What to Expect When You’re Expecting Digital Twins: A Guide for the Oil and Gas CIO

Published 12 November 2020 - ID G00728676 - 18 min read

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Initiatives: Energy and Utilities Digital Transformation and Innovation

As digital twins grow in scope and complexity, they will enable oil and gas companies to achieve dramatic improvements in efficiency, reliability and business performance. CIOs need to understand the implications of a growing portfolio of digital twins and prepare IT to sustain this class of asset.

Overview

Key Challenges

- The adoption of digital twin models by oil and gas companies is growing, and some models are now being shared and co-developed by multiple business entities. But most IT departments lack the governance mechanisms needed to manage the capabilities of shared software assets like digital twins over time.

- The next few years will see dramatic growth in the number of digital twin models, and each will have its own unique purpose and capabilities but also will need to connect with other digital twins for functionality beyond its scope. Modular architecture standards are needed to keep an interoperable environment manageable.

- Most digital twin models will mix software purchased or licensed externally with internally developed code. But few energy companies currently have the design capabilities to develop and maintain the software code and licenses needed by the expanding universe of digital twins.

Recommendations

CIOs driving digital transformation and innovation:

- Maximize the value of digital twin investments by managing them as enterprise business assets that must meet business unit performance, financial and other metrics.

- Design modular architecture and integration approaches that reduce costs and increase reliability by enabling digital twins to be reused over time and shared among multiple business units.
Introduction

The use of digital twins is growing rapidly across the entire energy sector. Feedback from Gartner clients establishes that energy companies are realizing substantial business value from sophisticated digital twins. One example: BP’s digital platform APEX is operating at all of the company’s oil and gas production locations worldwide, and the company credits it with delivering an additional 30,000 barrels of production in a single year.¹ Expectations for digital twins are definitely high in the oil and gas sector. The 2021 Gartner CIO survey (see Note 1) showed that 79% of the oil and gas respondents’ companies had either already deployed digital twins or planned to do so within three years (see CPP doc ID 735736).

Gartner defines an advanced digital twin as a virtual model of a physical thing, person or process that accurately describes current operations and may also predict future performance for a variety of scenarios for the purpose of optimizing business outcomes. One of the ways advanced digital twins deliver value is the high degree of integration that they create among internal systems, human activity and external business ecosystems (see Figure 1). This integration unlocks simultaneous improvements in three different value streams: economic efficiency, operational reliability and organizational adaptability.

Figure 1: As Digital Twin Become More Sophisticated, They Interact With More Things

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¹ Source: Gartner

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Analysis

Digital Twins in Oil and Gas — The Promise and the Challenges

Gartner client inquiries and other industry interactions show that implementing digital twins in oil and gas can be challenging. One of the most important is the lack of standardization across proprietary original equipment manufacturer (OEM) and engineering, procurement and construction metadata, standards and designs limiting interoperability, agility and scalability. (This also makes resolving entity identifiers labor-intensive and costly.) The complex, heterogeneous legacy systems that are commonplace in the industry, and the resulting need for extensive custom engineering and data manipulation, add significantly to these problems. Many oil and gas concerns also lack the technical skills needed to leverage digital twins across the industry ecosystem, and many find it extremely difficult to scale up results from proofs of concept. Another critical issue is the absence of clearly defined governance, roles and frameworks. And, more broadly, the strategic vision, architecture and culture needed to make digital twins work at a strategic level are inconsistent with the historically siloed organizational structures of most oil and gas companies. And the experience of other heavy-asset industries, such as utilities where data management alone is a serious challenge more than half the time, suggest that oil and gas companies will need to work hard to overcome these barriers.  

However, the scope of potential benefit is very large. Digital twin initiatives are applicable to every stage in the oil and gas industry value chain, as well as to all the departments and roles that relate to those stages:

- Exploration
- Production
- Transportation and storage
- Manufacturing
- Trading and supply
- Marketing and sales

Perhaps the most important benefit of a digital twin initiative lies in its capability to improve the performance of business assets. For example, digital twin models can ingest data from OT systems, process that data with other information and create semantic meaning for the situation (see Figure 2). The digital twin can go further and simulate the impact of multiple possible interventions offline without interrupting real-world performance. The results from the model feed into a broad array of enterprise systems, applications and processes, including:

- **Field service management** — Creating a trouble ticket to determine the appropriate response (repair, replacement or possibly no action taken)
This type of preemptive digital-twins-based problem solving can offer significant benefits in all three of the areas — economic efficiency, operational reliability and organizational adaptability — that we’ve identified as mission-critical. (For a real-world example of how this can work, see the Case in Point section below.)

The promise of digital twin technology in oil and gas is real, but as we’ve already noted, so are the challenges. CIOs trying to realize the desired outcomes and return on investment are struggling, especially to align digital twin initiatives with strategic objectives and to scale them at the enterprise level. That’s why Gartner has developed a set of best practices for CIOs evaluating, developing or managing digital twins.

Maximize the Value of Digital Twin Investments by Managing Them as Enterprise Business Assets That Must Meet Business Metrics

There is an emerging pattern for the life cycle of digital twin models in oil and gas. Typically, digital twin models start small. A maintenance team may, for example, see an opportunity to better use sensor, operational and financial data to increase the reliability of a physical asset, while simultaneously lowering overall maintenance costs. Initial analyses are narrowly defined, ad hoc models designed to support specific decisions at unique points in time. More sophisticated analytical tools, like machine learning, are employed to model the full range of factors driving maintenance decisions. As analytic models transition into permanent tools for use in ongoing business activities, they gain the attributes of digital twin models (see Figure 2). It is important to note that as the use of a digital twin model grows, so does the effort to produce and sustain it.
Figure 2: An Example of a Digital Twin in Use

Digital Twin Model for Condition-Based Maintenance

Digital twin models like the one shown above can continuously monitor data from the physical asset, manipulate the data, provide business-friendly visualizations to improve decision making and even simulate future performance to improve planning (see Demystifying the Digital Twin in Oil and Gas: Define Its Purpose to Achieve Results).

Over time, other teams in the company will become aware of the cost optimization and process improvements achieved by the initial digital twin model and, unsurprisingly, seek to adapt the digital twin to their own workflows. In this way, the maintenance digital twin model shown above could be extended by engineering to help make better decisions about component selection (like pump replacements) or customized to support investment decisions (like capacity debottlenecking). And other teams, like operations or health, environment and safety, could adopt and enhance the model for additional purposes. Eventually, its capabilities may become so rich that business teams and capital planners integrate them into their routine methodologies. Figure 3 illustrates how an individual digital twin model can provide value to multiple business units. Note that while some digital twins — for example, of a
compressor or a pump — may be easily transferable, this won’t always be the case. A digital twin of a specific complex, for example, will usually need to be customized, and will be hard to port over from one facility or one business unit to another.

**Figure 3: Each Digital Twin Model Can Provide Different Forms of Value to Multiple Business Units**

**Enterprisewide Use of Digital Twin Models**

Individual Digital Twin Models Provide Multiple Streams of Value to Multiple Business Units

Oil and gas companies should expect their portfolios of digital twin templates and digital twin models to deliver far-reaching impacts across multiple business units. This evolution and expansion in digital twin adoption across multiple business units clearly increases the value realized by the company. But it also makes enterprisewide governance more complex, more challenging and more important. (It would clearly be inappropriate, for example, for the maintenance department to have sole ownership of a digital twin model used by other teams). CIOs will need to work with stakeholders across a broad range of operations and functions to define and enforce a governance framework that considers the demands and impacts of digital twin models at the enterprise level. This will make it possible to maintain the integrity of individual digital twin models and the physical assets they represent over time.

Recommendations for oil and gas CIOs:
Design a Modular Architecture That Facilitates Fast Development of New Digital Twins and Efficient Enhancement and Reuse of Existing Twins Over Time

Oil and gas companies are, of course, highly complex enterprises, with a vast array of physical assets that work together as loosely coupled modules to deliver desired business objectives. One example is a conventional onshore oil field. Hundreds of injector wells may inject fluid into a single subsurface reservoir to alter pressure gradients and push hydrocarbon molecules toward producing wells, where submersible pumps drive them to the surface. Thousands of individual components, including pumps, compressors and reactor vessels, are organized into hundreds of small “units” (for example, water/gas separators) that are managed collectively to optimize the amount of oil recovered from the reservoir.

A complex digital twin model must be a complete model for a unique physical asset. This means the modularity of a complex model (the component parts of the model) must be consistent with the modular nature of the physical assets it represents. The twin must ingest information from multiple sources (including the output of other digital twins) and transform that input into a reliable representation of how the physical asset will behave. This suggests that the oil field in the example above will have thousands of low-level digital twins (each representing an individual pump or valve). These will be organized into hundreds of higher-level digital twins (each representing an individual well or processing plant). And they can be used collectively to analyze different tactics for optimizing the amount of oil recovered from the reservoir. The key to managing this complex swarm of evolving digital twin models is a modular architecture strategy.

In reality, digital twins will work together in a complex n-level architecture that includes feedback loops and nonlinear integrations. In other words, some models will have unique value of their own but also be components of a more complex model. At the same time, that model may also have other models included as part of its composition. This means a company’s portfolio of digital twins can become a complex environment to manage. Enterprise-level management of a dynamic portfolio of digital twins will be more effective if each is characterized in one of three groups (see Figure 4):

- **Discrete digital twins.** These are essentially static representations of low-level things (such as a pump), processes (such as an automated safety shutdown procedure) or people (such as a marketing persona for a class of customer). The physical assets associated with these twins change only very
infrequently, and the twin model itself is not dependent on other twin models. This makes discrete twins highly stable over time.

- **Composite digital twins.** These are higher-level digital twins, and they cover a broader range of physical assets. They may model natural processes, such as liquid/gas phase change in a pipeline. They may model the behavior of an engineered asset, such as how much heat is absorbed by crude oil flowing through a refinery furnace. They may model business behaviors, such as sales in response to price changes. And they may model relatively simple physical items, such as an individual oil well, or an extremely complex set of physical assets, such as an entire refinery. Composite twins consume the output of other twins, and will change whenever their physical assets are altered.

- **Digital twin of organization (DTO).** DTOs model an entire business system. Few real-world DTOs currently exist, but there are exceptions for some narrowly defined models, such as cash flow from operations. And development of more capable DTO models is already underway in the active strategic plans of digitally aggressive companies.

![Figure 4: Three Basic Types for the Nature of Digital Twins.](image)

**Basic Types of Digital Twins**

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<tr>
<th>Digital Twin Inspired</th>
<th>Digital Twin Complete</th>
<th>Digital Twin Aspired</th>
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<tbody>
<tr>
<td>Static Representation of Simple Physical Entity</td>
<td>Integrated Model of Dynamic Physical Asset</td>
<td>Semiautonomous System of Complex Assets</td>
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Given the obvious complexity of composite digital twins and DTOs, a modular architecture is required to enable CIOs to optimize integration, maintenance and reuse of individual digital twin models. This will be especially important in helping to contain costs and increase reliability. A nonmodular architecture — one in which digital twins are created as one-off projects for specific physical assets or functions — can’t be replicated efficiently, cost-effectively or at scale. And this makes a nonmodular architecture both more expensive and less reliable. A modular architecture, by contrast, makes it possible to develop modules that can be reused and adapted, with less effort and less cost, for use across the enterprise.
This modular approach implies that the CIO must take a leading role — if not the leading role — in digital twin development. Individual stakeholders, teams or departments can no longer be allowed to develop digital twins in isolation, without taking into account their impact, both immediate and potential, on other areas of the enterprise. The CIO must consolidate all digital twin activity enterprisewide, and ensure that all digital twin projects are developed, implemented and managed centrally, with ongoing attention to their place in the enterprise’s overall operations and strategy. This represents an important opportunity for the CIO to get legacy systems and rogue IT under control. It’s also worth noting that this also offers the CIO a valuable opportunity to be seen as a strategic decision maker, not just an IT professional.

Recommendations for CIOs:

- Create a modular architectural framework based on the three tiers of digital twins as a means of ensuring strategic enterprisewide interoperability and scalability.

- For each architectural tier, mandate modern technical standards such as internal/external APIs for all digital twins, to maintain modularity and reduce that cost of maintaining and enhancing models and to promote their reuse.

- Invest in appropriate software development processes, tools and talent to ensure that your code is well-built, manageable over time and reliable.

**Ensure Consistent Digital Twin Design by Using Gartner’s Four-Block Reference Model**

The design of any new digital twin model must take several important factors into account. First, because each model is paired with a unique physical world entity, it must be able to uniquely identify and represent that entity to other systems. Second, to produce valuable and reliable results, each model must gather, organize, manipulate and generate new information about its twinned physical entity. This means that each model must also encapsulate (at least interoperate with) any other analytic models that do the work of cleaning and contextualizing relevant data or make predictions about relevant input data. And, as a practical reality, each model must be faithfully created in software code so humans and other systems can interact with the model. And eventually, each model will exist as a connected component within a larger universe of business models and solutions. This makes designing each digital twin to work within a larger system of dynamically changing models essential to keeping the environment reliable, sustainable and value-creating.

Some digital twins will comprise software provided by external companies (for example, an OEM that provides a digital twin of its components). Other twins will be configured models built using vendor-provided software (for example, an individual oil well modeled within a geoscience platform). Other digital twins will be developed using unique software built entirely by the operating company. And many twins will be complex compositions of several of these components. Regardless of the digital twin use case, or whether a digital twin happens to be simple or complex, every digital twin design includes four basic building blocks (see Figure 5):
Figure 5: Four-Block Framework for Digital Twin Design

Digital Twin Reference Model

- **Entity metadata** — Information to describe the twinned object, including its physical components, how they’re assembled, and the object’s behavior and specifications (for example, the composition and operation of a turbine).

- **Generated data** — IoT sensor-based time series data, external contextual data, and whatever other data is used by analytical models (for example, the turbine’s speed, temperature and vibration).

- **Analytical models** — Software algorithms that ingest generated data and produce events that increase situation awareness (for example, a notification that turbine bearing No. 3 will fail in five-to-six hours).

- **Software components** — Application logic, visualization tools and other functionality to act, based on events produced by analytical models (for example, an automated instruction to generate a “Fix-It” ticket for bearing No. 3).

Recommendations for CIOs:
Case in Point

Aker BP, an oil production company active on the Norwegian Continental Shelf, created a sophisticated IoT-enabled digital twin initiative to optimize offshore oil platform maintenance and uptime, by automating drilling operations and minimizing offshore employees’ working hours. The company used IoT and data applications to analyze data using on-premises data historians and computing resources, and then built a model of its offshore platform using applied analytics. The results were immediate: reductions in labor hours and maintenance costs, as well as minimizing unplanned downtime when predictive maintenance identified a major component that needed to be ordered. This enabled Aker BP to avoid more than a week of unplanned downtime and associated lost production. In the long term, Aker BP expects a 30% reduction in maintenance work, a 70% reduction in shutdowns and a 40% increase in pump availability — part of its executive's strategy to reduce annual operating costs by $100 million.

Acronym Key and Glossary Terms

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<tr>
<th>Acronym</th>
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<tbody>
<tr>
<td>COP</td>
<td>Community of practice</td>
</tr>
<tr>
<td>DTO</td>
<td>Digital twin of organization</td>
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<tr>
<td>IoT</td>
<td>Internet of Things</td>
</tr>
<tr>
<td>OEM</td>
<td>Original equipment manufacturer</td>
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Evidence

1 Twin Win for Oil and Gas Production, BP Magazine
2 Digital Twins: Big Gains for Utilities, But Not So Fast, T&D World
3 Demystifying Digitisation, Petroleum Economist; Drilling for Data, Strategy&; and Creating Value With Digital Twins in Oil and Gas, BCG
Note 1: 2021 Gartner CIO Survey

The 2021 Gartner CIO Survey was conducted online from 14 July through 14 August 2020 among Gartner Executive Programs members and other CIOs. Qualified respondents are each the most senior IT leader (CIO) for their overall organization or a part of their organization (for example, a business unit or region). The total sample is 1,877, with representation from all geographies and industry sectors (public and private).

The survey was developed collaboratively by a team of Gartner analysts, and was reviewed, tested and administered by Gartner's Research Data and Analytics team. Results do not represent “global” findings or the market as a whole but reflect sentiment of the respondents and companies surveyed.

Recommended by the Authors

Demystifying the Digital Twin in Oil and Gas: Define Its Purpose to Achieve Results
Survey Analysis: IoT Digital Twin Adoption Proliferates Across Many Sourcing Options
Hype Cycle for Oil and Gas, 2019
Market Trends: Software Providers Ramp Up to Serve the Emerging Digital Twin Market
Use Digital Factories to Drive Deep Optimization Across the Enterprise
Why and How to Design Digital Twins
Digital Twins Will Impact Economic and Business Models
Tool: 50-Plus Digital Twin and IoT Cost Optimization Examples
Survey Analysis: Companies Heavily Use Digital Twins to Optimize Operations