DIGITAL TECHNOLOGIES THAT TRANSFORM the way upstream oil and gas companies solve key business problems can unlock an enormous amount of value. Pockets of digital excellence already exist in the industry within disciplines such as reservoir and flow assurance modeling. But there are still significant opportunities to use digital technologies to create value by enabling better integration across disciplines, asset organizations, and players in the value chain.

We’ve found that disruptive value creation from digital is being driven by two key factors. First, companies are creating innovative business models to become more competitive. Examples include operators establishing remote or integrated operations centers and suppliers providing a greater share of production optimization or maintenance as an outsourced service. Second, companies are benefiting from digital twin technology. By replicating physical equipment or real-world processes in a virtual environment using digital twins, companies are able to make faster and better decisions. As a company’s portfolio of digital twin use cases grows, each digital twin of an asset or plant becomes more impactful.

Although oil and gas companies are increasingly creating digital twins, many organizations are failing to capture the potential value, typically for three reasons:

- They prioritize use cases for digital twins on the basis of what the technology can do, rather than what generates the most value.
- They do not secure proper buy-in and commitment from the end users in the business.
- They underestimate the extent of the changes to the ways people work that are necessary to realize value.

No one approach to implementing digital twin technology is right for all companies, but our experience shows that successful companies avoid these pitfalls by following
several essential steps and maintaining a strong focus on value.

**How Digital Twins Create Value**

Digital twin use cases can help companies optimize the following value drivers: capital expenditure reduction, time-to-first-oil acceleration, recovery rate increase, production acceleration, operating expense reduction, and health, safety, and environmental improvement. (See Exhibit 1.) In general, digital twin technology enables companies to optimize operating processes and improve capital investments in a virtual world before applying them in the real one.

Some digital twin use cases require precision and the capability to leverage very-high-frequency data. For example, optimizing valve controls often involves sampling data at frequencies below one second. Other use cases are broader in scope and need less precision; these are typically used for optimization at a system or plant level. Rather than using a one-size-fits-all approach, the most successful companies adapt the data requirements and accuracy of their digital twins in order to chart a unique course to value creation. These operators also use digital twins to seamlessly navigate from broader to more detailed use cases to easily derive information and insights.

Digital twin use cases typically rely on a combination of engineering data, sensors, life cycle information, and digital models to replicate the real world and serve different needs. For example, a company can use a digital twin to see how a process or machine is working, create an analytical what-if model, or build a predictive what-will model. In addition, digital twins can enable automatic improvements and decision making—for example, by using an algorithm to alter valve settings.

A leading supplier decided to use digital twin technology to transform its offering.

<table>
<thead>
<tr>
<th>Exhibit 1</th>
<th>Use Cases for Digital Twin Technology Vary During the Project Life Cycle and Along the Hydrocarbon Chain</th>
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<tr>
<td><strong>Facilities</strong></td>
<td><strong>ASSESS AND SELECT</strong>&lt;br&gt;• Reduce the time needed to estimate project parameters by using digital simulators&lt;br&gt;• Improve concept selection decisions by using holistic well-to-export visualizations&lt;br&gt;• Speed up the testing of alternative concepts by using parametric net-present-value models&lt;br&gt;• Conduct asset-simulation dry runs to optimize asset value (such as better tradeoffs between operating expenses and capital expenditures)&lt;br&gt;• Increase the accuracy of cost-weight estimations by using integrated error-proof solutions</td>
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<tr>
<td><strong>Gathering systems</strong></td>
<td><strong>ASSESS AND SELECT</strong>&lt;br&gt;• Reduce the time needed to estimate project parameters by using digital simulators&lt;br&gt;• Improve concept selection decisions by using holistic well-to-export visualizations&lt;br&gt;• Speed up the testing of alternative concepts by using parametric net-present-value models&lt;br&gt;• Conduct asset-simulation dry runs to optimize asset value (such as better tradeoffs between operating expenses and capital expenditures)&lt;br&gt;• Increase the accuracy of cost-weight estimations by using integrated error-proof solutions</td>
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<tr>
<td><strong>Wells</strong></td>
<td><strong>ASSESS AND SELECT</strong>&lt;br&gt;• Reduce the time needed to estimate project parameters by using digital simulators&lt;br&gt;• Improve concept selection decisions by using holistic well-to-export visualizations&lt;br&gt;• Speed up the testing of alternative concepts by using parametric net-present-value models&lt;br&gt;• Conduct asset-simulation dry runs to optimize asset value (such as better tradeoffs between operating expenses and capital expenditures)&lt;br&gt;• Increase the accuracy of cost-weight estimations by using integrated error-proof solutions</td>
</tr>
<tr>
<td><strong>Reservoirs</strong></td>
<td><strong>ASSESS AND SELECT</strong>&lt;br&gt;• Reduce the time needed to estimate project parameters by using digital simulators&lt;br&gt;• Improve concept selection decisions by using holistic well-to-export visualizations&lt;br&gt;• Speed up the testing of alternative concepts by using parametric net-present-value models&lt;br&gt;• Conduct asset-simulation dry runs to optimize asset value (such as better tradeoffs between operating expenses and capital expenditures)&lt;br&gt;• Increase the accuracy of cost-weight estimations by using integrated error-proof solutions</td>
</tr>
<tr>
<td><strong>Top three value drivers</strong></td>
<td><strong>ASSESS AND SELECT</strong>&lt;br&gt;• Time-to-first-oil acceleration&lt;br&gt;• Recovery rate increase&lt;br&gt;• Capital expenditure reduction</td>
</tr>
</tbody>
</table>

Source: BCG analysis.

Note: Gathering systems are equivalent to subsea production systems and subsea umbilicals, risers, and flowlines for offshore assets. Decommissioning involves use cases that are similar to those in the second stage. AI = artificial intelligence. RFID = radio-frequency identification.
The company wanted to move from selling equipment and time to a more service-oriented business model based on equipment uptime and performance. Customer value would be created through quicker response times, deeper insights into how to optimize production and maintenance, and a more integrated service. To enable the transition, the supplier created a comprehensive asset-level digital twin by using engineering data, sensor data, 3D models, and simulation tools. The digital twin facilitated end-to-end operational processes, from diagnostics and problem solving to planning and execution, and reduced the supplier’s operating expenses and maintenance costs.

The Essential Steps to Success
Companies that successfully develop high-value digital twins follow several essential steps. (See Exhibit 2.)

Identify a handful of high-value use cases. It may be tempting to immediately build very faithful digital representations of an entire asset base, but companies should concentrate their efforts on first developing a small number of high-value use cases. When prioritizing, take a top-down approach to identify areas where the most value can be generated, and then figure out how digital can help capture it most efficiently.

Consider flow assurance. A company may want to develop a digital twin use case to improve the regularity of the flow of hydrocarbons in upstream operations. This use case could optimize value drivers such as higher throughput, lower operating expenses, and reduced safety risks. The implementation requiring the least effort would be a digital twin that visually represents pressure and temperature measurements so that an operator could monitor them more easily. The next level of sophistication could involve adding data about the dimensions and layouts of pipelines as well as the properties of hydrocarbon fluids. Such data would enable the company to create smart alerts that issue warnings if there is a danger of unstable flows.

At its most advanced, a fully integrated digital twin would simulate hydrocarbon flows from the reservoir to the receiving facility using real-time data. This would provide the operator with a bird’s-eye view of flows throughout the pipeline at any time and enable the company to analyze the possible impact of changing conditions. A company should choose the option that creates the most value given the implementation effort, which is likely to vary from one asset to another.

At this early stage, companies should create a list of flagship use cases that will help achieve the business’s priorities and have the support of senior management. Each will need to be sufficiently advanced, in terms of value creation potential, scope, and necessary resources, so that the company has enough information to decide whether to proceed to a proof of concept (PoC) phase. Although some longer-term planning is necessary, take a flexible approach since

<table>
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<tr>
<th>Identify a handful of high-value use cases</th>
<th>Develop a proof of concept</th>
<th>Build a minimum viable product</th>
<th>Scale up</th>
<th>Monitor and capture value</th>
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<td>• Prioritize according to value and feasibility</td>
<td>• Prove the value potential</td>
<td>• Create an end-to-end solution using real-world data</td>
<td>• Roll out a digital twin on the basis of value and asset similarities</td>
<td>• Track and monitor value creation closely</td>
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<td>• Focus efforts on the strongest use cases</td>
<td>• Build a simple mockup in a sandbox testing environment</td>
<td>• Verify value for end users at all steps</td>
<td>• Install mechanisms that provide feedback to the development team</td>
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<td>• Redirect resources from initiatives that are failing to those that are more likely to succeed</td>
<td>• Don’t solve the technical issues without a clear plan to capture value</td>
<td>• Don’t underestimate the effort involved in managing change</td>
<td>• Collaborate with asset organizations to ensure fast adoption</td>
<td>• Promote successes and terminate initiatives that fail to deliver value</td>
</tr>
</tbody>
</table>

GRADUALLY BUILD A FLEXIBLE IT AND DATA INFRASTRUCTURE

Source: BCG analysis.
technology and operating limits are rapidly evolving and new opportunities will emerge as you mature these initial use cases. By ensuring that the focus is on demonstrating value as quickly as possible, you can avoid getting bogged down in protracted IT projects, build support within the organization around a few early success stories, resolve problems quickly, and leverage lessons for future use case developments.

Digital twins are relevant to both legacy and new upstream developments. For legacy assets, companies typically use digital twins to enhance their understanding of value drivers and obstacles and improve visualization of real-time operations information. For new developments, companies can use digital twins to make better use of capital and accelerate the time to first oil.

We often find that companies decide to mature most of their flagship applications on a single asset, rather than spread them over several assets. Equinor has taken this approach in the Johan Sverdrup oil field. The benefits include being able to use the same data, IT infrastructure, and development teams, as well as having fewer stakeholders.

An international oil company wanted to screen its asset portfolio to find use cases for digital twin technology that would generate significant value. The operator used a three-pronged approach. First, it identified its main value drivers by assessing the reserves, production, uptime, and health and safety performance of each asset. The company then established each asset’s digital maturity by examining the availability of data, the IT infrastructure, and the current use of digital twins. Finally, the operator combined the findings with information about production volumes, capital expenditures, and operating expenses to identify value creation opportunities and create a priority list of use cases. This approach enabled the company to deploy resources more effectively and speed up value creation from its digital twin use cases.

Continue to focus on value while developing a PoC and building a minimum viable product. After prioritizing the digital twin use cases that have the most value, the next step is to develop a PoC that demonstrates the value and viability of each one. The PoC should be developed quickly over a few weeks or months, typically in a sandbox testing environment that is not linked to real-life production systems and data. Developing a PoC typically involves many different disciplines and actors, and it requires iterating frequently with end users to confirm that the PoC solves the intended business challenge and creates value. Companies will therefore need multidisciplinary development teams that use agile ways of working. These teams should be autonomous, properly resourced, and have strong governance mechanisms to remove obstacles.

If the PoC is successful, the next step is to develop a minimum viable product (MVP)—a working solution that taps data and creates value for end users in a real-world environment. A leading international oil company wanted to reduce instances of gas compressor failures. It formed a multidisciplinary team to develop an MVP that collected data from 1,500 sensors. Then, using advanced analytics, the team established the health of 12 key systems affecting compressor performance. The solution was deployed in the company’s onshore and offshore operations, with extensive personnel training. The digital twin is now on track to reduce compressor failures by more than 40%.

Operating processes and decision-making procedures—internal ones as well as those that guide relationships with suppliers and partners—will need to be adjusted at this stage. We find that changing the way people work is typically more than 50% of the overall effort of developing a high-value digital twin. Also in this phase, companies should actively involve end users, including decision makers, to ensure that the digital twin solution is effective and to create buy-in.

Scale up the digital twin, and monitor and capture value. Scaling up a digital twin brings its own challenges. Companies must
consider not only how to best roll out a
proven technology solution across an asset
portfolio but also how to free up resources
to develop the next wave of projects. These
projects may involve adding functionality
to existing use cases or starting new ones.

When scaling across an asset portfolio, pre-
pare early and determine the implementa-
tion sequence by considering how to deliv-
er the most value and which assets have
similar work processes, stakeholders, and
technology requirements. Ensure continu-
ity between development and scaling teams
by identifying the human resources needed
for each asset and onboarding them early
so that they can learn from MVP develop-
ment and hit the ground running in the
scaling phase.

As the organization moves from scaling to
daily operations, ensure that the operating
model and capabilities are in place to
maintain the digital twin as real-world con-
ditions change.

To monitor value creation, companies
should establish and track simple KPIs.
Furthermore, proper governance mecha-
nisms should be put in place to ensure fur-
ther development of successful digital
twins and termination of poorly perform-
ing ones. Communicating success stories
broadly throughout the organization will
build momentum and justify funding fu-
ture digital twins.

An upstream operator wanted to develop
several digital twin use cases to increase
throughput and cut maintenance costs.
Scaling up involved using the MVP with
three assets and then rolling it out across
some 30 assets over one to two years. Ex-
tensive work was done to optimize the roll-
out sequence and engage with the respec-
tive asset organizations to ensure that they
were ready to adopt the changes to their
operating models that were necessary to
capture value from the digital twin. The op-
erator’s goal was to increase throughput by
2% to 4%. KPIs were implemented to moni-
tor value creation. Current progress indi-
cates that the organization is ahead of its
target.

Gradually build a flexible IT and data
infrastructure. As companies go through
the steps outlined above, they will also
need to think about their evolving IT
requirements. Combining engineering and
production data in new ways is critical to
creating high-value digital twins. However,
ingesting, contextualizing, and making data
available for use is often difficult, because
different asset organizations or suppliers in
a company’s ecosystem have different
legacy systems and ways of categorizing
data. Several platforms are available to
help companies deal with these challenges.
(To learn how Cognite’s platform fit the
needs of Aker BP, see the sidebar “How
Platforms Can Help Oil and Gas Compa-
nies Solve Digital Twin Data Challenges.

To succeed, companies should build a flexi-
ble IT and data infrastructure, looking at the
process as a journey, rather than as a one-off
event. Players should adopt a modular ap-
proach, establish the overarching architectur-
al principles, and build the infrastructure
step-by-step while tackling the challenges
created by concrete digital twin use cases.

Data ingestion and governance can pose
particular issues. With legacy assets, engi-
neering and 3D data often need to be
recreated from scratch. To minimize the ef-
fort involved, it’s important to prioritize
must-have data over that which is nice to
have. By using new technologies such as la-
sor scanning, drones, and point cloud solu-
tions in georeferencing, companies can
save time and cut data ingestion costs. In
the case of greenfield assets, the main chal-
lenge is to embed digital requirements in
the engineering, procurement, and con-
struction processes and move toward the
exchange of information using structured
data and metadata, rather than unstruc-
tured data. With both types of assets, it is
essential to have well-defined governance
and ownership regimes to ensure that data
is properly maintained and updated.

For digital twin solutions to be effective,
upstream oil and gas companies will need
to develop or acquire new capabilities.
Faced with building digital twins, tradition-
al IT departments typically find that they
have gaps in software development, cybersecurity, data science, user interface design, and test management. A key consideration is whether to develop these capabilities in-house or to rely on external suppliers or off-the-shelf solutions. The decision should be guided by the strategic importance of controlling such capabilities.

Suppliers Must Redefine Their Roles
Suppliers are a vital part of the upstream ecosystem, and they can use digital twins to both broaden and deepen their offerings. To be successful, though, suppliers need to focus on how use cases add value for operators and remain flexible so that they can tailor their offerings to operators. For example, larger operators are more likely than smaller ones to build more digital twin capabilities in-house and outsource less work to suppliers; smaller operators are more likely than larger ones to outsource a bigger share of production optimization and asset management activities. In any case, it’s likely that having digital twin technology will soon be table stakes to bid on the majority of contracts.

Savvy suppliers can gain a competitive advantage from how they handle data orchestration—the process of pulling data from different channels and devices, mixing it, and adding previously collected data. Suppliers can create value for operators by developing digital twins for specific tasks and doing so in a way that anticipates future integration. For example, suppliers might create a digital twin of a piece of equipment so that it can easily be integrated in the future with an operator’s systems-level digital twin. Robust data controls and the ability to share the right level of information with the right individuals at the right time will be important for this kind of application.

Suppliers also need to think ahead. Long industry lead times mean that they must
define value propositions now to support exploration, development, and production activities that will be deployed years into the future. In addition, suppliers will have to introduce new commercial models that support investment in digital products and services, moving from remuneration models that are based on time and the cost of materials to performance-based ones. At the same time, suppliers will need to negotiate contracts smartly to avoid giving away their intellectual property, differentiate their offerings to avoid commoditization, and innovate to stay ahead of new players, such as pure analytics providers.

**DIGITAL TWIN TECHNOLOGY** has the potential to create significant value for oil and gas companies. But they need to be ready to use the technology to disrupt and fundamentally change the way their companies operate. We believe that digital twins will increasingly play a pivotal role in reshaping the industry’s operating and business models. Companies need to act boldly and embrace the disruptive potential of digital twins, or they risk losing out to competitors and new players.

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