yielding better quality input for e.g., ROP modeling. Our model achieves good accuracy and produces more geologically realistic interpretations compared to the deterministic single-output model. The evaluation time for a single inversion is 1.5 milliseconds.

Sergey Alyaev and Rodica Mihai (photo: Elisabeth Tønnessen)

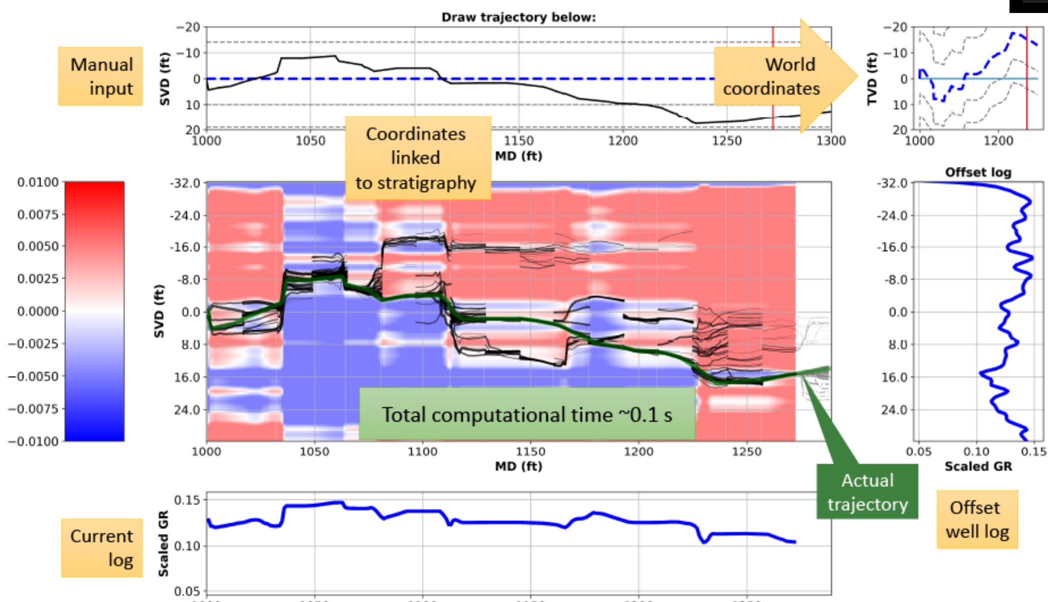


Figure 5. Sequential interpretation of the gamma ray (GR) log of the horizontal well (bottom) which is correlated to the offset log (right) by the MDN. The green line shows the "true" trajectory (in the stratigraphic vertical depth coordinates) provided by a geologist and the black lines are possible interpretations that are predicted by the MDN. The gray extension of lines shows the realizations of extrapolated geology ahead of data.

In a continuous drilling operation, this method needs to be applied sequentially to track all probable solutions. Our interactive demonstration showed that the MDN is indeed able to continuously track the correct interpretation over tens of steps even for a geological model provided by a geologist (unconstrained by the domain of the training data), see Figure 5. Yet the computational time for tracking all the possibilities and repeated inversions is maintained below 0.1 seconds in total.

Main results

In 2021 the team explored the applicability of transfer learning to ROP prediction and adapted state-of-the-art machine learning methods to the domain: quantile-regression prediction for ROP prediction with drilling efficiency uncertainty, and a stable mixed density network for multi-modal prediction of stratigraphy ahead of drilling. These results were summarized in the following publications:

1. Transfer Learning Approach to Prediction of Rate of Penetration in Drilling accepted in Springer Lecture Notes in Computer Science (International Conference on Computational Science, 2022). Authors: Felix James Pacis, Sergey Alyaev, Adrian Ambrus, Tomasz Wiktorski

2. Rate of Penetration Prediction Using Quantile Regression Deep Neural Networks accepted in OMAE 41st International Conference on Ocean, Offshore & Arctic Engineering. Authors: Adrian Ambrus, Sergey Alyaev, Nazanin Jahani, Felix James Pacis, Tomasz Wiktorski

3. Direct Multi-modal Inversion of Geophysical Logs Using Deep Learning submitted to Earth and Space Science. arXiv:2201.01871v1. Authors: Sergey Alyaev, Ahmed H. Elsheikh

4. Sequential Multi-realization Probabilistic Interpretation of Well Logs and Geological Prediction by a Deep-learning Method accepted for SPWLA 63 symposium (2022). Authors: Sergey Alyaev, Adrian Ambrus, Nazanin Jahani, Ahmed H. Elsheikh

EPIC 3
Project leader:
Rodica Mihai

Distributed Drilling Control

Innovative control methodology and hardware solution for vibration damping.

Vibrations of drill string often cause reduced drilling speed as well as damage to bottom – hole assembly elements and downhole tools. Drilling vibrations can also cause casing wear which is a major concern at the Norwegian Continental Shelf (NCS) due to increased reuse of wells. Furthermore, reduction of drill string vibrations may also help decrease the energy consumption during drilling operations due to improved energy transfer from topside to bit. Several solutions for mitigating drill string vibrations through active control of the top drive speed or torque have been developed. These solutions have been successful to a certain extent, but they often have more limited success in longer wells or with small diameter drill-strings.

Proposed solution

The distributed nature of the sources of excitations and negative damping requires that the drill string vibration problem is addressed along the whole string. It is desirable to reduce the impact of those sources of excitation and negative damping. On the other hand, increasing viscous damping can naturally damp out vibrations at their inception. Based on this principle, a passive sub using a non-rotating sleeve and introducing viscous friction has been designed. At the local level of the damping sub, axial and torsional motions are decoupled in order to attenuate vibration excitations caused by the transfer of mechanical friction between axial and tangential sliding. The damping sub outer diameter is slightly larger than the one of the surrounding tool joints to support the local weight on an element that presents lower mechanical friction forces than the neighboring contact points. Finally, the damping sub introduces decoupled viscous friction forces in both the axial and rotational directions so that incipient vibrations get quickly damped out. Several damping subs are spread along the drill string to augment the damping effect.

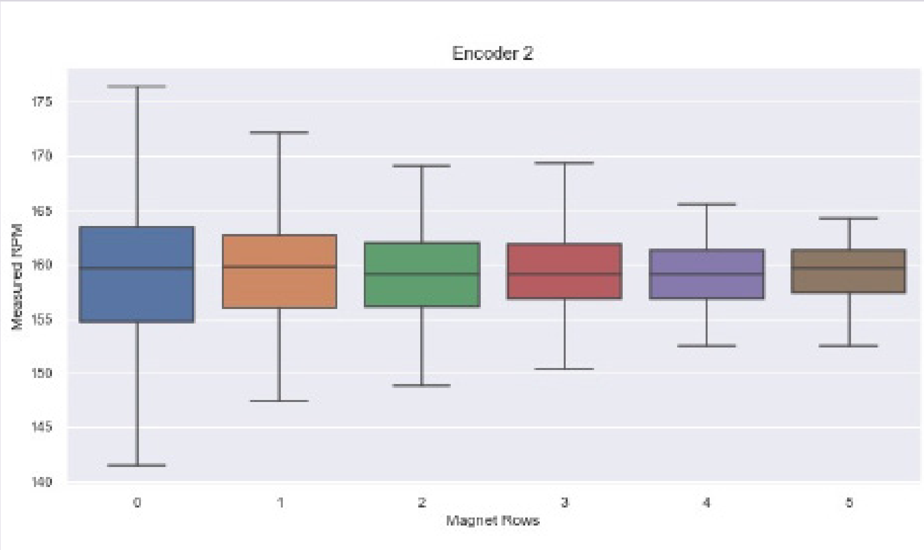
Laboratory set-up

A small-scale test bench for doing experimental testing of passive vibration damping has been as constructed as shown in the picture to the right.

Mathematical modelling

The concept has been investigated through simulations with a transient axial-torsional drill string model with distributed interaction with the wellbore modelled using Coulomb friction. The damping subs are included in the model at selected locations along the drill string. The model is completed by boundary conditions represented by the top drive dynamics and the bit-rock interaction. Case studies representative of field operations are simulated with different damping sub positions along the string to evaluate the resulting

Andrew Holsaeter demonstrates the laboratory set-up. Several experiments have been conducted to investigate the effect of introduction of damping subs including varying number of damping subs and strength of damping (photo: Lisa Ravna Rørmoen/Screen Story).



Example results from experiments showing damping of oscillations when accelerating from 0 to 160 RPM with different number of damping subs (magnet rows)

reduction in torsional drill string vibrations and mechanical friction during combined axial and rotational motion. The simulation results show that the viscous damping provided by 2-4 damping subs, placed at locations where high side forces are expected, can effectively remove torsional oscillations and reduce the top drive torque. These results indicate that use of the proposed damping subs can reduce damage to downhole tools, improve drilling performance, and also achieve lower energy consumption by the drilling rigs.

Main results:
An innovative concept for vibration damping of drill string has been developed.

Mathematical modelling and small-scale experiments related to damping subs have been the focus in 2021:

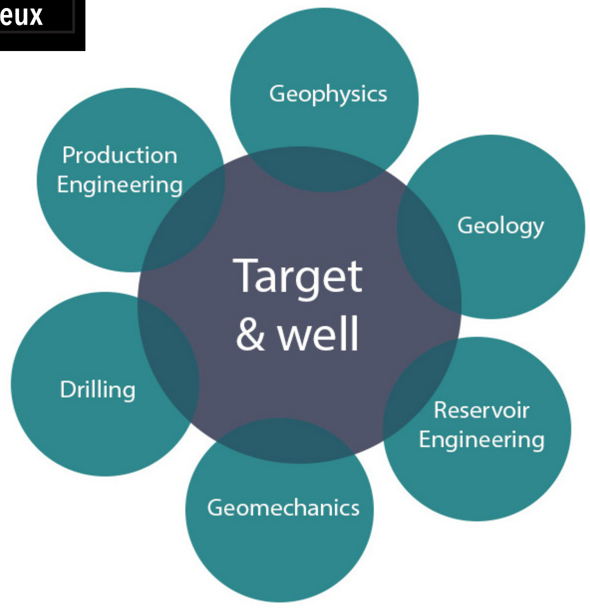
- Mathematical models for predicting the effect of applying damping subs along the drill-string have been developed
- A small-scale test bench for doing experimental testing of passive vibration damping has been constructed
- Simulation results compares well to experimental results
- Mathematical modelling for different scenarios has been performed and shows promising results.
- A patent for passive vibration damping of drill string vibration has been filed.
- A paper was sent to ASME 2022 41st International Conference on Ocean, Offshore and Arctic Engineering OMAE2022. A journal paper is under preparations.

More details about this work can be found in a paper that is going to be published at ASME 2022 41st International Conference on Ocean, Offshore and Arctic Engineering OMAE2022, June 5-10, 2022, Hamburg, Germany, OMAE2022-78339, "Modelling and analysis of non-rotating damping subs for removing torsional vibrations in drilling", by Adrian Ambrus, Ulf J. F. Aarsnes, Eric Cayeux and Rodica Mihai.

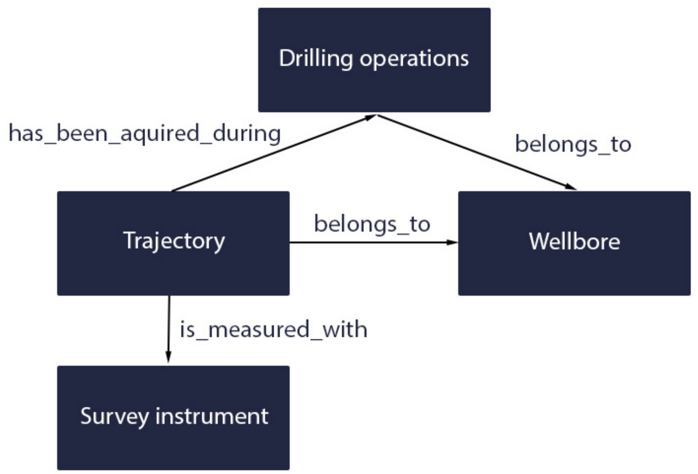
EPIC 4
Project leader:
Eric Cayeux

Organizational Interoperability - DDHub+

Semantic description of multi-disciplinary workflows allowing software solutions to discover drilling data whenever available and how they relate in terms of uncertainty propagation.



Many different workflows and multiple disciplines are involved in the planning, execution and post analysis of wells where information needs to be exchanged.



A simple example of a semantic graph for drilling

The drilling life cycle involves several steps from planning to post analysis. This is a complex process involving many disciplines and stakeholders. Pieces of information are often unknown, incomplete, erroneous or at least uncertain. Yet, during well planning and construction, drilling data quality and uncertainty are barely addressed in an auditable and scientific way. There are few or no placeholders in the relevant databases for documentation of uncertainty and its propagation.

Semantic Graph

The goal is to develop a method that increases confidence in understanding and describing data quality and uncertainty during well operations. This will result in improved overall decision-making related to the identification of risk and associated mitigation plans.

To achieve this, a more flexible and abstract knowledge representation is needed to address the relationship of drilling data uncertainty and quality. In this epic we have chosen a semantic network for this purpose. A semantic network is a graphical method, also known by other names in the literature such as semantic graph, semantic net, knowledge graph, semantic web, etc. Many companies who deal with unstructured and human-friendly information use this method to represent relationships in data.

A semantic network is quite difficult to explain in a simple way, but we give it a try! A semantic network is a collection of facts expressed in the form: subject – verb – object. These facts can be linked to each other's and therefore generating a directed graph. These semantic graphs capture how data are related by:

- Describing relations between the different data entities
- Describing the process that underlies the generation of data

Therefore, there is now a computer-readable description of work processes.

Data Lake

We then need to connect the semantical graph with actual data, the data lake. A data lake is a system or repository of data stored in its natural/raw format. A data lake is usually a single store of data including raw copies of source system data, sensor data, social data etc., and transformed data used for tasks such as reporting, visualization, advanced analytics and machine learning.

Each noun/node in the semantical graph has a uniform resource identifier (URI - a character sequence that identifies a logical (abstract) or physical resource) to connect to the data lake world. URIs can be defined for the different documents, databases and real-time sources.

Demonstrated Use Cases

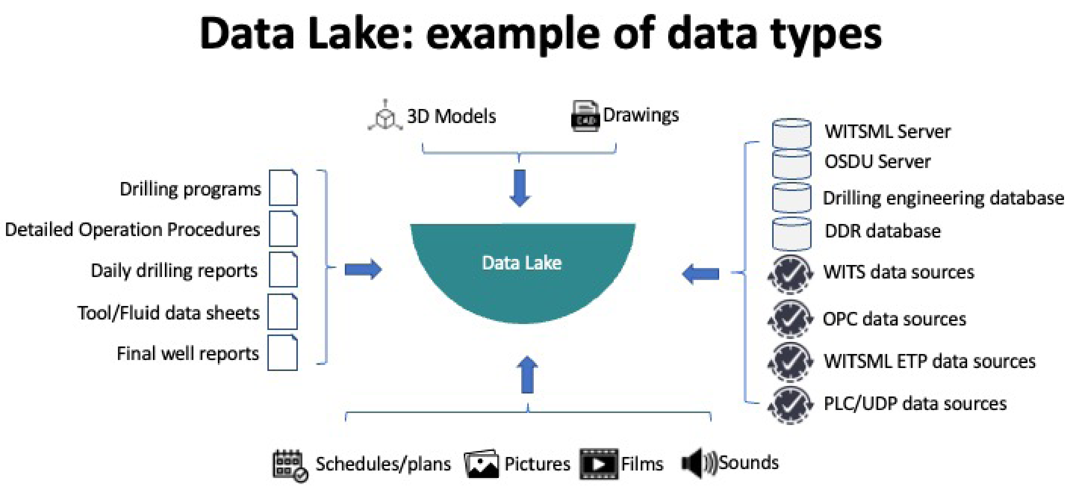
The methods developed are applicable in a generic fashion, but to demonstrate a rather abstract concept several use cases have been constructed from a "user story." The "user story" origin from material collected by the SPE sub-committee for "Drilling Data Quality and Uncertainty Description" (DDQUD). NORCE chief scientist Eric Cayeux is leading this sub-committee. You can read more about DDQUD in the section "International Forums and Committees."

The chosen user story selected to illustrate drilling data quality and uncertainty in this epic is:

Tabulation of well survey data is typically to two decimal places when the uncertainty, at deeper depths, is in whole meters / feet and multiples thereof. This is misleading to the end user and subsurface modelling (especially cross correlation of pressures) suffers badly. A common representation of uncertainty on shared measured depth (MD) and true vertical depth (TVD) data will help ensure that end users take into account the real uncertainty in the data.

This example of a user story breaks-down into 17 use cases that express the variability in measurements of measured depth, how TVD is estimated, and how these are managed and communicated – and the relative uncertainty that may propagate from this point through any interconnected measurement system. The use case technique enables us to display a set of behaviors the system may perform and observe how actors, be they human or other systems, interact to produce an observable result that contributes to the set goal. It has been demonstrated that the method based on semantic graphs has the potential to describe a broad range of complex drilling-related processes.

To understand further the editing and processing capability of the semantic network, we have developed a computer system to implement those concepts. We have also made available a simple web interface to create and manipulate semantic graphs for anyone who wants to become familiar with these concepts. [It is accessible here.]



Example of data types that can be found in the Data Lake.

Main Results

It has been verified that the method based on semantic graphs could capture the description of the work processes that link different entities and therefore document the dependence of these entities in terms of data quality and uncertainty. Microservices for managing semantic description of workflows involving geology & geophysics and drilling stakeholders have been developed. Furthermore, it is then possible for computer programs to discover information whenever available, and this allows for solution that adapts to a changing environment and variable work processes.

Semantic graphs are compatible with information stored in the data lake and facilitate for computer readable information allowing for more effective machine learning techniques. The work here is also compatible with semantic of real-time drilling signal (work done in an associated Demo2000 project Drilling System Interoperability Demonstrations).

Publications

Method is described in paper SPE-208754-MS «A Framework to Capture the Relationships in Drilling Data and the Propagation of Uncertainty» to be presented at the SPE/IADC Drilling Conference in Galveston, TX, USA, March 2022

Paper SPE-208732-MS "Best Practices to Improve Accurate Time Stamping of Data at The Well Site" to be presented at the SPE/IADC Drilling Conference in Galveston, TX, USA, March 2022.

Presentation "Drilling Data Quality and Uncertainty" at the SPE-WPTS ISCWSA conference (virtual) April 14, 2021

Presentation "The Role of Software Interoperability to Improve Performance and Quality of Service in Drilling Operations" at the SPE Virtual Workshop Asia Pacific Digital Week – "enhancing the energy value chain through Innovation and digital ecosystem", 9-11 Nov. 2021.

Benoit Daireaux and Eric Cayeux (photo: Sergey Alyaev/NORCE)

International Forums and Committees

The researchers in SFI DigiWells have important roles and are cooperating with different international forums and committees relevant for interoperability and standardization.

DDQUD

The Society of Petroleum Engineers (SPE) has formed a cross-disciplinary technical sub-committee to investigate how to describe and propagate drilling data quality and uncertainty. The Drilling Data Quality and Uncertainty Subcommittee (DDQUD) is a cooperation between the Drilling System Automation, Wellbore Positioning and Drilling Uncertainty Prediction Technical Sections. NORCE Chief Scientist Eric Cayeux leads DDQUD.

DDQUD and DigiWells epic DDHub+ benefit greatly from each other. The DDQUD has followed a methodology to identify topics that have a value for the industry by collecting "user stories". A "user story" can help software teams organize their understanding of the system and its context. Furthermore, a "user story" can be studied in more details resulting in several "use cases". A "use case" is a list of actions or event steps typically defining the interactions between a role (human or software) and a system to achieve a goal. For the Epic DDHub+ the highest ranked "user story" has been studied more closely resulting in 17 "use cases". Each of those "use cases" have been detailed and illustrated, then they have been described more formally using Semantic Graphs.

OSDU and D-WIS

Both the Open Group OSDU and D-WIS are international organizations with many participants from the industry focusing on standardization and interoperability.

OSDU

The mission for the Open Group OSDU Forum is to deliver an Open Source, standards-based, technology-agnostic data platform for the energy industry that stimulates innovation, industrializes data management, and reduces time to market for new solutions.

In 2021 both Cayeux and NORCE Senior Researcher Benoit Daireaux gave educational presentations at events organized by OSDU. Benoit on "Semantics of Real-Time Drilling Signals" and Eric on "Drilling Process Protection".

An opportunity for DDHub+ is to provide the source code of the microservices developed to OSDU so that service companies can construct software solutions around the proposed concept.

D-WIS

The objective of the D-WIS initiative is to establish recommended practices and standards that enable interoperability between all components, equipment and systems used in oil and gas well construction – regardless of the type or provider. D-Wis well integration is part of OSDU while D-WIS Industry Engagement Group is outside OSDU and focus on interoperability for Rig Operability Systems.

Cayeux and Daireaux are active participating in D-WIS work groups which are very relevant for the focus NORCE has on standardization and interoperability.

Interoperability

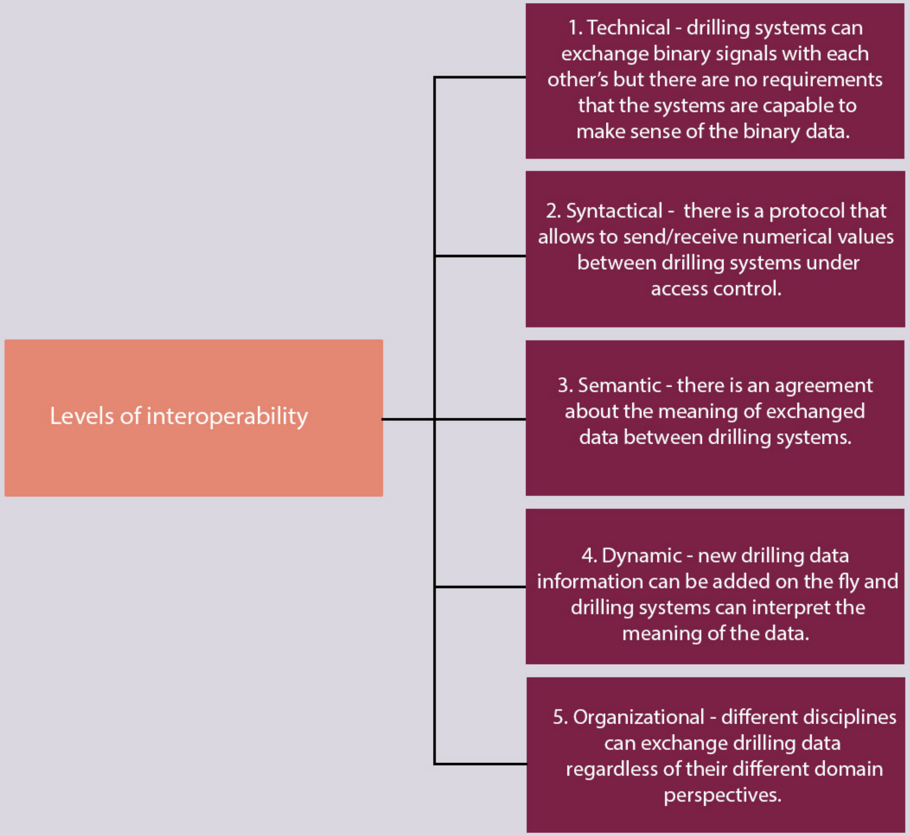
It can be very useful to have a common understanding of interoperability and the division of their levels. The D-WIS/OSDU definition of interoperability:

- Interoperability between systems in well construction is achieved when any system can exchange meaningful information with any other system, at present or in the future.
- The exchange of information occurs between authorized systems, without prior knowledge of each systems unique characteristics, and in an environment where the constellation of systems is constantly changing.

An overview of the levels of interoperability is given in the figure to the right. The DDHub+ epic is focused on number 5 the organizational level.

Semantical interoperability standards have been an area NORCE has been working on for many years. Previously, NORCE led a project, DDHub, that developed a semantical model for real-time drilling data. The semantical model is compatible with the one in DDHub+. As a continuation of DDHub, we have now an associated ongoing Demo 2000 project Drilling System Interoperability Demonstrations (DSID) (project owner: Prediktor, partners: AkerBP, TotalEnergies, Halliburton, Sekal and Baker Hughes). The goal is to demonstrate interoperability and real-time exchange of data between drilling systems, encompassing automation, monitoring or analysis systems.

DHUB and DSID focus on real-time drilling data and levels no. 1 to 4 in the figure showing the different levels of interoperability.



Innovation

To support innovation and industrialization of results from the center, an innovation committee has been established. The innovation committee consists of representatives from the end users. The first meeting was arranged in November 2021.

The activity related to distributed drilling control has resulted in an innovative concept for vibration damping and a patent was filed at the end of 2021. The concept has been analyzed using mathematical modeling and laboratory scale experiments. The next steps will be to evaluate critical factors for constructing such a damping tool and in dialogue with the innovation committee guide the next steps for possible industrialization.

A new concept for measurement of flowrate out was originally developed and tested in laboratory scale in DrillWell. Research aspects of extension of this concept have been a candidate for activity in DigiWells, but so far not prioritized. The next step will be to demonstrate the concept for larger scale and higher flowrates. Subject to successful demonstration, pathways for industrialization will be discussed.

The DEMO 2000 project “Demonstration of Autonomous Drilling” was based on the same philosophy, methodology base and the same NORCE personnel as in SFI DigiWells. This project was finalized with a demonstration of autonomous drilling at Ullrigg in September 2021. Now, nearly all the operators that supported the DEMO2000 project are involved in SFI DigiWells and all the operators in DigiWells are interested in continuing activity on autonomous drilling. Extensions of the results from autonomous drilling activities will be addressed in DigiWells. A special focus will be on autonomous tripping. Possibilities for industrialization of autonomous drilling results and later autonomous tripping will be discussed with the innovation committee.

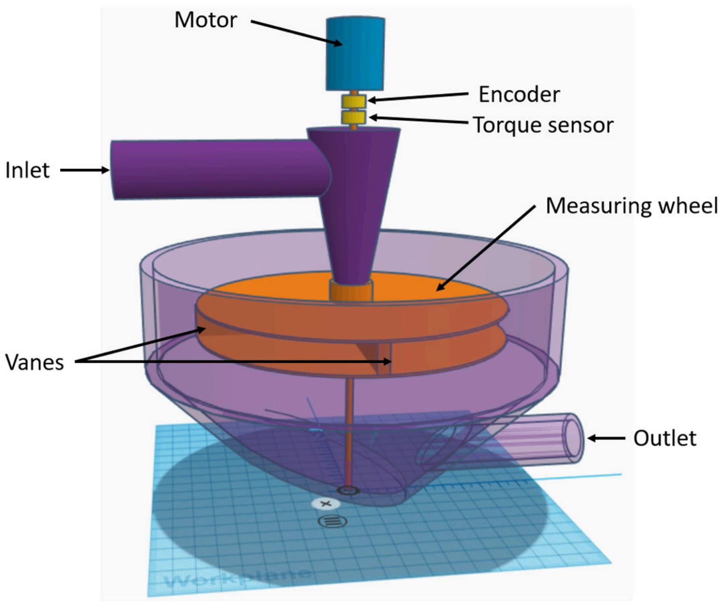


Illustration of flowrate out measurement device

A new methodology for well planning is being developed in DigiWells. The methodology takes the uncertainty of the subsurface and other uncertainties fully into account. Instead of making one plan for the drilling operation, an ensemble of drilling designs is generated resulting in a much more robust approach. Preferable ways for industrialization of this new workflow will be discussed with the innovation committee.

Microservices

To make it easier for the industry to do early testing of software developed in DigiWells, a strategy with microservice architecture has been used. For the new methodology for well planning and with the 2021 focus on anti-collision, seven functionalities have been packed as microservices. They form a suite of small services that are independently deployable and easily scalable by adding more instances of the necessary functionality. The microservices can communicate through standardized interfaces and typically adhere to the generic API: CRUD (Create, Read, Update, Delete) and thereby have the capability to work together with already existing software at the companies.

We aim for doing studies in 2022 together with the industry partners testing functionalities developed in the different epics in DigiWells and packed as microservices. It is an excellent starting point for industrialization. In parallel we will have dialogue with the innovation committee on how to secure further development and support, and make them commercially available.

Patents

Patents relevant for safety, reduction of energy consumption and the green shift.

In the last few years alone, Chief Scientist Eric Cayeux has been behind five new ideas that have either been granted as patents or are patent pending.

Flowrate out sensor contributes to well integrity

One of the patents that Cayeux is behind is a new method for measuring the flow rate out of a well during a drilling operation. This is especially important to detect if there is loss of drilling fluid to the formation or flow of formation fluid into the well. Both situations can lead to a well control event.

It has been a challenge for many years to create a measuring method that can measure the flow rate out of a well at atmospheric pressure and without requiring the measuring device to be filled with liquid. Cayeux's idea is based on a different principle than the traditional Coriolis mass flow meter. While a Coriolis meter is based on vibrating tubes, Cayeux's patented idea consists of a rotating measuring wheel surrounded by a container. This makes it possible to measure the flow rate out of a well. The mass flow meter has several functions and can also provide information about, among other things, how much cuttings come to the surface and about the composition of gas that is trapped inside the drilling fluid.

Three ideas from SFI DrillWell

The flowrate out sensor that has now been granted patent, comes from SFI DrillWell. In total three of the five patent applications have their background in SFI DrillWell. SFI DigiWells has given this research environment within automated and digital drilling a unique opportunity to continue the work and to make innovative ideas available for the society.

More recently a patent has been filed for a hardware solution for vibration damping. You can read more about this solution in the chapter about Distributed Drilling Control. In DigiWells we have established an innovation committee that gives us advice regarding the challenging industrialization phase. Many promising ideas are struggling to overcome the "Death Valley" and become commercially available.

Must have a benefit to society

Cayeux is clear that research is the driving force and not patenting. At the same time, he is concerned with the responsibility of researchers to have the overall picture and see if the research can be of benefit to society. The main motivation lies in research questions and solving problems he knows the industry are struggling with. Cayeux believes that the path to a good research project is often about having a good knowledge of what the companies or actors you work with need.

Drilling knowledge important in the green shift

In Norway, we are a world leader in drilling. Chief Scientist Cayeux believes it is important that we use this unique knowledge to come up with new ideas in the green shift. Several of the patents that are now being considered, can play an important role reducing the carbon footprint ranging from reduction of energy consumption for the drilling operation to an innovative idea for hydrogen production in abandoned wells.

The latter one on production of ammonia from hydrogen is based on electrolysis of salt water in old oil and gas wells. Many oil and gas wells are placed in subsurface formations with access to salt water suitable for electrolysis, and in a naturally heated and pressurized environment. Since the efficiency of electrolysis and Haber-Bosch processes is dependent on temperature and pressure, there is a potential to increase the efficiency significantly of both Hydrogen and ammonia production. Further research is needed to explore whether this idea can lead to a new life for old oil and gas wells that has not previously been considered.

Chief Scientist Eric Cayeux is a curious and innovative researcher coming up with many new ideas relevant for reducing the carbon footprint and contribute to the green shift (photo: private).

Photo: Lisa Ravna Rørmoen/Screen Story

Fulbrighter at the University of Texas at Austin

Nazanin Jahani had a research stay at the University of Texas at Austin from March 2021 to September 2021, as Norwegian Fulbrighter.

The Fulbright Program is the U.S. government's flagship international educational exchange program. It was created to increase mutual understanding between the peoples of the United States and other countries through the exchange of persons, knowledge, and skills. The Fulbright scolarship provides grants to individually designed research projects.

At the University of Texas at Austin, Nazanin Jahani collaborated with the formation evaluation research consortium, which is managed by Professor Carlos Torres-Verdin. This consortium has more than 20 industry partners. The purpose of the research consortium's program is to build knowledge for the industry.

On her Fulbright stay, Jahani worked with 3D numerical modeling of deep-sensing borehole resistivity measurements and petrophysical inversion. She focused on how electromagnetic measurements are used to evaluate the heterogeneity of formations. Likewise, she worked on numerical modelling of electromagnetic fields. Additionally, she got experience with implementing parallel algorithms in supercomputer clusters.
- My stay in the United States was useful, both personally and professionally, Jahani says.

Her passion is to apply mathematical modelling, computational methods, and numerical techniques to describe and represent the coupled physical processes, such as during drilling.

- On top of that, I love exploring and learning new things. My stay in the US opened me to new minds and cultures. I went through a uniquely shared history and knowledge with many people from diverse cultural and scientific backgrounds during my stay. I met several other Fulbrighters in Austin, and I established several long-term collaborations with other scientists at UT Austin as well as other Fulbrighters.

Nazanin Jahani has a PhD from 2015 in mechanical engineering. In addition, she has a master's in computer software engineering. Since 2017 she has been a Research Scientist at NORCE.

- Now I will use the knowledge and continue the work in DigiWells, Jahani says.

New 3D technology for formation evaluation can contribute to better decisions during drilling and improved oil recovery.
- In my research, I will develop fast and robust 3D models and algorithms for formation evaluation, Jahani, says.

3D models are more accurate than lower-dimensional approximations and can provide much more detailed insight into the structure of the formation but are also very computationally intensive.

- My research aims to make these computations more efficient. The fast updated 3D models will contribute to optimizing decisions during the drilling operation and

Nazanin Jahani (photo: Rune Rolvsjord/NORCE)

improve placement of the well. This may reduce costs due to avoidance of drilling problems, lower energy consumption and emissions and optimize the placement of the well resulting in improved oil recovery. Therefore, innovative technology may help the drilling crew and support team to make better decisions, Jahani says.

The ability to drill wells efficiently and safely in formations is essential in several contexts in addition to hydrocarbon extraction, like geothermal drilling, mining, and drilling of well for CO_2 storage.

Dan Sui and Luis Saavedra Jerez

Collaboration between academia and industry

The petroleum industry is evolving and will be different in the future.
- We need to do the transition step by step.

This is stated by Luis Saavedra Jerez, who has worked as a Ph.D. student as part of the Automated Drilling Engineering epic in DigiWells for approximately half a year.
- Drilling is helpful for the future. I recommend studying petroleum and automation! Jerez says, telling future potential students to focus on their work.

Dan Sui, professor at Energy and Petroleum Engineering Department, at the University of Stavanger (UiS), has followed Jerez during his master at UiS where he led the winning UiS Drillbotics team. She agrees with Jerez.

- For some students the traditional industry is not so attractive, but now we include digital tools into the fields and educate people and adapt to the needs of the industry. Among other things, Drillbotics is useful in this work, says Sui.

Fully autonomous drilling

Drillbotics is an international competition between universities organized by the Society of Petroleum Engineers (SPE). One challenge is to design, build and successfully implement either a fully functional drilling rig at lab scale to perform fully autonomous directional drilling through a rock sample. Another challenge is to develop a drilling simulator that designs, drills, controls and corrects the drilling parameters and trajectory autonomously.

- The principal task for our team in this competition is to develop a real-time drilling simulator that reaches a defined target without any human interactions, says Sui.

Close to the industry

The competition aims to promote the application of digital solutions and autonomous systems into drilling operations. This will create innovation and technology development from academia, which can be applied at an industrial scale.

- To have the possibility to interact and have feedback from the industry is an enriching opportunity. It has opened my eyes to the objectives of the industry and the way of working with the researchers, says Jerez, who works closely with the industry through his thesis and DigiWells, and also by participating in the Drillbotics Competition.

Not a dying field

The Drillbotics competition helps educate new relevant candidates both for the industry and for academia.

- The motivation is to inspire students' interests in drilling automation and digitalization by designing an autonomous physical rig or digital simulator. 90% of the students who participated in the Drillbotics got a job offer, so this is inspiring, says Sui.

The design criteria of the simulator were given by recognized experts in petroleum engineering, who know the problems and challenges they encounter during operations, and the real needs of the industry. Therefore, the design criteria of the simulator require students to use new tools, novel techniques, and ideas to solve and answer the problems and issues. During the project, the team members have been developing, investigating, and creating the code of diverse drilling models following the design criteria.

- The work done by our team members helps the petroleum industry to produce new strategies for solving diverse drilling issues, increase the efficiency of the drilling data management and create very useful software that could be applied in real situations to investigate or analyze different well plans, reducing the risk and cost of taking wrong decisions, says Sui.

From the project, students learn a lot from different disciplines, like computer science, data science, mechanical engineering, control engineering, and petroleum engineering. The students with cross-disciplinary backgrounds are needed by the industry.

- The Drillbotics project is a good example for students to understand what industry needs, what students need to focus on, and what the academia shall adapt to, says Sui.

Consider uncertainties

When it comes to Jerez's study, the first phase focuses on creating a planned trajectory considering the uncertainties during drilling.

- Most of the drilling plans nowadays only consider one planned well path. Nevertheless, most of the time, the real well path differs from what was planned. As a result, developing a drilling plan that considers uncertainties before the beginning of the drilling is an exciting topic to explore, says Jerez.

His current work is the analysis of an alternative method to the minimum curvature method, used by the majority of the industry to calculate the planned trajectory of the well. Drilling with the new curvature method should create a borehole with less tortuosity than the actual method.

- This new curvature method will be helpful to determine a planned trajectory to reach the driller's taking uncertainty into account. The industry is focusing on having control over the processes. NORCE can help with this – and develop standards for everyone in the industry to use – to save costs, Jerez concludes.

Drone photo: Veronica Helle/NORCE

Gilles Pelfrene, Adrian Ambrus and Liv Carlsen. Photo: Lisa Ravna Rørmoen/Screen Story

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SFI Director

WP7 - Project management

Helga Gjeraldstveit

SFI Assistant Director

WP6 - Studies and analysis

Sergey Alyaev

WP-leader

WP1 - Agile well construction work-flow

WP2 - Predictive modelling

Eric Cayeux

WP-leader

WP3 - Smart sensing

WP4 - Interopera-bility and user-sys-tem interaction

Rodica G. Mihai

WP-leader

WP5 - Drilling auto-mation and auton-omy

Mette Stokseth Myhre

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Research Council of Norway (Observer)

PhD students

Ressi Bonti Muhammad

PhD topic: Sequential decision analysis in drilling and geosteering

Affiliation: University of Stavanger
Supervisor: Reidar Brumer Bratvold
Co-Supervisor: Sergey Alyaev
Associated Epic: Real-time decision making in drilling and geosteering
Period: 2021-2024

I come from Indonesia. My BSc is from Bandung Institute of Technology in Petroleum engineering. I recently graduated and earned my master's degree from NTNU, also in Petroleum engineering.

Develop and improve a decision support system (DSS) that provides optimization-based decisions under geological uncertainty during drilling and geosteering. One of the main goals of the project is to include reinforcement learning (RL) for the DSS. Instead of building the model ourselves, we would like to develop a decision-maker/agent by training it directly on the environment, or in this case the drilling operation in the subsurface. The subsurface during a drilling operation remains uncertain, especially ahead of the bit. We try to reduce this uncertainty using the Bayes' theorem and its discrete approximations: Ensemble Kalman Filter, particle filter, etc.

Felix James Pacis

PhD topic: Online / Offline Deep learning models

Affiliation: University of Stavanger
Supervisor: Tomasz Wiktorski
Co-Supervisor: Sergey Alyaev
Associated Epic: Deep learning for drilling models
Period: 2021 – 2024

I am a Ph.D. research fellow in Machine Learning at the University of Stavanger as part of the DigiWells project. My MSc degree in Petroleum Technology, specializing in drilling and well engineering was completed at the University of Stavanger. I also have a BSc degree in Petroleum Engineering from Palawan State University.

The main objective of this project is to leverage Artificial Intelligence (AI) to build adaptive data-driven models for drilling and positioning wells. We want to keep models' predictive capability, but reduce the training time, and improve their generalization ability. Simulated data from OpenLab's high-fidelity drilling simulator will be utilized to build reliable machine learning models in the absence or in combination with real field data. Furthermore, we are interested in testing the models on real field data sets to ensure generalization. To achieve the objectives, our work focuses on:

Supervised deep learning models, learned from simulated and field data, capable of meaningful probabilistic predictions. All models are in the direction for more efficient, safer, and cost-effective drilling. The main challenges here are data quality issues and generalization ability.
Transfer Learning for building adaptive simulation models offline that can be adjusted based on available metadata and then tuned using the real-time data.

Luis Saavedra Jerez

PhD topic: Impact of the expected measurement quality and uncertainty while working on the engineering of a well

Affiliation: University of Stavanger
Supervisor: Dan Sui
Co-Supervisor: Eric Cayeux
Associated Epic: Automated Drilling Engineering
Period: 2021 - 2024

I got my bachelor's degree in Petroleum Engineering and Natural Gas in Bolivia (2018). I received my master's in drilling and well engineering at the University of Stavanger in 2021. During my master's, I was leading the winning DrillBotics team for the Virtual Rig part and was also awarded excellent academic performance at UiS.

The study focuses on analyzing the effects of uncertainty on parameters at the moment of making a drilling plan. Not knowing what will be found later carries some risks. Perhaps, considering another alternative plan will have a lower risk of finding further troubles. The combination of drilling models with deterministic, statistical physics, and some chaotic and/or non-holonomic models will be studied. The scope of the study considers the uncertainties involved in the directional drilling (where might the bit be?), geo-pressure window (what might the ranges of pressure in the formation be?), and drill-string vibrations (what might expect from the different vibrations in the drill string?).

Pauline Nüsse

PhD topic: Automatic control of sleeves for damping of drill-string vibrations

Affiliation: NTNU
Supervisor: Ole Morten Aamo
Co-Supervisor: Ulf Jakob Aarsnes
Associated Epic: Distributed Drilling Control
Period: 2021-2024

For my bachelor's and master's, I studied Computer Science in Engineering at the University of Augsburg in Germany. Here I mainly worked with modeling, calibration, and control of cable-driven parallel robots.

The main objective of my thesis is to actively control the torque-reducing sleeves developed in this epic to allow a more efficient way of drilling. The goal is to reduce vibrations, minimize energy consumption and ensure cutting transport. Several sleeves can be placed along the drill string at the positions with the largest side forces, to maximize the reduction of mechanical friction along the wellbore. The distributed nature of the sleeves must be taken into account when developing a control scheme. Here several scenarios are possible, depending on how many sleeves are used, where they are placed, how/if they can communicate with each other, and what measurements are available.

Tomasz Wiktorski and Robert Ewald. Photo: Lisa Ravna Rørmoen/Screen Story

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Journal

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Cayeux, Eric Automatic Measurement of the Dependence on Pressure and Temperature of the Mass Density of Drilling Fluids. SPE/IADC Drilling Conference 2021, 2021-03-09

Fossum, Kristian; Alyaev, Sergey; Suter, Erich Christian; Tossi, Gianbattista; Mele, Maurizio Reducing 3D uncertainty by an ensemble-based geosteering workflow: an example from the Goliat field. 3rd EAGE/SPE Geosteering Workshop 2021, 2021-11-02

Fossum, Kristian; Alyaev, Sergey; Tveranger, Jan; Elsheikh, Ahmed Deep learning for prediction of complex geology ahead of drilling. ICCS 2021: INTERNATIONAL CONFERENCE ON COMPUTATIONAL SCIENCE 2021, 2021-06-16

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Alyaev, Sergey; Elsheikh, Ahmed; Ambrus, Adrian; Jahani, Nazanin Deep learning for probabilistic inversion during geosteering. HPC, DEEP LEARNING, AND NUMERICS IN GEOPHYSICS 2021, 2021-11-18

Muhammad, Ressi Bonti; Bratvold, Reidar Brumer; Alyaev, Sergey Reinforcement learning for better geosteering decisions. DigiWells seminar 2021, 2021-11-23

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Cayeux, Eric Drilling Data Quality & Uncertainty. ISCWSA #53 Virtual Meeting 0, 2021-04-14
Jahani, Nazanin; Torres-Verdin, Carlos HPC and finite-difference modelling of deep EM logs. SFI Digiwells Annual Seminar, 2021-11-23

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Demo

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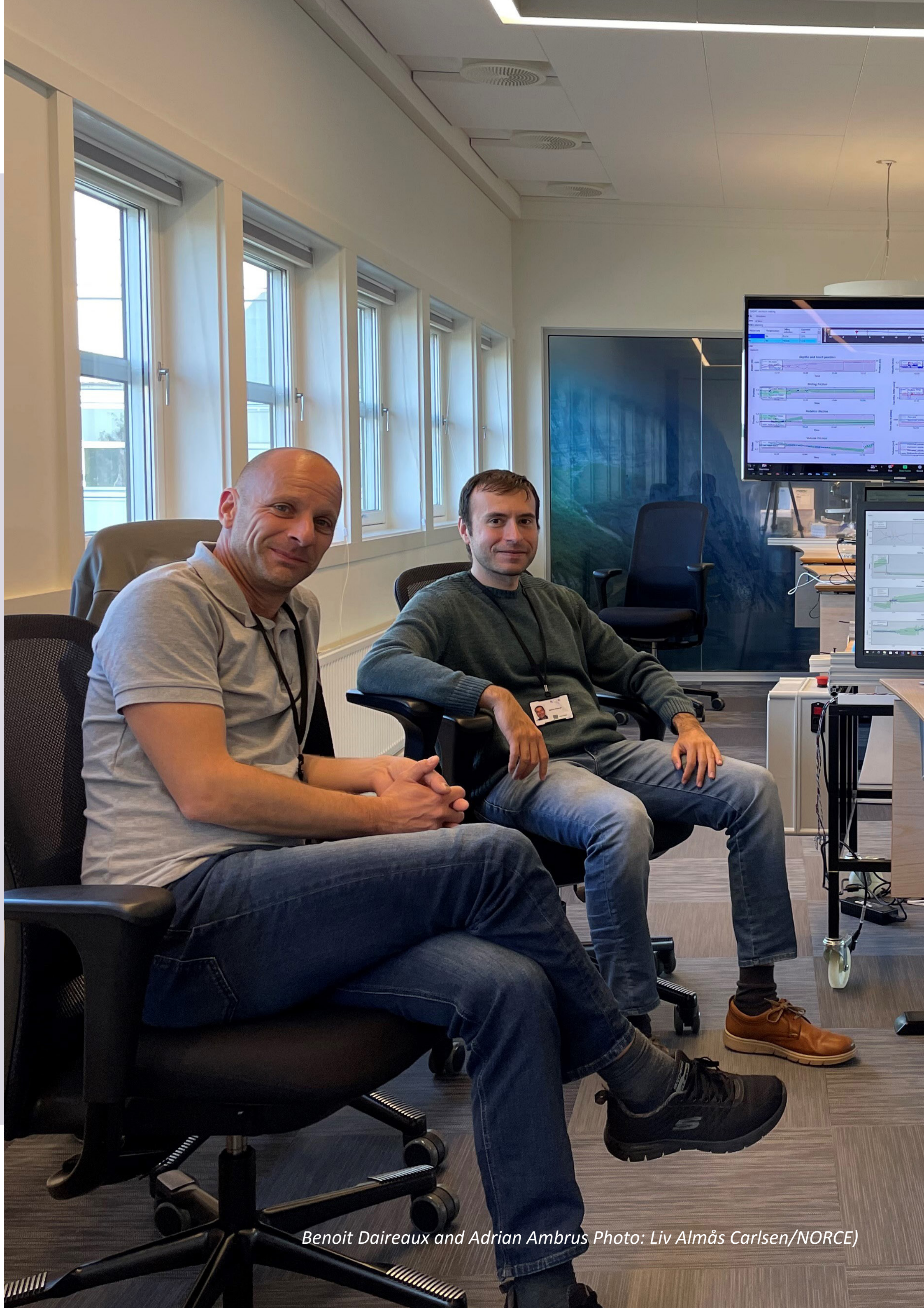
Cayeux, Eric; Dvergsnes, Erik Wolden; Carlsen, Liv; Mihai, Rodica G. Automated Drilling Engineering: 2022 final demonstration focused on directional drilling. Technical Meeting, 2021-12-01

Mihai, Rodica G.; Holsaeter, Andrew Martin; Cayeux, Eric; Ambrus, Adrian Demonstration of passive damping of vibrations in a lab experiment coupling rotational and axial movement. DigiWells Technical Meeting, 2021-12-06

Media

Fanghol, Tor Arne; Vefring, Erlend 175 pågående forsknings-prosjekter på olje og gass.

Miner, Dylan; Alyaev, Sergey Challenges of developing a geosteering AI Rosie.



Benoit Daireaux and Adrian Ambrus Photo: Liv Almås Carlsen/NORCE)

Personnel

Key researchers	Institution	Research area
Sergey Alyaev	NORCE	Geostreering
Adrian Ambrus	NORCE	Drilling
Ole Morten Aamo	NTNU	Controls
Ulf Jakob Aarsnes	NORCE	Drilling
Reidar Bratvold	UiS	Decision Analysis
Liv Almås Carlsen	NORCE	Drilling
Eric Cayeux	NORCE	Drilling
Benoit Daireaux	NORCE	Drilling
Erik Wolden Dvergsnes	NORCE	Drilling
Robert Ewald	NORCE	Drilling
Kristian Fossum	NORCE	Reservoir Engineering
Helga Gjeraldstveit	NORCE	Drilling
Jan Einar Gravdal	NORCE	Drilling
Andrew Holsaeter	NORCE	Drilling
Morten Jacobsen	UiB	Reservoir Geophysics
Nazanin Jahani	NORCE	Geosteering
Rodica Mihai	NORCE	Drilling
Sonja Moi	NORCE	Drilling
Gilles Pelfrene	NORCE	Drilling
Dan Sui	UiS	Control System
Erich Christian Suter	NORCE	Geosteering
Jan Tveranger	NORCE	Geology
Erlend H. Vefring	NORCE	Geosteering
Tomasz Wiktorski	UiS	Data Science

PhD students with financial support form the Centre budget

Name	*Nationality*	*Period*	*Sex M/F*	*Topic*
Ressi Bonti Muhammad	Indonesian	2021-2024	M	Sequential decision analysis in drilling and geosteering
Luis Alberto Saavedra Jerez	Bolivian	2021-2024	M	Impact of the expected measurement quality and uncertainty while working on the engineering of a well
Felix James Pacis	Filipino	2021-2024	M	Online / Offline Deep learning models
Pauline Nüsse	German	2021-2024	F	Automatic control of vibration-damping sleeves for drill strings

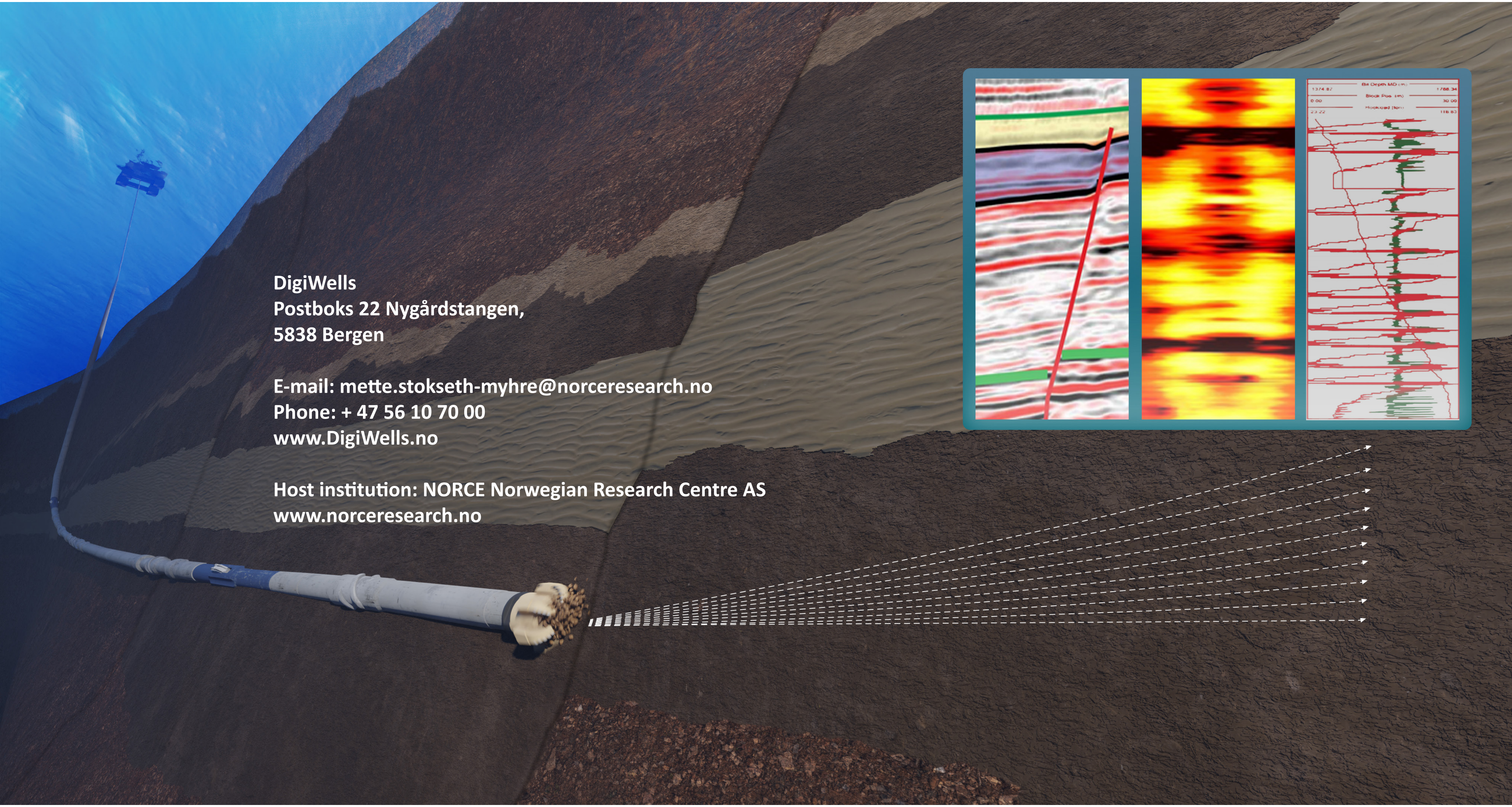
Master degrees

Name	*Period*	*Sex M/F*	*Topic*
Amund Buer	10/1 - 20/6-22	M	Design and implementation of a mobile app for in-situ recommendations related to rig heave during offshore oil well drilling”
Stig Hope Eriksen	10/1 - 20/6-22	M	
Tobias Aanstad	10/1 - 20/6-22	M	
Alina Shashel	1/2 - 15/6-22	F	Uncertainty analysis of supervised machine learning predictions applied to formation classification in real-time drilling
Karim Mostafi	1/2 - 15/6-22	M	ROP modeling using data driven models & ROP optimization
Muhammad Usama	1/2 - 15/6-22	M	Application of Deep Reinforcement Learning in Automated Managed Pressure Drilling
Emre Baris Gocmen	1/2 - 15/6-22	M	Automated Well Trajectory Planning and Controlling
MD Fazlul Haque	1/2 - 15/6-22	M	Optimizing the well path using Reinforcement Learning based on coordinates
Ali Tahir	1/2 - 15/6-22	M	Impact of data preprocessing techniques on Machine Learning models

Statement of accounts

(All figures in 1000 NOK)

Funding			
	Amount	In-kind	Sum
The Research Council	8 000		8 000
The Host Institution (NORCE Energy)		1 000	1 000
Research Partners*			
Universitetet i Stavanger, UiS			
Universitetet i Bergen, UiB			
Norges Teknisk-Naturvitenskapelig		46	46
Enterprise partners			
Operators	8 630	1 121	9 751
Vendors		35	35
Public Partners			
Sum	**16 630**	**2 202**	**18 832**
Costs			-
The Host Institution (NORCE Energy)	16 630		16 630
Research Partners		46	46
Enterprise partners		2 156	2 156
Sum			**18 832**



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NTNU Norwegian University of Science and Technology