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Digital Technologies Transforming Workflows From Subsurface To Facilities

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HOUSTON–Much of the exuberance around the rapid rise of America's unconventional resource plays has, understandably, focused on the successes in the top-tier acreages. Factory-mode production, coupled with the sheer ingenuity of operators and service firms, has made these plays economic at lower oil and gas price decks. However, as leasing costs skyrocket to $60,000 an acre or more in core areas, and even with today's higher oil prices, it is incumbent on operators to consider ways to profit from production outside these known sweet spots.

Digital technologies can help. The ability to represent unconventional workflows in a digital twin virtual simulation can provide the extra insight needed to make these outside-the-core plays economic.

Fundamentally, the power of digitization is its ability to create a simulated view of the real environment in advance of making a capital decision, and test the downstream impact of drilling and production scenarios.

This approach is pervasive outside of the oil and gas industry. No automobile manufacturer would design a new car without a rigorous simulation of its performance characteristics. Indeed, the creation of digital simulation models has come so far that advanced nations no longer conduct physical nuclear tests, confident that virtual simulations are sufficient.

In the oil and gas industry, however, the adoption of digital twins remains piecemeal. Some parts of the overall workflow are modeled, a subset of these models is simulated and a tiny percentage of these are updated with the real results to improve future simulations. Adoption within the industry also runs along a spectrum. Deepwater plays, with their need for substantial upfront capital and significant risk of a dry hole, tend to have the highest commitment to simulation and scenario analysis. The lowest adoption, unsurprisingly, is in mature brownfields with high water cuts and extended production declines.

Yet even in areas with less potential for increasing production, digitization can be valuable for preserving the play's overall economics. Understanding how to manage the water cut and extend the life of the field remains critical to overall economic performance.

Profiting From Digitization

Unconventional assets, in general, suffer from a lack of digitization throughout their life cycles. Yet there is reason to believe they may profit the most from this technology. While these plays pose a lower dry hole risk, understanding the geology, designing the optimal completion and operating in the correct production regime are of the utmost importance.

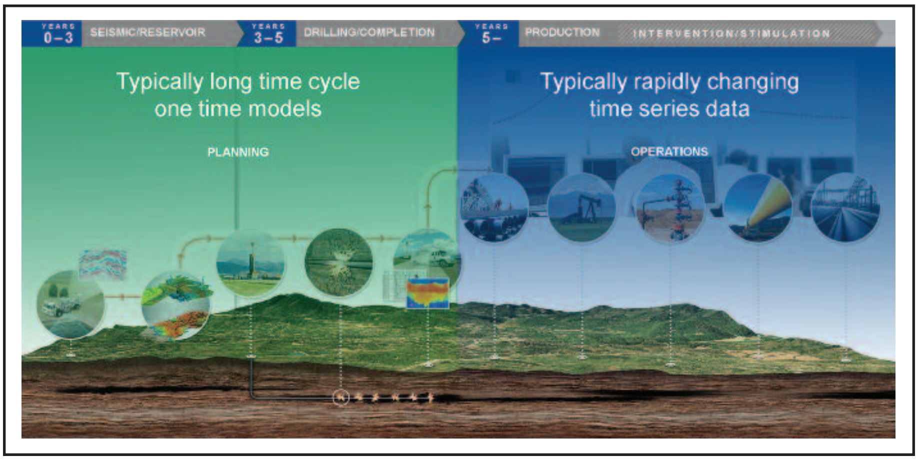
A fundamental transformation is needed to unlock these gains. We must connect the workflows across our digital twin of the subsurface geology (the reservoir model) with the digital twin of surface operations (the production model). Figure 1 shows a unified workflow using a single digital twin that spans subsurface planning and surface operations.

Today, three key barriers inhibit this integration. For one, the piecemeal models are kept siloed, accessible only from the builders' desktops. The increasing adoption of the cloud can help interconnect this information more easily. This is happening faster for U.S. unconventional operators, since the United States has led the move to all types of cloud-based solutions.

Second, the integrated digital twin data must make sense, not only to the builders of these models, but to their consumers as well. Today's reservoir models and simulations are so complex that only very specialized, long-tenured veterans can decipher their meanings. This is of no help to the operations teams that must make rapid decisions, and cannot accept the safety risks of getting it wrong. A new breed of Web-based industrial Internet of Things (IIOT) applications is simplifying domain specific outputs so that they become usable by the consumers of this information.

FIGURE 1

Unified Workflow in Single Digital Twin Spanning Subsurface and Surface



Simulating At Rig Speed

Finally, it must be possible to conduct this integrated digital twin simulation at the speed of the rigs. The biggest reason for the lack of scenario testing and analysis in unconventional development projects is the rapid pace of factory-mode production that is needed to remain economic in these plays. However, advances in both computer technology and domain-specific science are allowing software providers to clear this hurdle with computational speeds that exceed previous standards by a hundredfold or better.

These include a new, Web-based software application that can conduct flow simulations in fractured media. The solution produces results at speeds two orders of magnitude faster than traditional approaches, and generally with higher accuracy. Machine learning approaches also are enabling these quantum leaps in speed by using data science approaches to make predictions. Finally, the advent of graphics processing unit technology is unlocking a step change in computational time.

Underlying the digitization effort is a significant information technology challenge that is being solved at the same time. This is the need to bring the disparate data types across subsurface and surface activities to the same place. Structured, unstructured, sensor, document and third-party vendor data all need to "talk" to one another. Operators recognize that there cannot be a single database implementation to solve this problem, and this is leading to the rise of so-called data lakes.

The data lake concept is a federation of different databases, each purpose-built for specific data types, but with interconnectivity between them. A data lake will comprise a data catalog that contains the information being sought. As an example, finding the proppant data used in the first stage of a fracturing treatment might traverse the catalog from upstream → production → unconventional → region → well → proppant → time frame.

FIGURE 2

Digital Operations Platform with 'Data Lake' Between IIOT Sensor and Model Data

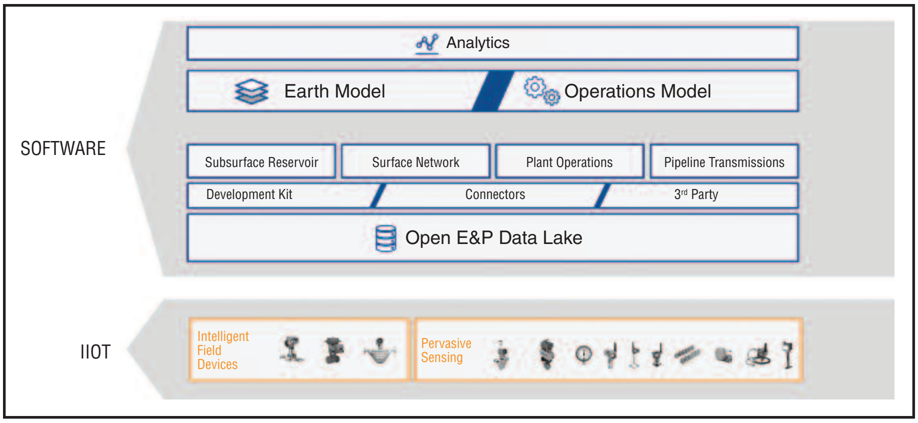


Figure 2 shows a data lake between the IIOT sensor data and subsurface model data. This new IT approach is providing the foundational layer for creating a single, interconnected digital twin for unified analytics of the entire exploration, drilling, completion and production workflow, rather than piecemeal efforts.

Digital Representation

The last part of this solution includes the components that make up the digital twin for surface operations. Together, these three main components create a complete digital representation of a physical asset.

The first is a process modeling engine to model physical process dynamics and chemical reactions in real time. Using advanced equations of state and known physical properties, a real-time simulation engine can replicate the performance, responses and dynamics of the physical asset accurately and reliably.

This approach is referred to as "first principles-based modeling," where instead of using historical data from existing processes or best-fit polynomial curves, the model calculates the dynamics based on the laws of physics, allowing accurate simulation across the entire operating range. Advanced versions of the software enable this high level of fidelity to be deployed easily through the use of an extensive library of advanced modeling objects. The days of building models using rudimentary function blocks or proprietary programming languages are over.

Next, there is the control system emulation environment, which allows the execution of control elements and control modules without physical controllers or input/output communication hardware. By using native control system emulation environments, a direct copy of the control system being used by operators and engineers is inserted in the digital twin. This offers several unique advantages. The look and feel of the graphics and faceplates are identical, alarm points remain unchanged, and the control logic and algorithms are the same in both systems.

Finally, the virtual reality engine creates a 3-D, digital representation of the physical asset. The virtual reality environment has rigorous data linking to the control system and process modeling engine, so that an operator can walk around and study process conditions displayed on a level gauge, for example, and interact with the environment and manipulate manual control elements, such as solenoid valve resets and valve hand-wheels.

The data linking is two-way, so that the virtual reality operator sees live data, and interactions are captured by the simulation engine. The virtual reality operator is able to practice upset condition responses, perform standard walk arounds, and learn the "lay of the land" without ever leaving the office, reducing safety risks and expanding operators' skills in a way never before possible.

Five Key Capabilities

As illustrated in Figure 3, the combination of a high-fidelity/real-time simulation engine, a virtualized control system and a virtual reality 3-D model creates the digital twin for surface operations and provides five key capabilities that apply to the entire reservoir production life cycle:

- Front-end feasibility studies;
- Control system validation;
- Operational performance;
- Control performance; and
- Compliance.

The digital twin enables feasibility studies of the top-side process design at the beginning of the design stage. The ability to validate the performance of selected equipment across the well pad's broad range of operating conditions is highly valuable for reducing downtime and ensuring adequate performance of supporting equipment. Another valuable application includes examining the feasibility of reusing equipment on the current well that previously had been installed on a decommissioned well. This allows equipment to be reliably reused and maximizes investment across the organization.

Once the design of the equipment is finalized, a control system needs to be developed. Using the high-fidelity model, the control system strategy can be validated and tuned against a working process model. This reduces risk, complexity and duration in control system projects. It is at this stage that digital transformation technology selection can be implemented. A thorough understanding of the process and control system technology enables the most effective implementation of pervasive sensing technologies that feed into data analytics software. It applies to both active production well pads and passive completion well pads.

As engineering is finalized and construction begins, the digital twin can be leveraged to begin training operators on effective and safe methods to control the process and respond to upset conditions. A longtime practice in downstream businesses, recent advances in technology have a two-faceted impact on the upstream sector. First, automation is becoming more pervasive, down-scalable, and easily deployable to the well pad. Second, technologies supporting the digital twin are becoming more advanced, enabling the effective training of field-based operations personnel through the use of virtual reality. These technologies encourage a faster response by personnel to the rapid deployment of well pads in the unconventional space.

The early engagement with operations personnel means that standard operating procedures and best practices can be refined and verified before actual upset conditions occur in the field. It means that operators can hit the ground running with a minimal learning curve, maximizing their effectiveness from day one and drastically reducing human-induced upsets. It also means that knowledge can be transferred from an experienced older workforce to the next generation in a more formal and structured way, and that personnel can be trained in the safety and comfort of their offices without exposing them to the risks of a live process or incurring travel costs.

A real-time, dynamic process simulation engine must also offer robust operator training management tools to help facilitate the aforementioned activities. By utilizing standard, scorable training scenarios, operator learning can be verified and certified. By facilitating the use of field-operable devices and process composition changes, operators can be exposed to a seemingly endless number of possible conditions.

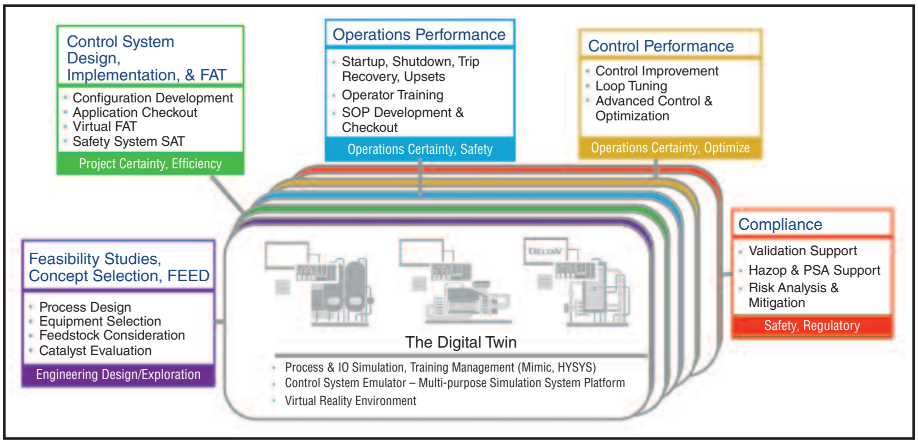
Continuous Improvements

As operations get under way, it is important to maintain continuous improvements to ensure the highest profit and safety margins. The digital twin can be used as an effective test bed to validate and confirm control system, process or equipment changes. The close integration of the high-fidelity process modeling engine and the control system emulator enable control system changes to be put into effect and studied, without the risk of impacting real-life processes.

Once these changes are confirmed, they can be copied easily from the digital twin to the live system. This process is intuitive when the emulation environment/simulation platform is the same as the live control system. Pervasive sensing and IIOT-enabled datasets help identify these case studies,

FIGURE 3

Surface Operations Digital Twin Capabilities over Well Lifecycle



as control loops that are underperforming become easily identifiable.

Of course, compliance is becoming increasingly important throughout the full life cycle of the well pad as governmental regulations and requirements become tighter and safety moves to the forefront of corporate policies. The digital twin, which enables adherence with these standards through support for the automated checkout of critical I/O mappings and control system responses against the simulated control system, increasingly is being adopted by leading oil and gas companies as they face progressively tighter margins and economic pressures.

Earlier in the life cycle, the digital twin can be used to explore the impact of failed safety systems and mitigation devices in the hazardous operations study phase of the process design. The digital twin approach enables asset teams to take an active part in mitigating the consequences of potential threats ahead of time, rather than having to deal with them after they become a reality. ❒

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