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DRILLING TECHNOLOGY

Drilling automation: A system view

Autonomous drilling has not progressed as far as previously thought. As an industry, we silo parts of the autonomous system. This needs to change to a full-system approach to progress further.

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As an industry, we have not yet fulfilled the vision of autonomous drilling despite the industry focus for the past several decades. One of the reasons is due to the automation of siloed, sub-systems. A change in the industry is needed to shift to system-level autonomous drilling.

In this article, we define autonomous drilling as the ability of a system—software and hardware—to learn, adapt and evolve in response to a dynamic drilling environment to consistently deliver wells at the highest drilling performance that maximizes reservoir exposure. An effective autonomous system requires a seamless end-to-end solution, not disparate parts, or sub-systems.

In directional drilling, this means the system automatically takes in a well plan, uses real-time sensors and a digital twin to realize the most recent state of the well, autonomously determines what actions to implement, executes those actions—adjusting drilling parameters or steering decisions in real time—and then repeats these steps until total depth is reached. One reason the industry has not seen widespread deployment and adoption is a lack of focus on the complete autonomous system.

In 2012, the SPE Applied Technology Workshop in Vail, Colo., convened to draft a Drilling Systems Automation

(DSA) vision. The published vision states, "In 2025, well plans are uploaded into an interoperable drilling system that automatically delivers a quality wellbore into the best geological location, installs the casing and zonal isolation according to plan, installs the completion system according to the program, updates remote operators and experts in real time to changes in the situation, and identifies potential paths for success for the experts to input control" (DSA Roadmap, 2019).

In 2022, at the joint symposium organized by the SPE Drilling Systems Automation Technical Section and IADC Advanced Rig Technology committee, the DSA vision and timeline were revisited (Jacobs, 2022). The industry has made significant strides toward achieving this vision, as evident in the multiple successful demonstrations, pilots, and commercialization of different automation sub-systems, but it has not achieved a unified autonomous system yet.

The proliferation of sub-system-focused solutions is one of the reasons the adoption of autonomous solutions is lagging. When autonomous solutions are developed for discrete drilling areas, instead of viewing what is required for the entire system, gaps are created. This article addresses three key gaps in automation systems: integration between the rig and the downhole sub-system, integration between drilling and sub-surface (formation evaluation), and the interaction humans have with the system.

AUTONOMOUS SYSTEM GAPS IN INTEGRATION AND INTERACTION

Rig and downhole sub-system integration. As an industry, we have focused on the development and deployment of autonomous projects and solutions, based on our role and responsibility during the drilling process. The rig owner or contractor owns the rig sub-system, and their focus has been on creating automated workflows and processes around the rig system. The service companies responsible for the downhole sub-systems required to drill the well have focused on creating autonomous workflows and processes related to their specific sub-systems.

Since it is realistically impossible for humans to repeat the same actions consistently for a prolonged period and repeatedly deliver the same flawless results, operators, service providers and contractors are extending their research efforts to accelerate automated applications across the lifecycle of the well.

From a traditional, capital-intensive approach, focused on designing and building automated rigs, rig contractors, such as Nabors, have recently started to retrofit previous generation rigs (Nabors, 2022). This approach reduces capital investment and serves as a potential opportunity to upgrade rigs without having to replace them entirely. This approach opens up new opportunities, especially when workforce resources are a challenge and drilling performance is a priority for operations.

When it comes to rig automation, repetitive drilling activities like tripping-in/tripping-out, making pipe connections, pipe handling and others can benefit most from automation and deliver optimized, consistent performance. Systems like Auto-driller and TripMonitor maintain consistent performance by following a preset configuration to meet drilling objectives, with minimum interference from the driller. While drilling a well with a mud motor bottomhole assembly (BHA), a driller can set up the auto-driller system to seamlessly adjust weight-on-bit and differential pressure, without changing the auto-driller settings. It allows further optimization to improve on-bottom performance, by automatically regulating surface parameters like differential pressure, weight-on-bit and torque.

Service companies have historically focused on automating the directional steering process, such as steering to a pre-defined well plan, while avoiding drilling dysfunctions. For example, a typical well plan includes kickoff from vertical, a curve section and then a tangent or lateral section. Halliburton's autonomous system automatically ingests the well plan and autonomously performs kick-off, followed by drilling the curve to the landing point. The landing point can be adjusted, based on the current well position and the geologist's requirements, and can change in real time. The system automatically switches to geosteering on the well plan as soon as drilling the lateral starts, and the geologic targets can be updated, modified and transferred to the autonomous system. A few years back, these steps were done manually by directional drillers and geosteering engineers.

Today, we don't have standards or guidelines that allow for seamless integration with the variety of rig control systems available in the market. Depending on the rig system, multiple ways exist to get data from the rig and send set points and commands to the rig controls. The Drilling and Wells Interoperability Standards (D-WIS) industry group has been working diligently to develop standard interfaces to enable a seamless exchange of data between the different sub-systems (D-WIS Industry Group, n.d.). Service providers, such as Halliburton, have taken

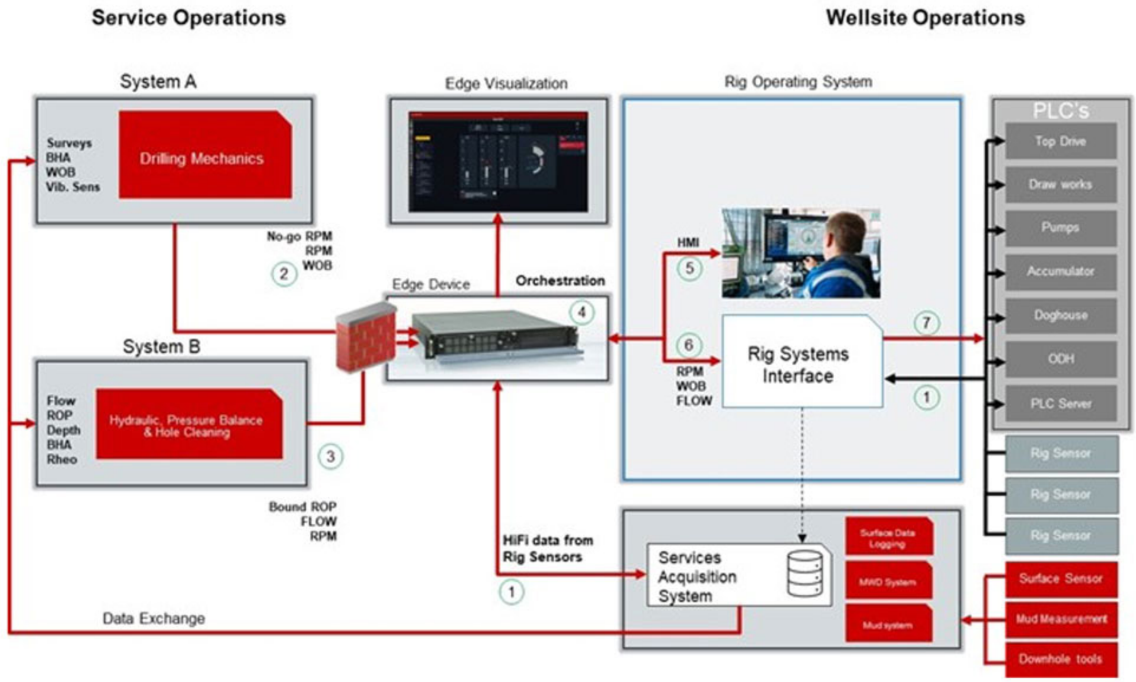

Fig. 1. Illustrative data flow.

an approach to develop a rig-agnostic system to connect and communicate to the rig system (**Fig. 1**) to allow for bi-directional data flow, as well as send parameter set points to the rig (e.g., WOB or flow set points, recipe parameters). It uses industry standard communication protocols, such as OPC-UA, modbus, etc., and proprietary protocols that are specific to certain rig control systems (Grøtte, Marck, Parak, Laing, & Kvammen, 2022).

At Halliburton, a pilot program for autonomous directional drilling was rolled out in Norway, to drill three-dimensional wells in an automated mode, where steering commands were carried out autonomously (Heredia, et al., 2021).The rollout plan used remote operations to relocate personnel from the rig location to remote drilling centers. Three rigs implemented the autonomous solution, and the data were compared with the drilling performance of three-dimensional wells drilled by the conventional method from the last two years.

This pilot project proved that autonomous drilling can drill smoother wells, by reducing friction factors and tortuosity. This translates to direct cost-savings per foot (or meter) and a reduction in the overall well delivery time, while achieving remote execution and well performance monitoring.

Northern Kuwait provides another example of a successful autonomous steering system deployment. The deployment resulted in a best-in-class performance in that area (Farhi, et al., 2022).

Additional work is still required to make the integration to the rig control system seamless. Data needs are being addressed, while the requirement for an integrated or systems approach to provide critical information to the driller is getting the attention needed to be addressed too.

Drilling and sub-surface (formation evaluation) integration. The primary objective of drilling a well is to produce oil, so the goal for the drilling industry should be to increase production by maximizing reservoir exposure. However, for a long time, the goal was only to drill as close as possible to the pre-defined well plan, in the fastest possible time. The industry focused on maximizing on-bottom rate of penetration (ROP), celebrating the breaking of basin ROP records and footage/day records. With the introduction of formation evaluation tools and real-time interpretation of their data, the drilling process started to shift toward making real-time changes to a well plan, based on the data interpretation. This real-time data interpretation capability, and the maturity of geometric-based steering automation, allows us to autonomously incorporate real-time sub-surface insight, to drive changes in the well trajectory and autonomously drill to the adjusted trajectory.

The manual process to modify a well path, based on geosteering decisions, involves the geosteering engineer

Fig. 2. Drilling and geosteering workflow integration.

communicating a new target to the directional driller. The driller then performs multiple calculations and uses manual steering to reach the new target.

Recently, Halliburton demonstrated the industry's first fully automated workflow (**Fig. 2**) to incorporate geosteering-based target changes into its LOGIX® autonomous drilling platform. The automated process to modify the well plan takes seconds to complete. Automating communication of geosteering target changes eliminates communication hurdles between the geologist, geosteering engineer and directional driller, and it eradicates the need for manual projections. The result is accurate well placement, delivered consistently. In addition, the autonomous steering system maintains the drilling performance simultaneously through the whole process.

The next step in this process is to automate the geosteering data interpretation and decision-making, to further reduce the overall cycle time and drive consistency in the data interpretation.

Humans and autonomous system interaction. Even with autonomous systems, people will continue to participate in the drilling execution process. Autonomous systems are designed by people; design verification and validation are required. The human role initially shifted toward monitoring and intervention, with a management-by-exception strategy. The autonomous system (hardware and software) will detect, analyze and act in real time to deliver the well, while people monitor and intervene when the autonomous system is unable to make a decision or fails to deliver.

An autonomous solution focused on an individual sub-system, without consideration for how someone will interact with the overall system, will result in an increased cognitive load on the individual user, who must manage multiple automated sub-systems and determine the correct course of action, by using the data provided by each. This becomes more complicated in a remote, real-time operation setting, where an individual is responsible for monitoring multiple rigs.

A focus on human factors—human performance, technology, design and human-computer interaction—is now considered pivotal when designing automated systems, developing training and planning deployment. The drilling industry recognizes the need for this expertise, and it is discussed in section 11 of the DSA Roadmap Report (DSA Roadmap, 2019). Recently, SPE and the Human Factors and Ergonomics Society (HFES) signed a letter of cooperation, to drive engagement between the two organizations, in order to accelerate the application of human factors in the oil and gas industry and, by extension, achieve the oil and gas automation vision (JPT, 2022).

Halliburton has taken the systems approach, working with customers to develop a human interface (Grøtte, Marck, Parak, Laing, & Kvammen, 2022) for the driller, with a focus on presenting context-specific information and integrating different views of the operation. The philosophy is to consider the system as an active collaborator in the decision-making process, where the automation system not only alerts the operator to take control but also provides options/solutions to help make the decision.

Conclusion. The industry continues its pursuit towards a complete, closed-loop autonomous drilling system, where sub-systems integrate to form one end-to-end solution that can deliver wells seamlessly. On this quest, Halliburton has embraced a system-level autonomous drilling approach to close three gaps: rig and downhole integration, drilling and sub-surface integration and humans and autonomous system integration. As additional companies collaborate toward this system-level autonomous drilling, the industry should see faster progress toward autonomous drilling. WO

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Lead Photo: The industry needs to adopt a full-system approach, so that autonomous drilling can progress further.

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