Annual Report 2024

DigiWells

Contents

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

Vision

Unlock subsurface resources through improved 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 processes for planning the well delivery process by new 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 case studies in collaboration with end users

Center management and EPIC leaders, from left: Eric Cayeux, Helga Gjeraldstveit, Benoit Daireaux, Mette Stokseth Myhre, Erlend H. Vefring, Rodica Mihai and Sergey Alyaev. Photo: Screen Story

Oh, we’re halfway there

Dear reader,
A new Annual report from DigiWells is available for you to read. The report is full of information about the activities in DigiWells to date. The DigiWells focus is on developing digital technologies to improve the well construction process with the aim of increasing efficiency, reducing costs, and minimizing environmental impact. DigiWells is also a valuable supplier of digital well competence to the industry through several PhDs and Postdoctoral researchers.

Last year we discussed how improving drilling efficiency is not only good for oil and gas industry, but also for several “green shift” technologies that will generate jobs in the future.

When writing this we have just received the half-term, or midterm, performance evaluation from a panel of external industry experts. The report leaves no doubt that SFI DigiWells is on the right track to achieve its goals. To mention some of the highlights mentioned:

The DigiWells Center has in accordance with the initial project proposal conducted focused state of the art and high-quality research in supporting the goals to be capable to perform Automatic well Engineering, Automatic Drilling Operational Plan, Geosteering and Interoperability.

The research has resulted in the ability to test out the suggested workflows at the Ullrigg drilling test center in Stavanger in 2025 and an offshore test in cooperation with Aker BP is planned for 2026.

Practical results of the research are launched as 22 microservice apps that are made available for free to be integrated with industry partners own well planning and drilling software.

The DDHub/Blackboard/DWIS has been developed together with SPE community to provide the tools to transform drilling well data to a common readable data platform independent of the service providers data format.

The quality of the research work meets high international standard, resulting in 30 publications in reputable peer reviewed journals and a significant number of international and national conference papers.

Key researchers have been invited to give multiple demonstrations and seminars at various important international venues, e.g. SPE Annual Technical Conference, SPE DSATS & DWIS, 85th EAGE Annual Conference & Exhibition, IADC/SPE International Drilling Conference and Exhibition and SPWLA Symposium.

The SPE Drilling Award to Eric Cayeux and the SPE live podcast with 500 followers he and Rodica Mihai demonstrates the scientific excellence within the project team. Mihai has been invited to national and international AI events.

The 14 PhD´s and 3 Postdocs are presenting their research result in relevant national and international conferences.

Tron Golder Kristiansen. Photo: AkerBP

There are also a couple of suggestions to improvement that we will also take a closer look at.

The heading is also this year from a famous song, this time from “Livin’ on a prayer” a song by Bon Jovi. The song is a motivational anthem for the working class. It is an expression that points to the idea of living by faith, and the person who is practicing such a lifestyle has nothing to rely on except his or her own prayers. We as sponsors do have faith for the next half and the final results of the SFI DigiWells center for research-based innovation.

Tron Golder Kristiansen, Board Chair

Message from the Center Director

The center has now been operational for just over four years and has recently undergone a midterm evaluation. During the fall of 2024, multiple reports encompassing fact summaries, self-evaluations, and plans for the final period were prepared and submitted to the Research Council of Norway and an expert panel. A meeting with the expert panel was held in February 2025. The evaluation report from the expert panel was highly positive, as affirmed in the message from the chairman of the board, providing us with great motivation for the second half of the center's tenure.

Remarkable achievements have been made in 2024 thanks to the dedication and hard work of our talented scientists, PhD students, professors, and support team, as well as our close collaboration with industry partners. For 2024, we prioritized three main activities: automatic drilling engineering, automatic drilling operational planning, and dynamic verification and validation. These activities were chosen in consultation with the end users and continue the initiatives originally started by the center. A significant milestone was the successful defense of the thesis by our first PhD student, Ressi B. Mohammad, on January 10th, 2025.

In 2024, Petrobras joined SFI DigiWells and the spin-off project DigiWells Innovation Program started. Supported by six operators, the DigiWells Innovation program aims to extend and mature results from SFI DigiWells, initially focusing on interoperability and autonomous drilling. Planned demonstrations, including virtual environment at OpenLab, full scale rig Ullrigg, and an offshore rig, will showcase the developments.

The spin-off projects "3D Geological Interpretation for Geosteering of Wells" and "DISTINGUISH: Decision Support Using Neural Networks to Predict Geological Uncertainties When Geosteering" have been active since 2023. The verification project "In-line PVT Measurements" started and the competence-building project "Towards Autonomous Coiled Tubing Operations" was awarded in 2024. Together, these projects complement the overall objectives of DigiWells and create significant synergies.

A crucial ongoing activity involves the center's key personnel participating in international forums and committees, promoting interoperability and standardization. Center scientists collaborate with the cross-industry group D-WIS (Drilling and Wells Interoperability Standards). Several demonstrations with different industrial players are scheduled for 2025 and 2026. These endeavors are expected to facilitate the vision "develop once and deploy anywhere," significantly impacting the industry and simplifying the implementation of automation solutions.

The two-day annual DigiWells seminar was held in November for center partners and representatives from key external entities, including service companies, industry clusters, and public authorities. This annual seminar is vital for dissemination of knowledge and strengthening relationships with key stakeholders. This year, the seminar also featured a panel debate and extensive interaction with participants.

Erlend H. Vefring. Photo: Rune Rolvsjord/NORCE

We eagerly anticipate an exciting 2025, filled with further advancements in research, development, innovation, support for industrialization, and collaboration.

Erlend H. Vefring, Centre Director, NORCE

About DigiWells

Digitalization, new sensors, interoperability, automation, autonomy, and improved work processes have the potential to enable a step change of the well delivery process.

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

The centre aims to develop new 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 are planned to be demonstrated, often in spin-off projects, at the national research infrastructures OpenLab Drilling, Ullrigg and against field data from operators.

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

Results from the research performed in DigiWells are disseminated to operators, service companies, public authorities, and academic partners to enable innovation and value creation.

Partners

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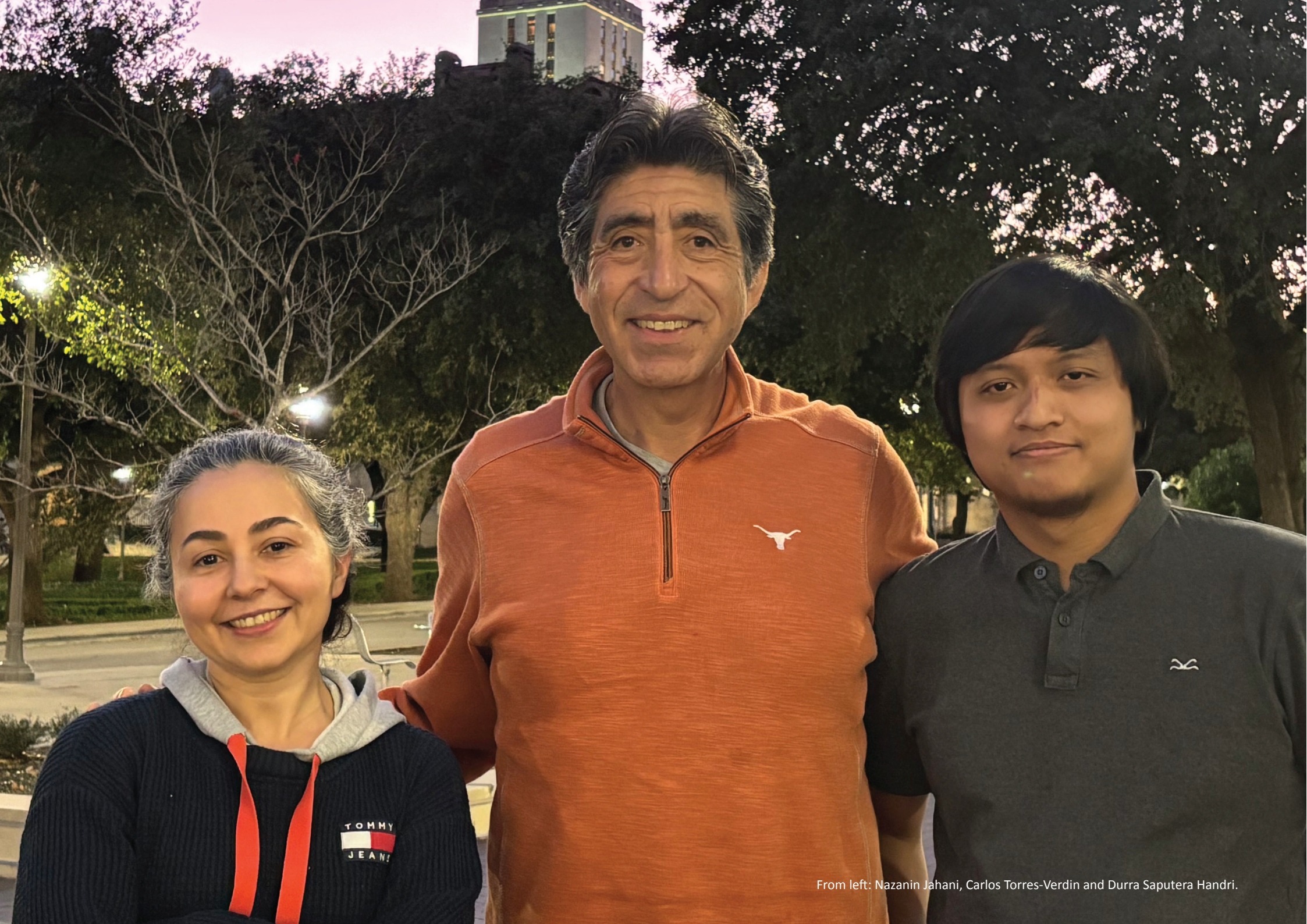


From left: Nazanin Jahani, Carlos Torres-Verdin and Durra Saputera Handri.

Automatically Generated Drilling Program

From static and manually generated drilling programs to automatically generated dynamic drilling programs designed to support decision-making during well construction with advanced automation systems.

Digitalization of the drilling process gives new opportunities. A novel framework for automatically generating drilling programs to support both automated and autonomous drilling is being developed.

In well-construction, a plan and a strategy are essential for achieving the mission of drilling and completing the well as effectively and safely as possible. The plan involves drilling and completing the well section by section, progressing one stand at a time until reaching the total depth (TD) of each section. The strategy provides an adaptable framework to handle drilling challenges such as optimizing hole cleaning and managing drill-string vibrations to stay within an acceptable level. However, due to uncertainty about actual subsurface conditions and the operational risks inherent in drilling, adjustments often must be made to accommodate with scenarios that are different from those anticipated during the planning phase. Various tactics are employed to manage the complexity of well construction like for example adjusting the flow rates or rotational speed to control cuttings transport. Such real-time adjustments may have been investigated in advance and may stay within the margins set by a drilling strategy.

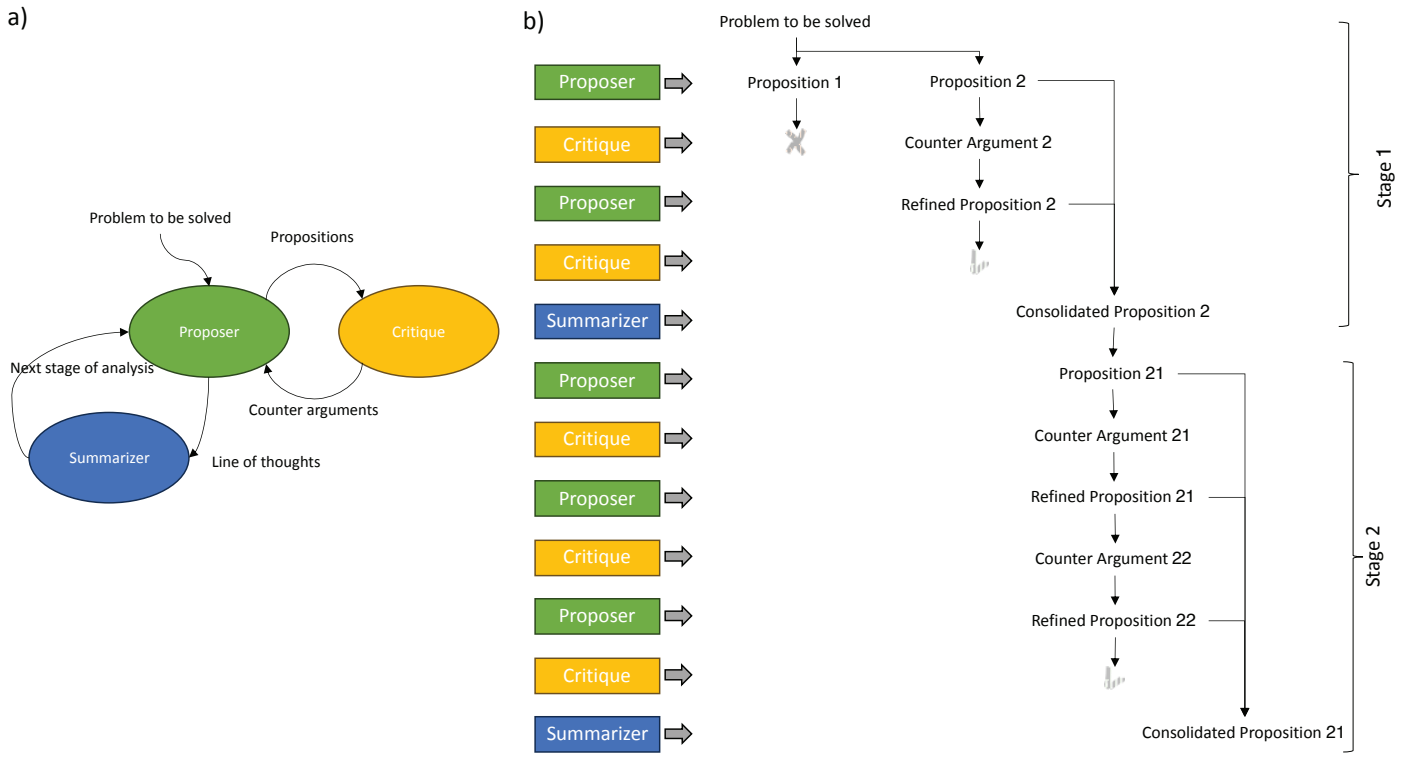


Fig 1: The framework is inspired by the concept "diagram of thoughts". The cycle repeats until satisfactory solutions emerge.

Fig 2: The drilling program is organized into a sequence of stages. The DoT framework is applied either to specific stages or partially across several successive stages, consistently providing an increasing level of detail throughout the sequence

The plan can be viewed as a hybrid arrangement of sequential steps (such as drilling sections) combined with recommended strategies and tactics. It enables an autonomous system to make informed decisions and generate dynamic plans to overcome challenges, when encountered, throughout the well construction process by utilizing the strategies that have been explored at the planning stage. The method is generative, as it automatically creates potential solutions.

A disruptive shift in well planning using the latest from generative AI methods

The new framework for well planning, is inspired by the Artificial Intelligence (AI) concept of “diagram of thoughts” (DoT), which models iterative reasoning in large language models. The DoT framework assumes the presence of three entities, each with a distinct role. For well planning these are:

- **Proposer**: Generates solutions
- **Critique**: Evaluates each solution and eliminates poor choices
- **Summarizer**: Groups similar viable solutions into clusters

In this process, the proposer generates solutions that are then evaluated by the critique. The proposer refines or adjusts the solutions to address the weaknesses highlighted by the critique, and this cycle repeats until satisfactory solutions emerge. At this point, the summarizer consolidates the entire process, removing or merging unnecessary or redundant steps, see Fig. 1.

The drilling program is organized into a sequence of stages as illustrated in Fig 2. The DoT framework is applied either to specific stages or partially across several successive stages, consistently providing an increasing level of detail throughout the sequence.

For instance, Stage 2 in Fig. 2 focuses on generating a set of simplified trajectories that originate from potential tie-in points, reach candidate targets or target groups, and adhere to various subsurface constraints, such as anti-collision criteria with existing wellbores, crossing multiple faults at high

incidence angles, or maintaining a specified distance from a given horizon. Stage 2 acts as a proposer, but the simplified trajectories often require postprocessing at Stage 6 to address their potential tortuosity and ensure suitability for further evaluation. While the tortuous nature of these trajectories may be a drawback, the advantage of the generator algorithm is its ability to systematically explore the entire solution space under a multidisciplinary set of constraints.

The DoT framework reduces the complexity and makes it possible to avoid combinatorial explosion by:

- Filtering out weak designs early, preventing wasted computations.
- Grouping connectively equivalent solutions together, sometimes called bundling
- Optimizing well construction choices at multiple levels of details

The framework is built on a microservice architecture giving strong advantages in deployment and maintenance. This approach enables independent development of drilling components, collaboration across multidisciplinary teams and efficient handling of large datasets and real-time decision-making. Read more about microservice architecture in publication 1 or in Annual Report 2023.

Summary

This new approach shifts the drilling program's focus from a static and manually generated plan to a set of adaptable strategies and tactics linked by an overarching plan. These strategies and tactics can assist decision-making during well construction when actual downhole conditions deviate from expectations. The framework captures and propagates uncertainty throughout the entire process. The method promotes collaboration among multidisciplinary teams, enabling each discipline to share, clarify, and justify its constraints. This collaborative approach allows teams to prioritize constraints and design parameters collectively.

Publications:

(1) "Drilling Automation: Revisiting the Digital Drilling Program", E. Cayeux, G. Pelfrene, R. Mihai, NORCE, IADC/SPE International Drilling Conference and Exhibition, 4-6 March 2025, doi: https://doi.org/10.2118/223774-MS

(2) "Assisting Directional Drilling by Calculating a Safe Operating Envelope", L. Saavedra Jerez, UiS, E. Cayeux, NORCE, D. Sui, UiS, SPE Journal Oct 2024, https://doi.org/10.2118/217707-PA

(3) "Automatic calibration of systematic biases in directional drilling control for planar and non-planar curves", L. Saavedra Jerez, UiS, E. Cayeux, NORCE, D. Sui, UiS, Geoenergy Science and Engineering, Volume 246, March 2025, https://doi.org/10.1016/j.geoen.2024.213642

(4) "Approach Uses Multidisciplinary Constraints for Automatic Well-Path Generation", Chris Carpenter, Journal og Petroleum Technology, Sep 2024 https://doi.org/10.2118/0924-0097-JPT

(5) "Facilitating Directional Drilling Work to Reach the Target Entry by Calculating a Safe Operating Envelope", L. Saavedra Jerez, UiS, E. Cayeux, NORCE, D. Sui, UiS, IADC/SPE International Drilling Conference and Exhibition, 5-7 March 2024, Galveston, USA https://doi.org/10.2118/217707-MS

(6) "A New Paradigm for Automatic Well Path Generation Using Multidisciplinary Constraints", E. Cayeux; G. Plfrene; R. Mihai; E. Dvergsnes; B. P. Tjøstheim; A. Baume; R. Khosravanian; T. G. Kristiansen, SPE Annual Technical Conference and Exhibition, San Antonio, Texas, USA, October 16–18, 2023, https://doi.org/10.2118/215021-MS

(7) Paper presented at the, SPE-208791-MS: An Ensemble-Based Solution for Automating Drilling engineering: Application to Directional Surveying by Eric Cayeux, Erik W. Dvergsnes, Liv A. Carlsen and Rodica Mihai, SPE/IADC International Drilling Conference, Galveston, Texas, USA, March 2022, https://doi.org/10.2118/208791-MS

The work has gained international attention in the Journal of Petroleum Technology (JPT), Publication no 4:
As a result of this new process, the multidisciplinary team can focus on the relevance of the constraints rather than on the details of the planned trajectory.

DrillOpPlan - Automatic Drilling Operation Plan

Several drilling programs are automatically evaluated in a probabilistic framework capturing uncertainty, performance and potential incidents using Monte Carlo simulations. The framework facilitates the selection of a drilling program and associated drilling operation plan. The ultimate goal is to include operational plan optimization and have an iterative automated workflow from the planning phase to the execution phase.

Well design and drilling operation planning has for a long time suffered from siloed organizations and software systems. Although recent efforts attempt to streamline the process via digitalization, it is still challenging to achieve agile well planning and construction because of the difficulty of revising existing plans and programs based on operational observations or unexpected events.

In DigiWells we have already done a lot of work to achieve automatically generated drilling programs. In this process, several well designs (drilling programs) and plans are automatically generated and evaluated. The evaluation enables an objective comparison between various design/plan candidates so that the planning crew can select the best options.

DrillOpPlan introduces a probabilistic framework to automatically evaluate the design/plan candidates capturing uncertainty, performance and potential incidents using Monte Carlo simulations.

Framework and Methodology

The simulation platform that is being developed is a hybrid approach where physics-based models are enriched with learning techniques and historical data. This is crucial for effective uncertainty management and reduction of computational time.

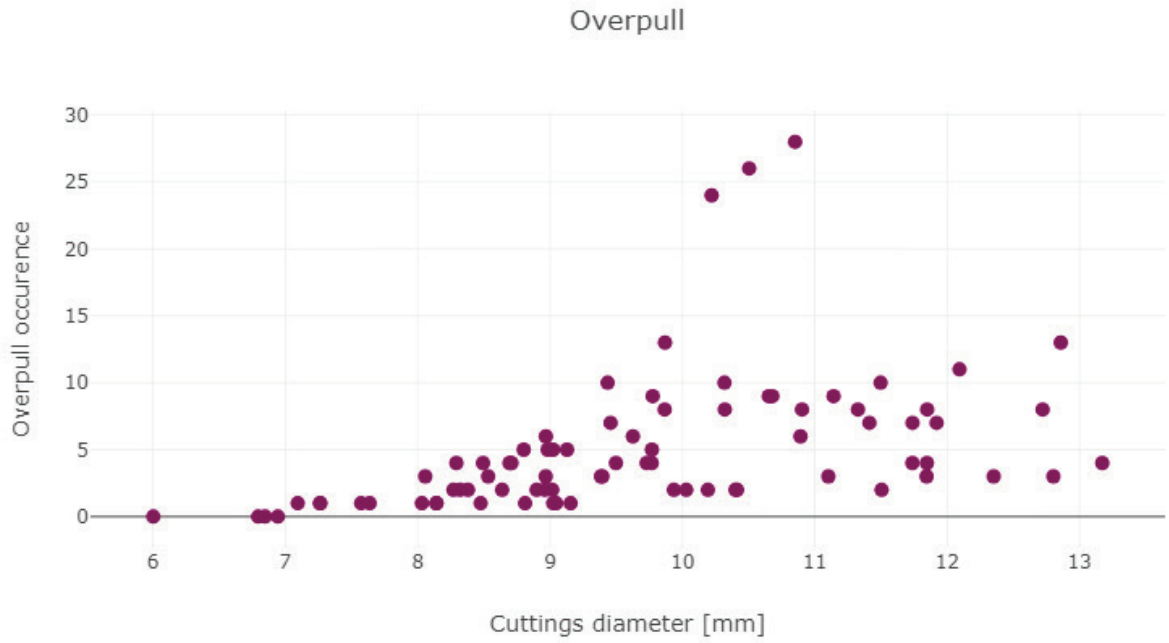


Fig 1: Overpull occurrences as a function of the drill cuttings diameter. One dot corresponds to one simulation. One clearly observes a correlation between the size of the cuttings and the incidents related to cuttings transport.

To further handle uncertainty and the impact of incidents on the operation, Monte-Carlo simulations are introduced. The framework models the drilling process using randomized sampling to capture variations in geological conditions, operational factors and drilling incidents. Each simulation generates a probability distribution of performance metrics allowing for risk-informed decision-making.

The performance of drilling operations depends not only on the well design but also on how the operations are conducted. It is useful to distinguish between the notions of plan and strategy: in our context, a plan is a prognosed sequence of operations to be executed until the overall objective is reached, while a strategy is a mechanism that dynamically modifies the plan based on available observations. Although we have referred to plans so far, it is worth emphasizing that our system aims at analyzing a drilling strategy.

Decision Agents

The framework includes automated agents that simulate decision-making during operations. To represent the different levels of decision making, we consider a hierarchical structure of nested Decision Agents, each having access to a set of Mission Agents, responsible for the execution of a specific mission. The missions that are currently embedded in our system are:

- **Analysis Agent**: Construct Well.
- **Operation Agent**: Build Section.
- **Sequence Agent**: Run in Hole, Drill, Pull Out of Hole, Pull Out String, Clean Hole, Lubricate.
- **Drilling Agent**: Drill Stand, Trip Stand Down, Trip Stand Up, Reciprocation, Friction Test, Circulate Hole Clean, Add Stand, Remove Stand, Lubricate Stand.

This list is incomplete if one considers the real well construction process. It is constantly extended, but the current version still provides a level of realism sufficient to perform relevant analyses.

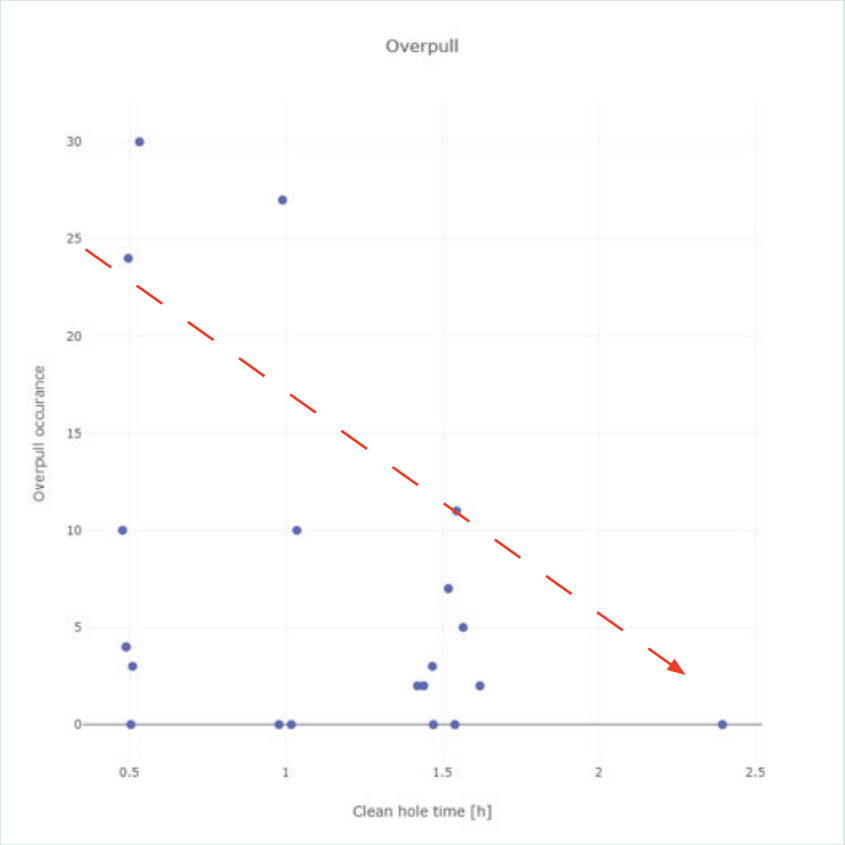


Fig 2: Occurrences of overpulls against the hole cleaning strategy. One can observe a strong correlation between the hole cleaning time and the number of experienced overpulls.

Case Study: North Sea Well Analysis

Although the presented framework is developed as a component of a revised planning workflow, it is desirable to use it as a stand-alone analysis tool in some situations, for example for validation purposes of the framework or as a post analysis tool of already drilled wells.

The case study used is based on a field case of a horizontal multi-lateral well drilled with particular focus on the 12 ¼" x 13 ½" main bore section. The section was drilled with a rotary steerable system and a 13 ½'' under-reamer was used to open the 12 ¼" hole beyond the 13 3/8" casing set at 1800 m MD. The well trajectory included two build sections with the final one reaching an inclination of 90° at 2400 m MD. A micronized oil-based mud with a density of 1.43 s.g. was used.

Key challenges for this case were hole cleaning issues causing overpull and pack-off incidents during tripping. Investigation had as an objective to identify the possible risks associated with the case, and the same parameters as the ones used during the real operations were used. Furthermore, the hole cleaning operations used the same parameters as the ones used during the real operations, with small variations regarding the flowrate and top-drive RPM. Nevertheless, we randomized the overall duration of the sequence to study the effect of hole cleaning.

The overall performance of the case is given by the distribution of the time taken to build the considered section. The simulations experienced a large amount of overpulls. This is a clear indication that cuttings transport during drilling or hole cleaning were not optimal, see fig 1. It is possible with the simulation framework to investigate the root causes of the problem. One can see that the cuttings size clearly correlates with the occurrence of overpulls, and that overpulls are more frequent for shorter cleaning times.

Benoit Daireaux. Photo Screen Story.

With the simulation tools it is possible to revise the drilling strategy to try to achieve better overall performance. The effect of hole cleaning on the number of overpulls is illustrated in fig 2, where one can measure the impact of the cleaning strategy. The simulation results demonstrated that prolonged hole cleaning improved overall efficiency by preventing overpulls despite slightly increased initial NPT.

This is an illustration of the possibilities that a risk-based simulation framework opens, as it provides means to investigate the possibly contradicting effects of planning decisions.

Coming work

Finally, it can be considered to use the risk-based evaluation of a drilling strategy to do optimization of this strategy. The developed framework can indeed be seen as a training platform for drilling agents, which can learn an optimal policy so that they can accomplish their mission in an autonomous way. It is our ultimate objective to extend this work to such a Reinforcement Learning environment. Recent works in autonomous drilling (Cayeux et al. 2021, https://doi.org/10.3390/en14040969) and (Mihai et al. 2022, https://doi.org/10.2118/210229-MS) are indeed based on Monte-Carlo simulations for the determination of the transition functions of the underlying Markov Decision Process. Such a system would greatly benefit from a dedicated simulation platform, allowing for customization of both the state space and the cost or reward functions.

Publication:

«A probabilistic Framework for the Risk-Based Evaluation of Drilling Plans", B. Daireaux, A Ambrus, S. Moi, E. Cayeux, NORCE, SPE/IADC International Drilling Conference and Exhibition, Stavanger, Norway, March 2025, doi: https://doi.org/10.2118/223781-MS

Dynamic Verification and Validation

How to evaluate the status of a complex drilling automation system continuously online? A framework facilitating online verification and validation in Complex Multi-Provider Drilling Automation Systems is proposed.

Drilling automation has seen significant advancements, with multiple vendors contributing specialized functionalities. However, ensuring seamless integration and reliability among these distributed automation agents presents a major challenge. Verification and validation (V&V) methods traditionally rely on pre-operational static checks, which fail to accommodate dynamic changes during operations. This method fails to account for dynamic changes that can occur during drilling, such as automation agents becoming unavailable, being replaced, or new functionalities being introduced. As a result, inconsistencies in data flow and system behavior may go undetected until they cause operational disruptions.

To address these challenges, a dynamic online V&V framework is designed to ensure that automated agents within a multi-provider system can collaborate effectively, detect inconsistencies, and respond to changing operational conditions without compromising safety or efficiency (Fig 1).

Key Elements of the Proposed Framework

The proposed framework introduces a multi-agent system approach where independent automation agents provide specialized functionalities while continuously verifying data consistency.

Key aspects include:

- **Dynamic Validation**: Instead of one-time checks, continuous monitoring ensures the availability of essential data and functional dependencies.
- **Information Flow Monitoring**: Automated agents rely on real-time data and shared operational constraints, necessitating a structured method for tracking dependencies and changes.
- **Heartbeat Monitoring**: Each agent sends periodic signals to indicate its availability, enabling early detection of system failures or disruptions.

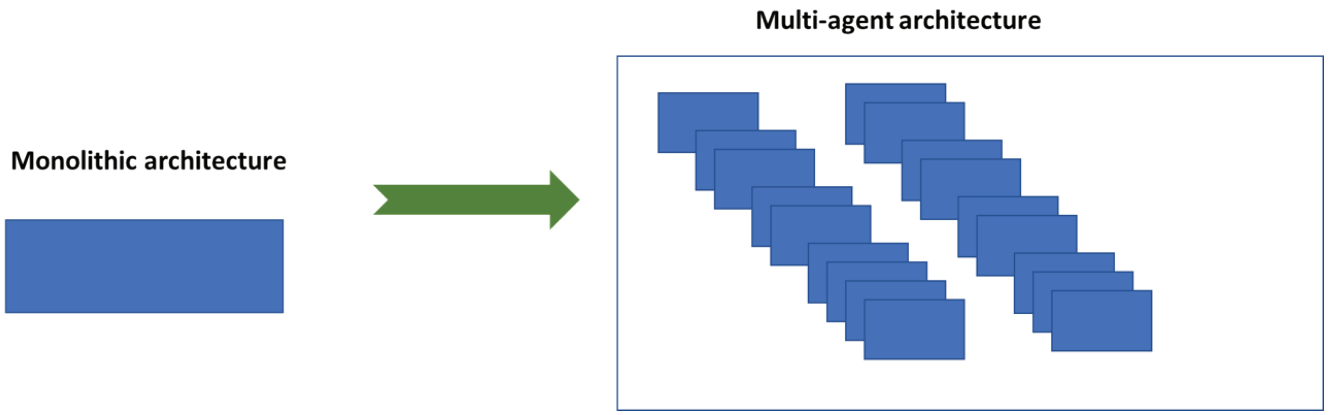


Fig.1: Change in architecture of the system. Traditionally the merging was done through humans in the process having a monolithic architecture. When moving towards higher level automation systems and autonomous systems, a multi-agent architecture is introduced and the interplay between the different subsystems needs to be monitored automatically without the need for human intervention.

The framework is designed using a graph-based approach, where interconnected automation agents exchange critical information. This structure enables the detection of inconsistencies that might occur, such as due to missing information and data, communication delays, or unexpected changes in dependencies. Each agent sends periodic heartbeat signals, which indicate its availability and functionality status. If an agent stops sending these signals or fails to provide the expected data, the system can flag potential issues before they escalate into operational failures. This mechanism also allows for self-evaluation and adaptive verification, ensuring that the system remains stable even as new components are introduced or existing ones change.

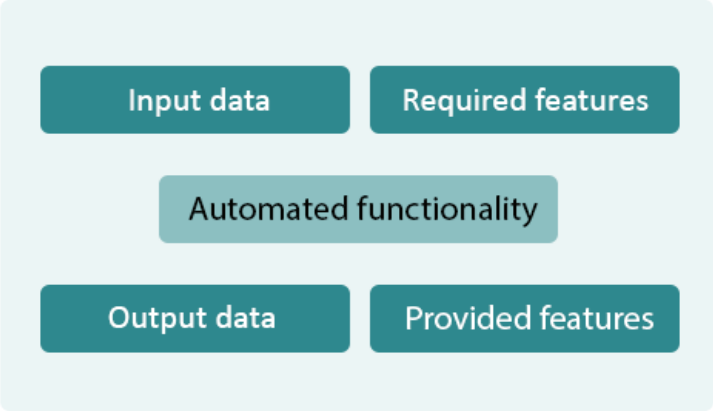


Fig 2: Description of input and output contextual information for a given automated functionality or agent. For a complex drilling automation system, many boxes communicating with each other will be present.

Example

Each automation agent depends not only on receiving accurate data inputs but also on other agents providing specific functionalities. For instance, an agent optimizing the Rate of Penetration (ROP) may rely on another agent supplying safe operating envelopes for drilling parameters. The framework ensures that all required data and functionalities are available at any given moment, paving the way towards real-time validation in practice.

Challenges & Future Work

The proposed framework presents several challenges that require further research and refinement, including:

- Defining **dynamic requirements** for validation across multiple providers to enhance compatibility and interoperability.
- Addressing **synchronization issues** and managing real-time data inconsistencies to improve system reliability.
- Exploring **cybersecurity implications**, ensuring that automated agents function securely without exposure to threats.
- Developing **self-evaluation mechanisms** that enable automation agents to independently verify their operational stability and adapt to changes dynamically.

Summary

By implementing an online V&V framework, the drilling industry can significantly enhance the reliability, stability, and efficiency of multi-provider automation systems. This approach facilitates real-time monitoring, automatic detection of inconsistencies, and seamless adaptability to evolving drilling conditions. The framework for multi-agent advisor systems can potentially also be of use in dealing with aspects related to cybersecurity threats and assist the human operator by generating a warning when inconsistencies are detected. The aim is also to provide a list of possible causes for these inconsistencies in order to help the human operator assess the situation.

Publications:

"Advancing Online Verification and Validation in Complex Multi-Providers Drilling Automation System", R. Mihai, NORCE; M. Edwards, Edwards Energy Innovation Consulting, LLC, USA; J. de Wardt, DE WARDT & CO, USA; S. Dharmaselvan, Ensign US Drilling Inc, USA; J. Carney, NOV, Norway; SPE Annual Technical Conference and Exhibition, New Orleans, Louisiana, USA, September 2024, https://doi.org/10.2118/220774-MS

«Code Generation of Automatic Drilling Control System Functions with Embedded Verification and Validation Functionalities», E. Cayeux, NORCE; R. Mihai, NORCE; R. V. Herikstad, BTWN; K. K. Olsen, Halliburton; K. Antosz, Halliburton; M. Pham, Aker BP, SPE/IADC International Drilling Conference and Exhibition, Stavanger, Norway, March 2025. doi: https://doi.org/10.2118/223716-MS

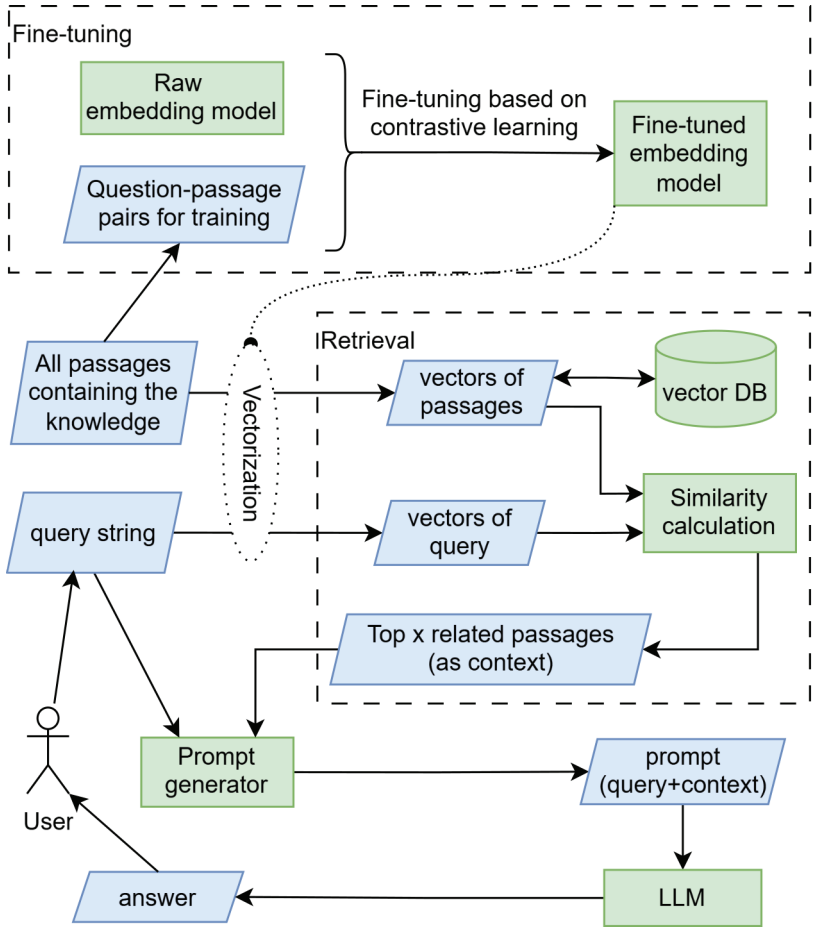
A Cloud-Free Chatbot for Offshore Drilling Knowledge Retrieval

Geoscientists and engineers often require quick, reliable answers based on factual data. Previous work by DigiWells PhD candidate Felix Pacis highlighted the potential of Large-Language-Model-based (LLM) chatbots to deliver accurate summaries when they can access relevant information. These chatbots function as Retrieval-Augmented Generation (RAG) applications, where the key challenge lies in efficiently retrieving relevant context from a knowledge base. However, cloud-based LLMs are typically restricted from accessing internal data due to security concerns, limiting their application in industrial scenarios such as offshore drilling.

The success of the prestudy motivated the team led by PostDoc Liang Zhang to quickly assemble and test a local, self-hosted chatbot that integrates a locally deployed LLM with an AI-driven search system optimized for offshore drilling data. In our demonstration, this chatbot successfully answered offshore-well-related questions using an offline knowledge base comprising 5,977 documents from a heterogeneous knowledge base consisting of Norwegian Offshore Directorate documents.

The Figure illustrates the proposed framework, which consists of two main parts:

- **Fine-Tuning**: Question-passage pairs are generated from collected passages and used for contrastive learning to fine-tune an embedding model, enhancing retrieval accuracy.
- **Retrieval & Response Generation**: The fine-tuned model vectorizes user queries. Then, the most relevant passages are retrieved based on similarity, and a prompt is constructed by assembling the user question and retrieved passages. The self-hosted LLM then generates a contextually accurate response.



Postdoc Liang Zhang. Photo: Screen Story

The chatbot's effectiveness largely stems from improved retrieval accuracy. Different embedding models produce distinct vector representations of the same text, impacting similarity measurement and retrieval performance. Our fine-tuned model ensures similar text is positioned "closer" in the search space, enhancing retrieval quality.

To facilitate adoption and further development, we provide an open-source repository that helps connect individual components required for the offline chatbot. The repository includes the infrastructure for running a locally deployed LLM with an optimized retrieval system using a preloaded fine-tuned model. Thus, our open-source repository makes it easy for specialists to deploy and test their version of a secure, domain-specific AI assistant for knowledge retrieval.

Reference:

Zhang, L., Pacis, F. J., Alyaev, S., & Wiktorski, T. (2025). Cloud-Free Question Answering from Internal Knowledge Bases: Building an AI for Drilling Applications. First Break, 43(2).

https://doi.org/10.3997/1365-2397.fb2025012

GitHub repository:

Liang Zhang, Felix James Pacis, Sergey Alyaev (2025). Cloud-Free Question Answering Chatbot for Drilling Applications

https://github.com/NORCE-DrillingAndWells/drilling_cloudfree_chatbot

From left: Pauline Nüsse and Rodica G. Mihai. Photo: Screen Story

DigiWells Annual Seminar

Around 70 participants gathered for DigiWells Annual seminar, where both industry and researchers shared their insight on digitalisation, automation and autonomous well construction.

One of the highlights of the seminar, was a panel debate about “Critical factors for further implementation of digitalization and automation within drilling and well”.

– As an industry we do not have a unified approach to digitalization. We get individual improvements, but at the same time we get additional work processes to implement the improvements. We have building blocks, but we lack the seamless integration and interoperability, said Praveen Jain, leader of drill and well technology at Equinor, in the panel debate.

– It is hard to agree on a standard – to make a blueprint – when we deploy new technology with so many different vendors working side by side, agreed Oddbjørn Kvammen, Well Construction Advisor Digital Domain at Halliburton.

Odfjell drilling pointed out another essential factor.
– The uptake in the organization is also crucial. If you can involve the organization and give them ownership to the technology, it is a lot easier to be successful, said Andre Bådsvik, Project Manager of Digital Operations at Odfjell Drilling.

– By the end of DigiWells in four years’ time we will have figured it all out, finished Tron Golder Kristiansen, board chair of DigiWells and Chief Engineer Drilling and Wells, Aker BP.

From left: Praveen Jain, Andre Bådsvik, Oddbjørn Kvammen and Tron Golder Kristiansen. Photo: Screen Story

Elisabeth Arndt, Human Factors Engineer at Equinor spoke on how changes in the driller's cabin affect the driller and what to do about it, together with Svein Harald Gabrielsen, Advisor Digital Solutions for drilling and Wells, Equinor. Photo: Screen Story

Center management and board member representatives, from left: Andre Leibsohn Martins, Petrobras; Tron Helgesen, Harbour Energy; Helga Gjeraldstveit (Assistant Director), NORCE; Geir Dyrstad, ConocoPhillips Skandinavia; Praveen Jain, Equinor Energy; Erlend H. Vefring (Director) NORCE; Sergey Sakharov, Vår Energi ASA; Tron Golder Kristiansen (Board Chair), AkerBP. Photo: Screen Story

DigiWells Innovation program

In 2024, the DigiWells Innovation Program started, financed by six industry partners.

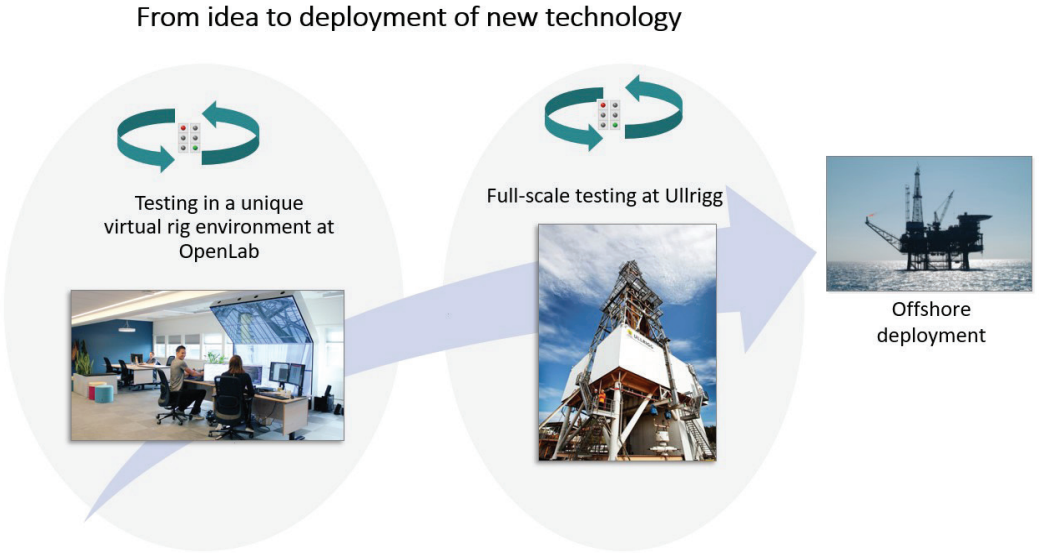
The DigiWells Innovation Program (DIP) will enable further development and maturation of results from SFI DigiWells and adjacent projects towards industrialization. DIP is fully funded by the industry through support from AkerBP, ConocoPhillips, Equinor, Petrobras, TotalEnergies and Vår Energi. DIP will accelerate development and industrialization of drilling and well technology and improve standards with the goal of increasing efficiency, reducing costs and risk, and improve safety. This will be achieved through the execution of projects with frequent demonstrations. The initial focus will be on autonomous drilling and interoperability.

Activities in DIP will be based on earlier developments and demonstration of autonomous drilling performed at Ullrigg in a project entitled "Autonomous Drilling – Phase I". By autonomous system we here mean the highest level of automation, namely a system that can adapt to changing environments and changing goals, to learn both from experience and on-the-fly, and to make appropriate choices given perceptual limitations and finite computation. The system drilled 500 m completely autonomously with very challenging unexpected situations occurring from the first day of the experiments and without any incident not being recovered from. After the demonstration it was concluded that:

- Further work is required before the system can be made available
- Aspects related to how to best convey information to users, and human factors when taking into use such an autonomous decision-making system, need to be addressed

These challenges will be addressed in DIP.

The functionalities handled by automation is becoming more and more complex and advanced, while the number of commercial players and solutions involved in the drilling automation ecosystem increased significantly. The explosion of automation solutions and players have made clear the lack of interoperability within the industry. The different solutions are seldom interchangeable, be it in terms of functionality or data communication. Industrial initiatives such as the D-WIS (Drilling and Wells Interoperability Standards) organization represent a development front for the drilling community. An ambition of activities in DIP is to specify and implement requirements for fully interoperable autonomous solutions and be actively involved in D-WIS. These endeavors are expected to facilitate the vision "develop once and deploy anywhere," significantly impacting the industry and simplifying the implementation of automation solutions.



Demonstrations are planned in the virtual environment at OpenLab, at the full-scale rig Ullrigg, and at an offshore rig to showcase the developments of interoperability and autonomous drilling.

From left Tim Tønnesen (Halliburton), Erlend Vefring and Karl Kristian Olsen (Halliburton). Photo: Screen Story

Inline measurement of PVT and thermophysical properties of drilling fluids Wells

Accurate calculation of drilling fluid density at downhole conditions with update in real time is important for several reasons. When feeding more accurate values into thermohydraulic models, deviations between e.g. measured and calculated downhole pressure can be understood better and earlier such that upcoming events can be spotted and handled more accurately. More accurate determination of key parameters like the drilling fluid's PVT helps reducing the risk of costly events like stuck pipe, and operations can be run closer to margins without increasing risk. Furthermore, accurate and reliable sensor readings is required by autonomous operations, and the addition of new high-quality sensors is enabling higher degree of automation with fewer humans in the loop. By that, a successful implementation of the PVT sensor will contribute to reducing risk and cost of drilling for oil and gas, geothermal energy, storage of CO2, and more.

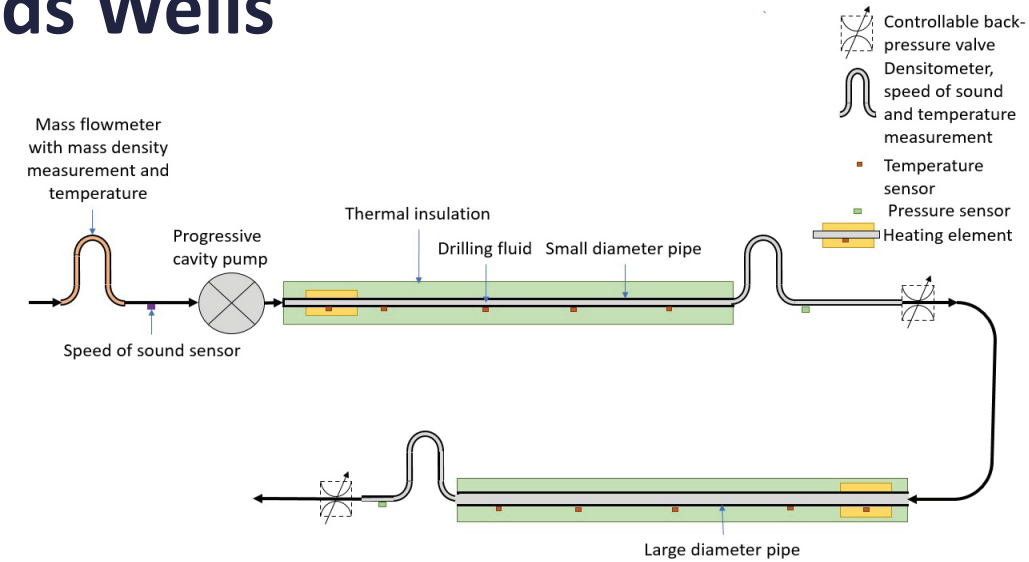


Fig 1: Schematic overview of the concept.

The new sensor is an invention by Eric Cayeux, who has published the ideas behind the concept in the journal article https://doi.org/10.2118/204084-PA resulting in the setup shown by Fig 1, and NORCE has patented the invention.

The main features of the sensor include the following. A small fraction of the flow of the drilling fluid is directed through the inline sensor which has its own dosing pump to control flow at a very low rate, and two automatic chokes are used to obtain three different pressures over the sensor; around atmospheric, 20 bar, and 40 bar. Both density and speed of sound are measured at each pressure such that compressibility can be calculated from speed of sound, which depends on compressibility and density of the fluid.

Furthermore, the fluid is heated by the two heating elements to obtain measurements at three different temperatures. By that, a more accurate extrapolation of density to higher temperatures is obtained. Measurements along the pipes marked with green are added to get specific heat and thermal conductivity of the drilling fluid. While this is often not required for accurate PVT, it is adding information that is very useful for real-time temperature models.

The invention has received interest from many industry companies, and the Research Council of Norway has awarded a proof-of-concept project that runs in 2024 and 2025. Purchasing components and building the loop is currently ongoing, after which measurements will be combined with calculations to obtain more accurate PVT at downhole conditions than is possible with current methods.

Publication:

Automatic Measurement of the Dependence on Pressure and Temperature of the Mass Density of Drilling Fluids, E. Cayeux, SPE Journal, https://doi.org/10.2118/204084-PA

NORCE/NFES Geosteering and Formation Evaluation Workshop

Sergey Alyaev and Nazanin Saeedi successfully organized the NORCE/NFES Geosteering and Formation Evaluation Workshop, held on November 11-13, 2024, at the Sola Strand Hotel in Stavanger, Norway. The event brought together over 100 participants, including students, researchers, and professionals from energy companies and service providers.

The program featured technical presentations and case studies, with sessions highlighting advancements in ultra-deep azimuthal resistivity (UDAR), innovative reservoir mapping techniques, and successful well-placement strategies. Supported by sponsors Equinor, Halliburton, SLB, Vår Energi, Logtek, and ROGII, the workshop provided a vibrant platform for learning, collaboration, and innovation in geosteering and formation evaluation.

A highlight of the workshop was the engaging panel discussion, “Where is Geosteering Going in the Next 10 Years?” which featured lively audience interaction and expert insights.

The international panel included David Holbrough (Baker Hughes), Frank Antonsen (Equinor), Michael Rabinovich (BP), Karol Riofrio (Halliburton), and Igor Kuvaev (ROGII), with moderation by Sergey Alyaev (NORCE) and Nigel Clegg (Halliburton). This session offered a forward-looking perspective on the evolving challenges and opportunities in geosteering, leaving participants inspired to explore the future of the field.

Several researchers from NORCE held presentations at the NORCE/NFES Geosteering and Formation Evaluation Workshop held on November 11-13.

- Sergey Alyaev et al.: Laying the Foundation for Generative AI-Enhanced Geosteering: The Complete DISTINGUISH Workflow

- Hibat Errahmen Djecta and Yasaman Cheraghi (University of Stavanger) et al.: Improvement of Reinforcement Learning Strategies of the Pluralistic Robot Validated in Competitive Geosteering

- Jan Tveranger (NORCE) et al.: Generating ML training data for real-time geological interpretation of LWD logs: Extraction of tool-specific synthetic logs from pre-drill geomodels

- Carlos Torres-Verdin (The University of Texas at Austin) et al. presented some results from Nazanin Jahani in Recent developments and verifications for the multi-dimensional and data-adaptive interpretation of borehole UDAR measurements using fast deterministic and stochastic inversion methods.

Additionally, our students received several Travel Grants from the Norwegian Formation Evaluation Society NFES:

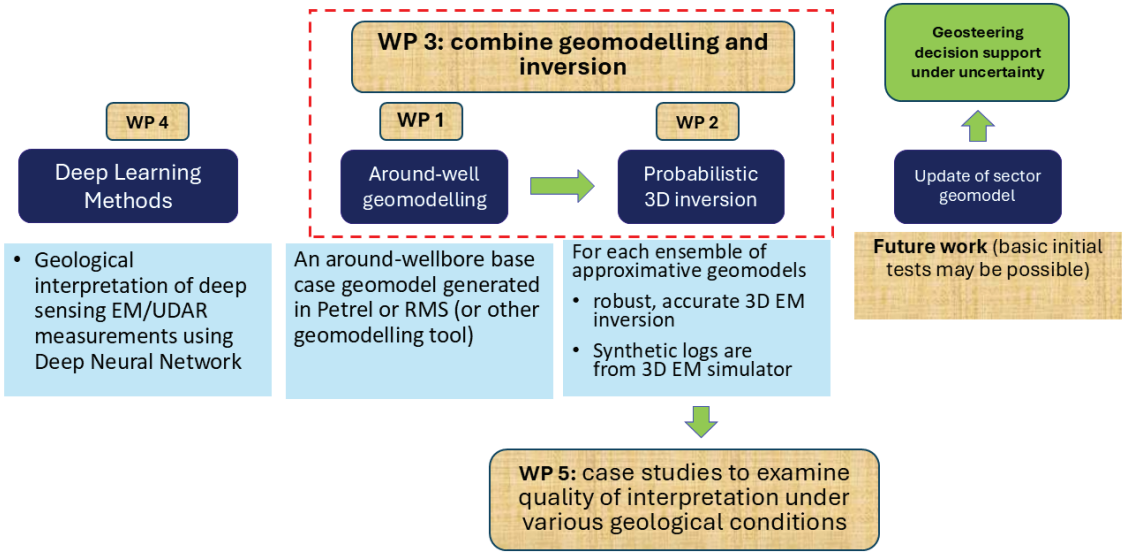
Hibat Errahmen Djecta and Yasaman Cheraghi (both co-supervised by Sergey Alyaev) received the grant for the Geosteering event. Dler Mirza (NFES President, Aker BP) also presented a travel grant to Durra Saputera for the past SPWLA Symposium in Rio. Morten Jakobsen and Nazanin Jahani received the certificate as co-authors on his behalf.

The NORCE/NFES Geosteering and Formation Evaluation Workshop. Photo: Screen Story

3D GIG: 3D Geological Interpretation for Geosteering of Wells

Along string elements with active control can dampen shocks and vibrations, control wobbling of drillstring to improve hole cleaning and reduce the energy requirements. By having active control of the magnetic damping elements, it is possible to optimize the damping effect with a reduced number of sleeves.

This project focuses on developing an automated workflow for 3D geological interpretation to support real-time geosteering. The objective is to link a global-scale 3D geomodel with high-resolution electrical resistivity images around the well trajectory. These images are generated using: (1) a 3D stochastic multi-resolution inversion of ultra-deep azimuthal resistivity (UDAR) and electromagnetic measurements, and (2) deep learning models predicting resistivity patterns based on collected data. As new measurements are acquired, the resistivity image is updated to refine the global geomodel in real time. This process improves geological structure identification, enhances well placement strategies, and reduces drilling risks. The project integrates uncertainty quantification to improve decision-making. Key developments are divided into four work packages: WP1) Automated generation of the most probable 3D geomodel using pre-drill information and seismic data, WP2) Multi-fidelity inversion strategies that improve efficiency by reducing input data volume and sparsity, WP3) Automated linkage between geomodel and inversion grids for improved data integration, and WP4) Deep Neural Networks (DNN), combining RNNs and CNNs, to estimate formation structures near the wellbore.



Project Partners:
Academic: University of Stavanger, University of Texas at Austin. Industry: Equinor, AkerBP, Vår Energi, ConocoPhillips, Harbor Energy, TotalEnergies
Project webpage: https://geosteering.no/3d-gig
Project Leader: Nazanin Jahani

References:

SPWLA-paper: Jahani, Nazanin, Saputra, Wardana, Torres-Verdín, Carlos, and Egil Romsås Fjeldberg. "Fast Stochastic Inversion of UDAR Measurements Using Adaptive Multi-Grid Simulated Annealing Guided by Model Parameter Error Estimation." Paper presented at the SPWLA 65th Annual Logging Symposium, Rio de Janeiro, Brazil, May 2024. doi: https://doi.org/10.30632/SPWLA-2024-0071

Geophysical Prospecting Journal: Jahani, N., Torres-Verdín, C. & Hou, J. (2024) Limits of three-dimensional target detectability of logging while drilling deep-sensing electromagnetic measurements from numerical modelling. Geophysical Prospecting, 72, 1146–1162. https://doi.org/10.1111/1365-2478.13451

Spin-Off Project “DISTINGUISH”:

Decision Support Using Neural Networks to Predict Geological Uncertainties when Geosteering Wells

An essential objective of SFI DigiWells is to develop ensemble-based decision support that balances drilling risk and recovery within drilling program constraints. DISTINGUISH extends this by bridging the gap between drilling and well placement at the field scale through complex real-time geomodeling. The project enables real-time geosteering by developing Generative-Network (GN) geomodels that ‘learn geology’ before operations and run with sub-second performance.

In 2024, we presented an initial version of a combined workflow for real-time data assimilation and decision-making during drilling with GN-geomodels [1]. This workflow integrates GN-geomodels for geological parameterization, ensemble methods for model updates, and global optimization for decision support. By stepwise reducing uncertainty with real-time data, it enhances predictive models of geology ahead of drilling, leading to more accurate steering decisions.

The Figure shows a step from a synthetic operation in a fluvial reservoir where the trajectory can be adjusted from 87 to 93 degrees stepwise. The uncertainty is reduced from the measurements around the bit, refining the prediction many meters ahead of drilling for many scenarios modeled by a GN in real time. The global optimization algorithm finds the best trajectories for each scenario, combining this knowledge for the immediate decision.

DISTINGUISH will develop this concept and combine it with AI for more realistic decision spaces, transforming the geosteering mentality from “depth of detection” to “distance of prediction” and probabilistic decision support. GN-geomodels and the new decision-support workflows can strengthen DigiWells’s research and enhance applicability for geologically complex NCS fields. These developments address well-placement research challenges from an Oil-&-Gas-21 machine-learning report [2]. According to the report, better well placement may lead to additional discoveries on the Norwegian Continental Shelf, an increased net present value from drilling, and significant CO2 emission reductions.

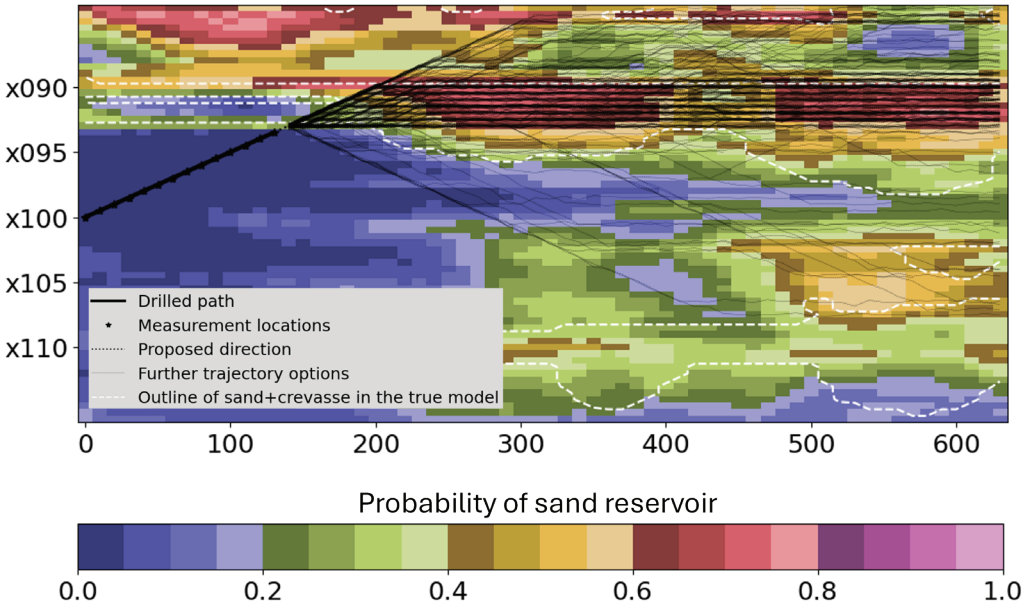


Figure: A step from a synthetic operation in a fluvial reservoir.

Project partners:
NORCE, University of Bergen, University of Stavanger, Heriot-Watt University, Aker BP, Equinor
Project webpage: https://geosteering.no/distinguish
Project leader: Sergey Alyaev

References:

Alyaev, S., Fossum, K., Djecta, H. E., Tveranger, J., & Elsheikh, A. (2024). DISTINGUISH Workflow: a New Paradigm of Dynamic Well Placement Using Generative Machine Learning. In ECMOR 2024. Submitted for peer review. Pre-print: https://arxiv.org/abs/2503.08509

Ellingsen, H. P., Angelsen, S., Sollie, O. K., Suyuthi, A., Mistry, R., Myrseth, P., & Tveiten, O. G. (2020). OG21 – Study on Machine Learning in the Norwegian Petroleum Industry. DNV GL. https://www.og21.no/contentassets/c50b419de39e4f56ba230f0d6a7862c0/og21-final-rev-0-24092020.pdf

Status from UiB

Overview

The DigiWells Project at the University of Bergen (UiB) has one PhD student, Durra Saputera Handri. Durra is developing faster and more accurate methods for modelling and inversion of induction logging data collected while drilling in the context of geosteering. He is supervised by Professor Morten Jakobsen at UiB, with additional guidance from Senior Researcher Nazanin Jahani, Assistant Professor Koen van Dongen, Senior Researcher Kjersti S. Eikrem, and Senior Researcher Sergey Alyaev. Durra is also collaborating with Professor Carlos Torres Verdin and his team at the University of Texas at Austin. He is currently spending six months at UT Austin to work closely with these experts, exchange ideas, and gain new insights.

Durra's Research

Durra: "My research focuses on developing new methods to better understand the induction logging data collected from sensors while drilling. This helps us get a clearer picture of what lies beneath the surface, which is crucial for safe and efficient drilling operations. By working with experts from different fields, we aim to create more accurate models that can improve drilling processes." The DigiWells project at UiB is unique because it combines knowledge from various fields to solve complex problems in subsurface exploration. By integrating different techniques, the project aims to create more detailed and accurate models of the underground structures encountered during drilling. This approach not only improves the accuracy of the models but also enhances the overall efficiency and safety of drilling operations. The collaboration with the University of Texas at Austin highlights the project's commitment to excellence and innovation. By working with Professor Carlos Torres Verdin and his team, Durra can access advanced resources and knowledge, furthering the development of cutting-edge methods for understanding subsurface formations. This international partnership underscores the global importance of the research and its potential impact on the field of geophysics.

Durra Saputera Handri. Photo: Rune Rolvsjord/NORCE

Morten Jakobsen, UiB.

Research Focus

The PhD project focuses on the development of methodologies, including theory, algorithms, and computer codes, for modeling and inversion of induction logging data while drilling, specifically in the context of geosteering. The project emphasizes the application of integral equation (Green's function) methods, which involve solving integral equations for the electrical and magnetic fields equivalent to solving Maxwell's equations.

Project Goals

- Developing Advanced Numerical Methods: Creating and implementing numerical algorithms for solving integral equations related to electromagnetic fields.
- Enhancing Subsurface Imaging: Improving the accuracy of subsurface imaging techniques to better locate natural resources and assess geohazards.
- Real-Time Data Analysis: Utilizing real-time induction logging data to make informed decisions during drilling operations, enhancing the efficiency and safety of geosteering.

Collaborations and Industry Interaction

Durra's workplace is at the Department of Earth Science at the University of Bergen, where he is a member of the geophysics group. This group has significant expertise in quantitative and observational seismology, as well as the development of methodologies for seismic modeling and inversion in the context of petroleum research. Although the geophysics group is not central to his project, the integral equation methods that Durra develops are similar to those used in seismic waveform modeling and inversion. This similarity allows Durra to explore and exploit synergies between seismic and electromagnetic geophysical methods.

Durra is actively engaging with industry partners through SFI DigiWells and the complementary project on electromagnetic geophysical methods called 3D GIG also described in this annual report, led by Senior Researcher Nazanin Jahan. This interaction provides valuable insights and practical applications, enhancing the relevance and impact of his research.

References:

Saputera, D. H., Jakobsen, M., van Dongen, K. W., Jahani, N., Eikrem, K. S., and Alyaev, S. (2024). 3-D induction log modelling with integral equation method and domain decomposition pre-conditioning. Geophysical Journal International, 236(2), 834-848.

Saputera, D. H., Jakobsen, M., van Dongen, K. W., and Jahani, N. (2025). Sequential Multi-dimensional Parameter Inversion of Induction Logging Data. Geophysical Prospecting, accepted.

Saputera, D. H., Jakobsen, M., Jahani, N., and van Dongen, K. W. A. (2024, May 19). Adaptive QuasiNewton Inversion of Electromagnetic Induction Logs for Subsurface Imaging While Drilling. Paper presented at the SPWLA International Student Paper Contest - 65th Annual SPWLA Symposium, NORCE UiB.

Saputera, D. H., Jakobsen, M., Jahani, N., van Dongen, K. W. A., Alyaev, S., and Eikrem, K. S. (2024, June 10-13). Inversion of Electromagnetic Induction Log in Anisotropic Media using an Adjoint Integral Equation Method. Paper presented at the 85th EAGE Annual Conference & Exhibition, NORCE UiB.

Saputera, D. H., Jakobsen, M., Jahani, N., van Dongen, K. W. A., Alyaev, S., and Eikrem, K. S. (2024). Inversion of Electromagnetic Induction Log in Anisotropic Media using an Adjoint Integral Equation Method. In 85th EAGE Annual Conference & Exhibition (pp. 1-5). European Association of Geoscientists and Engineers (EAGE). ISBN 9789462824980. UiB NORCE.

Saputera, D. H., Jakobsen, M., Jahani, N., Alyaev, S., Eikrem, K. S. (2023). Towards Real-Time 3D Modeling of Induction Logs Using an Integral Equation Method. Paper presented at the 84th EAGE Annual Conference & Exhibition, UiB NORCE.

Saputera, D. H., Jakobsen, M., Jahani, N., Alyaev, S., Eikrem, K. S. (2022). GPU-accelerated integral equation method for 3D modelling of induction logs. Presented at the Geosteering and Formation Evaluation Workshop by NFES and NORCE.

AI vs. Humans – A Sandbox Geosteering Experiment

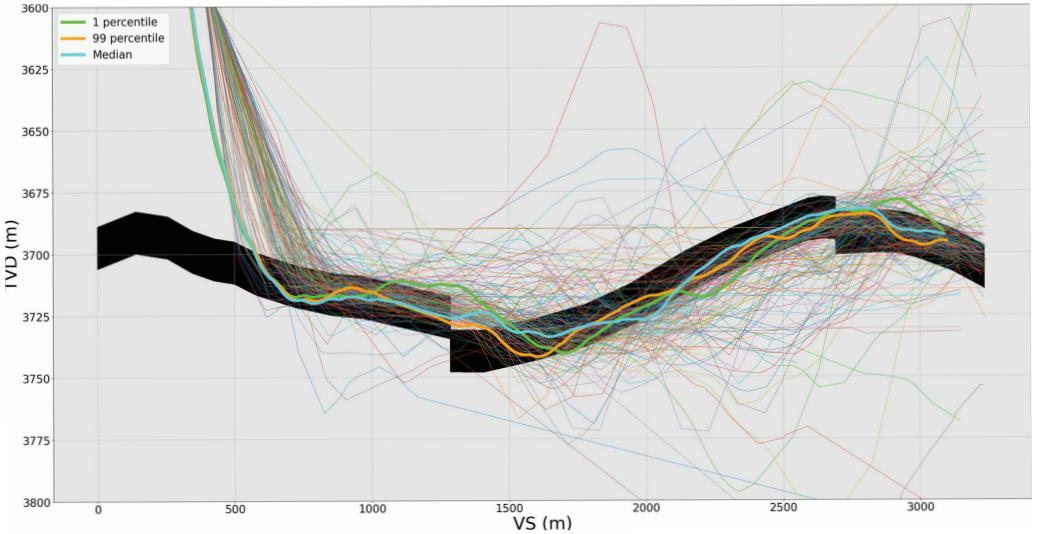
Humans are unpredictable and make mistakes. When designing automated systems, the goal is to remove human error and create something reliable and predictable. But how predictable are AI-powered geosteering systems?

At the NORCE annual wide-audience dissemination event, Sergey Alyaev presented a geological sandbox problem that enabled a comparison of humans and AI. This wide-audience communication was later presented at the international Geilo Winter School on Inverse Problems. The Sandbox Problem

Geosteering allows well adjustments in real-time as new information comes in. In a simplified test environment, the geology consists of layered formations. Drilling position within these layers can be determined by correlating well measurements with data from a nearby vertical well—creating a "barcode"-like pattern that helps track the well's location.

However, even in this controlled setup, challenges arise. Structural features like faults disrupt the "barcode," making it harder to determine well placement and increasing uncertainty.

Over: Sergey Alyaev. Under: GWC 2021 results



AI vs. Human Decision-Making

Geologists use their expertise to interpret geology and make steering decisions, but their choices are subjective and sometimes incorrect.

Researchers from DigiWells and spin-off project Distinguish, together with their collaborators from UiS and Stanford developed an AI-powered geosteering system to tackle this challenge. The AI learns geological patterns from data and simultaneously tracks thousands of possible scenarios. But despite its ability to model uncertainty, it still has to make a single decision at every step—just like a human.

Repeating the same sandbox experiment hundreds of times reveals a fascinating insight. Due to randomness, slight variations in decisions at each of the 40 steering points can lead to significantly different well paths. Even an identical AI has variability in execution.

Results from the Geosteering World Cup

A large-scale virtual competition, the Rogii Geosteering World Cup (GWC) 2021 provided valuable insights into human geosteering performance in layered geological scenarios similar to our sandbox environment. Although results may seem suboptimal, they reveal a realistic yet rarely seen picture of variability arising from geological uncertainty, limited real-time data, and rapid decision-making. Unlike real-world drilling, where repeated testing is logistically impossible, the GWC offers a fair and realistic benchmark for AI decision-making under complex conditions. It can be a key step toward real-world validation, bridging the gap between synthetic testing and practical application.

GWC 2021 results (see Figure) showed a broad distribution of human performance. The AI system, leveraging automated interpretation, probabilistic modeling, and advanced decision-making algorithms, delivered highly competitive results. While its average performance was superior to that of human participants, its best individual run outperformed all human competitors. This study is published in the concluding paper of Ressi Bonti Muhammad's PhD (SPE-*). His work provides critical insights into the behavior of AI-powered geosteering systems and their decision-making variability in uncertain geological conditions.

Key Takeaways

- **Modeling uncertainty is essential** – Understanding geological uncertainty improves geosteering reliability.
- **Modeling decisions is even more critical** – AI systems must optimize decision-making strategies, not just interpretation.
- **Sandbox experiments provide critical insights** – Controlled testing environments allow assessment of AI robustness and consistency.

These findings highlight that while AI-driven geosteering is highly effective, decision variability remains a key challenge. By refining uncertainty modeling and decision optimization, AI-based geosteering can achieve even greater reliability and outperform human experts in complex drilling scenarios.

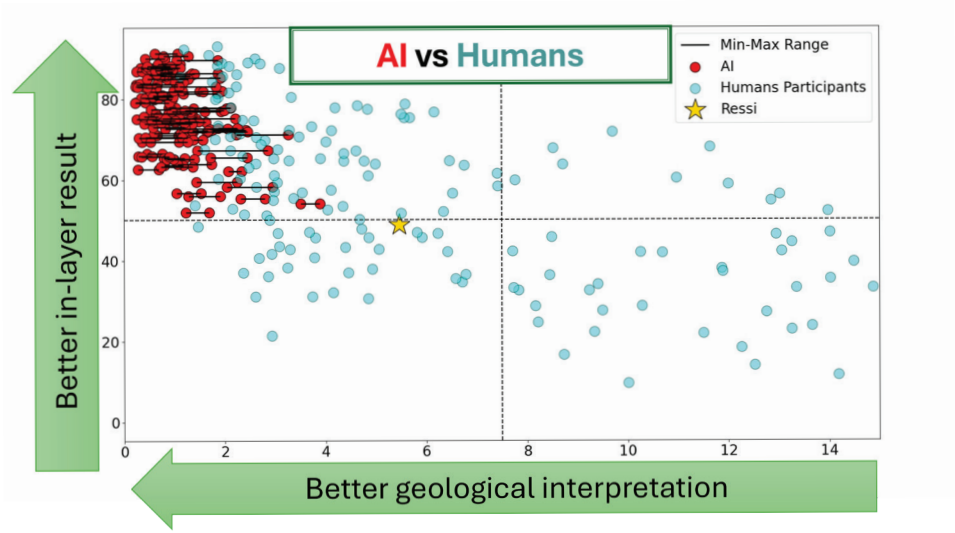


Figure shows the performance of Human participants and repeated attempts by the same AI agent. The results are evaluated based on the following:

- **Geological interpretation accuracy (x-axis)** – how well participants interpreted subsurface layers and the well location. Note that the AI system had a range of interpretations for each run.
- **Percentage of the well within the target layen (y-axis)** – how effectively they steered towards the optimal drilling zone.

Reference:

Muhammad, R.B., Cheraghi, Y., Alyaev, S., Srivastava, A. and Bratvold, R.B., 2025. Geosteering Robot Powered by Multiple Probabilistic Interpretation and Artificial Intelligence: Benchmarking Against Human Experts. SPE Journal.

The First Group of PhD students in DigiWells

We have interviewed the first group of PhD students from DigiWells. Luis, Felix, Ressi, and Pauline talked about their experiences with DigiWells and how they use their competence today.

Luis Alberto Saavedra Jerez, Ressi Bonti Muhammad and Felix Pacis have now all started working in the industry.

– I work in Aker BP today, as a graduate in the Drilling & Wells department. I'm part of a two-year program where I will rotate into four different areas inside the Drilling & Wells department, to learn and experience the different aspects of the drilling industry phases – planning, drilling, completion and well interventions, says Luis Alberto Saavedra Jerez.

Ressi Bonti Muhammad now works at eDrilling.

– I am developing an AI agent for autonomous drilling, using similar reinforcement learning principles as I focused on in my PhD-project. The objective is performance optimization and decision-making, explains Muhammad.

Felix Pacis have started working as a Data Scientist at Cognite.

– My main responsibility is to bridge the gap between our products and our clients' needs, ensuring we deliver meaningful value. The time I spent focusing on drilling and AI during my PhD has been incredibly relevant—it's given me a strong foundation to tackle the complex challenges we face every day, says Pacis.

Gilles Pelfrene, Felix Pacis, Pauline Nüsse, Rodica Mihai, Adrian Ambrus, Eric Cayeux and Luis Alberto Saavedra Jerez at the SPE Drilling Conference in Galveston, USA, in 2024. – A highlight, says Nüsse about the conference.

Muhammad together with his supervisors Reidar Bratvold (UiS) Alejandro Escalona (UiS) and Sergey Alyaev (NORCE) at his defense.

Crucial industry insight

The PhD candidates highlight the insight into the industry, that DigiWells provides.

– My experience with DigiWells was very pleasant; during this time, I learned a lot about the industry's future. Besides, the people who form DigiWells are very knowledgeable and enjoy helping you all the time, which makes working with them a great experience, says Jerez.

Looking back, it was such a privilege to do PhD with DigiWells. I always felt supported, whether it was through my brilliant supervisors or close collaboration with industry partners. That level of real-world exposure is a rare privilege and was invaluable for my work in applied AI. I'm grateful for the chance to bring my expertise into a role where I can continue pushing the boundaries of what AI can do—and I owe much of that to the strong foundation I built during my time at DigiWells, says Pacis.

Useful PhD gatherings

Pauline Marie Nüsse will continue in a PostDoc-position with DigiWells, starting June.

She highlights the collected experience in the centre, and the collaboration with the other candidates.

– Doing my PhD with DigiWells was a great experience. Especially getting input and ideas from the experienced people in the project, was a great win for me. The PhD gatherings set up about twice a year were a good opportunity to get to know and stay in touch with the other PhD students in the project, even though we are spread out over Norway, says Nüsse.

Centre management

Erlend H. Vefring

SFI Director

WP7 - Project management

Helga Gjeraldstveit

SFI Assistant Director

WP6 - Studies and analysis

Sergey Alyaev

WP-leader

WP2 - Predictive modelling

Eric Cayeux

WP-leader

WP1 - Agile well construction workflow

WP3 - Smart sensing

WP4 - Interoperability and user-system interaction

Rodica G. Mihai

WP-leader

WP5 - Drilling automation and autonomy

Mette Stokseth Myhre

Administrative coordinator

Board of Directors

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Tron Golder Kristiansen (Board Chair)
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Praveen Jain
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TotalEnergies

Sergey Sakharov
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Harbour Energy Norge AS

Andre Leibsohn Martins
Petrobras

Øystein Arild
University of Stavanger

Morten Jakobsen
University of Bergen

Ole Morten Aamo
Norwegian University of Science and Technology (NTNU)

Aina M. Berg
NORCE AS

Halil Qzarpa (Observer)
Research Council of Norway

Post Doc.

Liang Zhang

Post Doc.: DDBot – AI for automatic population of semantics

Affiliation:	**Energy and Technology, NORCE**
Supervisor:	**Benoît Daireaux, Sergey Alyaev**
Associated Epic:	**WP4 - Interoperability and user-system interaction**
Period:	**06.2043 - 06.2026**

Liang Zhang received the Ph.D. degree in Engineering from the Dept. of Mechanical and Industrial Engineering at NTNU Trondheim in 2024. He also holds the M.Sc. degree in Naval Architecture and Ocean Engineering.

Liang works on a Drilling Data Bot (DDBot) leveraging LLM to automatically convert mnemonics-based metadata of drilling signals into semantic models based on predefined DDHub terms. These models can be integrated into various digital platforms including DDHub, to enable effortless exchange of drilling signals.

Liang presented a simple version DDBot in DigiWells seminar 2024 and published a paper “Cloud-Free Question Answering from Internal Knowledge Bases: Building an AI for Drilling Applications”. He is currently developing “DDBot-chat”, importing user interactions to assist the modeling. A future “DDBot+” is envisioned for more capable modeling by incorporating natural-language documents.

PhD students

Durra Handri Saputera

PhD topic: Borehole electromagnetic modeling and inversion

Affiliation:	**University of Bergen**
Supervisor:	**Morten Jakobsen**
Co-Supervisors:	**Sergey Alyaev, Nazanin Jahani, Kjersti Solberg Eikrem**
Associated Epic:	**Real-time geophysical data imaging while drilling**
Period:	**2022-2025**

I am a PhD student at the University of Bergen, working on borehole electromagnetic induction tool data inversion to provide subsurface imaging around the borehole during the drilling process.

My work is focused on exploring 3D forward modelling and inversion methods to reduce the computational cost required. So far, I have developed the integral equation method for 3D forward modeling of electromagnetic induction log and successfully implemented it on GPU, achieving up to an order of magnitude speedup in computation time and using the domain decomposition method in the integral equation method for further reduction in computational cost.

In addition to forward modeling, I have implemented the matrix-free adjoint method for inversion. Moving forward, I plan to explore different algorithms for stochastic inversion to quantify uncertainty. Furthermore, I am considering data-driven methods, such as physics-based machine learning, as a potential alternative for fast computation.

Marios Gkionis

PhD topic: Physics-Informed Multi-task Learning, applications to Fault Detection and Diagnosis

Affiliation: NTNU, Department of Engineering Cybernetics
Supervisor: Ole Morten Aamo
Co-Supervisors: Bjarne Andre Grimstad, Ulf Jacob Flø Aarsnes
Associated Epic: Distributed Drilling Control
Period: 2022 - 2025

I am a Mechanical Engineer (received my Integrated Master's degree with honors from the Aristotle University of Thessaloniki, Greece in 2020) and hold extensive experience in dynamics simulations and Nonlinear Model Predictive Control. My interests lie in the development of intelligent control algorithms and data-efficient learning algorithms.

The goal of the PhD project is to combine the Multi-task Learning architecture with Physics-Priors in order to develop general and data-efficient Deep Learning training algorithms for System Identification problems. We have been focusing on the application of multiple Fault Diagnosis and Detection in Drilling, wherein the Washout, Pack-off and Mud Loss faults are identified and Diagnosed using a single Neural Network. Since the collection of faulty measurements in this application bears significant costs, injecting Physics-Priors into the Network can help with a correct identification without the need for expensive labeled data.

As a first step, we have successfully implemented a Physics-Informed Multi-task Learning Neural Network for multiple Fault Diagnosis and Detection for the case of steady-state Drilling data, which were supplied to the Network using a steady-state model. The conference paper with title "Fault Diagnosis For Drilling using a Multitask Physics-Informed Neural Network" was accepted in DYCOPS25 (14th IFAC Symposium on Dynamics and Control of Process Systems, including Biosystems). At the moment, our work focuses on performing Fault Detection and Diagnosis when the input data are described by timeseries. This requires leveraging the Automatic Differentiation capability of deep learning training algorithms in order to inject Partial Differential Equation loss in the loss function of the Neural Network.

Future directions of the PhD project include; generalizing the approach by exploring a new application though a Research Visit, applying Discrepancy Modeling and/or Meta-Learning in order to perform real-time fine-tuning of the Network's parameters when presented with data that is described by higher-complexity phenomena not captured in the Physics-Priors of the Neural Network.

Åsmund Aamodt Resell

PhD topic: Annular fluid flow coupled with drill string vibration

Affiliation: University of Stavanger
Supervisor: Hans Joakim Skadsem
Co-Supervisors: Rodica G. Mihai, Knut Erik Teigen Giljarhus
Period: 2023 - 2026

I received my master's degree in mechanical engineering from NTNU in Trondheim. My specialization is in structural mechanics and fluid dynamics, with a strong focus on numerical modeling and computational analysis.

This project aims to improve our understanding of fluid dynamics within the annular space outside the drill string and to strengthen our knowledge of the coupling between drill string vibrations and fluid flow. The work investigates how the fluid forces acting on the drill string is affected by varying flow regimes in the annulus, which again can be affected by the rotation and eccentricity of the drill string itself. The work of the thesis also investigates how the coupled effects can be captured in real-time models suitable for use in operational settings. The research work uses various numerical and machine learning methods such as computational fluid dynamics, finite element analysis and genetic programming.

Resell, Å. A., Giljarhus, K. E. T., and Skadsem, H. J. (December 9, 2024). "Entrance Lengths for Fully Developed Laminar Flow in Eccentric Annulus." ASME. J. Fluids Eng. May 2025; 147(5): 051302. https://doi.org/10.1115/1.4067129

From left Liang Zhang, Pauline Nüsse, Marios Gkionis, Nils Christian Wilhelmsen, Lucas Volpi and Åsmund Aamodt Resell. Photo: Screen Story

Publications 2024

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Alyaev, Sergey; Muhammad, Ressi Bonti; Cheraghi, Yasaman; Bratvold, Reidar Brumer; Srivastava, Apoorv; Tartakovsky, Daniel M.. How to Explain Geology to a Robot? DISTINGUISHing Patterns for Optimal Geosteering Decisions. DigiWells Seminar 2024; 2024-11-26 - 2024-11-26 NORCE UIS

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Alyaev, Sergey; Pacis, Felix James Cardano; Wiktorski, Tomasz. Cloud-Free Question Answering from Internal Knowledge Bases: Building an AI for Drilling Applications. DigiWells Seminar 2024; 2024-11-26 - 2024-11-27 NORCE UIS

Alyaev, Sergey; Pacis, Felix James Cardano; Wiktorski, Tomasz. Domain-adapted Embeddings Model Using Contrastive Learning for Drilling Text Data. FAIEMA 2024; 2024-10-01 - 2024-10-02 NORCE UIS

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Cayeux, Eric. Demonstration of Seamless Interoperability for Automatic Drilling Management in a Multi-Vendor Context. SPE Annual Technical Conference and Exhibition; 2024-09-23 - 2024-09-25 NORCE

Cayeux, Eric. How digitalization and automation will shape the future of drilling operations. DEA(e) 3rd quarter 2024 meeting; 2024-09-05 - 2024-09-06 NORCE

Cayeux, Eric. The Role of Semantic Networks in Mitigating Risk During Data Exchange in Multi-Disciplinary Well Construction. SPE/IADC Drilling Conference; 2024-03-05 - 2024-03-07 NORCE

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Cayeux, Eric; Macpherson, John D.; Pirovolou, D.; Laing, Moray; Florence, Fred. A General Framework to Describe Drilling Process States. SPE Journal 2024 ;Volum 29.(12) s. 6819-6836 NORCE

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Saputera, Durra Handri; Jakobsen, Morten; Jahani, Nazanin; van Dongen, Koen W. A. Adaptive Quasi-Newton Inversion of Electromagnetic Induction Logs for Subsurface Imaging While Drilling. SPWLA International Student Paper Contest - 65th Annual SPWLA Symposium; 2024-05-19 - 2024-05-19 NORCE UiB

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Society of Petroleum Engineers, Society of Petroleum Engineers. Approach Uses Multidisciplinary Constraints for Automatic Well-Path Generation. Journal of Petroleum Technology 2024

Personnel

Key researchers	Institution	Research area
Eric Cayeux	NORCE	Drilling
Sergey Alyaev	NORCE	Geostreering
Rodica Mihai	NORCE	Drilling
Adrian Ambrus	NORCE	Drilling
Erik Wolden Dvergsnes	NORCE	Drilling
Gilles Pelfrene	NORCE	Drilling
Knut Steinar Bjørkevoll	NORCE	Drilling
Benoit Daireaux	NORCE	Drilling
Steen Agerlin Petersen	NORCE	Drilling
Sonja Moi	NORCE	Drilling
Nazanin Jahani	NORCE	Geosteering
Ulf Jakob Aarsnes	NORCE	Drilling
Andrew Holsaeter	NORCE	Drilling
Hanieh Foroush	NORCE	Drilling
Jan Einar Gravdal	NORCE	Drilling
Henrik Anfinsen	NORCE	Drilling
Morten Jacobsen	UiB	Formation physics
Reidar Bratvold	UiS	Decision Analysis
Dan Sui	UiS	Drilling
Hans Joakim Skadsem	UIS	Fluid Mechanics
Tomasz Wiktorski	UiS	Computer science and Data science
Ole Morten Aamo	NTNU	Cybernetics

Postdoctoral researchers with financial support from the centre budget

Name	*Nationality*	*Period*	*Sex M/F*	*Topic*
Nils Christian Aars Wilhelmsen	Norwegian	2023-2024	M	Modeling and detection of slip in damping subs
Liang Zhang	Chinese	2024-2026	M	DDBot - AI for automatic population of semantics

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
Durra Handri Saputera	Indonesian	2022-2025	M	Efficient integral equation methods. For modelling and inversion of electromagnetic induction data: Focus on the use of different scattering approximations

PhD students working on projects in the centre with financial support form other sources

Name	*Funding*	*Nationality*	*Period*	*Sex M/F*	*Topic*
Marios Gkionis	NTNU	Greek	2022-2025	M	Extremum seeking control using ideas from reinforcement learning
John Isak Fjellvang Villanger	UIS	Norwegian	2023-2024	M	Modeling and optimization of the drilling process using tools within machine learning. Physics informed machine learning in drilling
Åsmund Aamodt Resell	UIS	Norwegian	2023-2026	M	Computational fluid dynamics and drill string mechanics

Master degrees

Name	*Sex M/F*	*Period*	*Topic*
Sondre Løver	M	Aug 2023 - June 2024	Optimal Control Strategies for Minimizing Bendign Moments in Marine Risers
Alisher Khodajev	M	Aug 2022- June 2024	Efficient integral equation methods. For modelling and inversion of electromagnetic induction data: Focus on the use of different scattering approximations

Statement of accounts

(All figures in 1000 NOK)

Funding			
	Amount	**In-kind**	**Sum**
The Research Council	13,074		13,074
The Host Institution (NORCE Norwegian Research Centre AS)		1,000	1,000
Research Partners			
Universitetet i Bergen, UiB		-	-
Universitetet i Stavanger, UiS		2,118	2,118
Norges teknisk-naturvitenskapelige universitet, NTNU		1,493	1,493
Enterprise partners			
Operators	10,654	1,699	12,353
Vendors		49	49
Public Partners			
Sum	**23,728**	**6,359**	**30,087**
Costs			-
The Host Institution (NORCE Norwegian Research Centre AS)	18,752		18,752
Research Partners	5,976	3,611	9,587
Enterprise partners		2,081	1,748
Sum			**30,087**

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Universitetet i Stavanger

UNIVERSITY OF BERGEN

NTNU
Norwegian University of Science and Technology

From left: Sergey Alyaev, Nazanin Jahani and Gilles Pelfrene Photo: Screen Story