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February - March 2020

How new subsea power systems could change the way fields are developed

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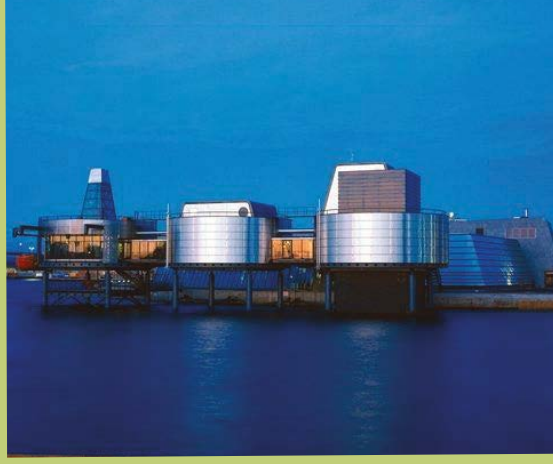

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Adaptable culture could be the key to success- Liv Hovem

The companies which are thriving in today's business environment may be the ones with more "curiosity, ability to adopt new technologies, and who collaborate across sectors," says Liv Hovem, head of oil and gas with DNV GL.

These ideas follow her analysis into the results of a survey of 1000 oil and gas leaders, as research for DNV GL's 2020 "Outlook for the Oil and Gas industry" study.

The survey showed (see article on the next pages) that oil and gas professionals who regard their companies as 'digital leaders' were more likely than 'digital followers' to also be showing leadership on their approach to climate change and how they manage their workforces.

"Maybe the companies that do well are the ones that set themselves up to be adaptable. It is more likely embedded in the company culture," she says.

In terms of interesting macro industry trends, Ms Hovem sees that companies are looking for ever quicker return on investment for their oil and gas production projects. There is more development of small fields, and more subsea developments, and with more electrification.

On the decarbonisation agenda, many companies are still finding ways to be more energy efficient in their operations, and decarbonise in other ways, such as by connecting to a lower carbon power source.

There are often clear goals of what companies want to achieve, and expectations from each company, Ms Hovem says.

Investors are putting more pressure on companies to decarbonise. "It will become a license to operate, if you can demonstrate that you have a more sustainable, decarbonised approach," she says. Oil and gas companies "realise there's a changing environment for doing business."

But E&P companies have to balance that with the profit expectations, or it has to be combined with some governmental incentive.

Meanwhile, more and more companies are diversifying into gas. This doesn't solve the decarbonisation problem. Carbon capture and storage - the only currently-available technology to deeply decarbonize hydrocarbon use – according to DNV GL's Energy Transition Outlook report, will not be employed at-scale until the 2040s unless governments develop and enact more definitive policies on its use.

Hydrogen is "still the future", fitting more into the "research" portfolio of the company rather than development decisions for today.

"A lot of things that need to be looked into with the hydrogen value chain, how will that work. The regulatory side, market side, demand side. Not everybody is convinced about hydrogen, people are concerned about safety. The industry has to provide clear evidence that this is manageable."

Hydrogen is not predicted to have a big role in the overall energy industry according to DNV GL's projections for 2030-2040.

But, "we know also that the more investment that's going into the technology, the quicker the cost of that technology will fall, so government incentives are not needed so much" she said. "We see now that there are a lot of projects with hydrogen. Maybe hydrogen will play a much bigger role, time will tell."

Ultimately hydrogen could be used for power generation, if tied to carbon capture, and ways are found to bring the cost down.

Government incentives are critical with new technologies like this. "Electrical vehicles would never have happened without an incentive," she says.

Another interesting trend is "sector coupling" she says, such as integrating the gas world with the electricity generation world, or electrifying offshore oil and gas production.

Hydrogen could be an "integrator" between renewables and offshore, if surplus electricity is used to electrolyse water to make hydrogen, which is then used in generators to power offshore equipment.

There is a significant role hydrogen can play as a clean energy carrier globally, helping the world limit global warming through a successful energy transition.

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Cover photo - Cover photo: the ABB subsea power system - undergoing testing in Vaasa harbour, Finland, See page 6

What "digital leaders" do

DNV GL's survey asked 1000 senior oil and gas professionals if they classed themselves as 'digital leaders' – and brought out some interesting insights into how 'digital leaders' differ in other aspects of their business approach

DNV GL's annual survey of over 1000 senior oil and gas professionals "Outlook for the Oil and Gas Industry", asked respondents if they would classify their companies as "digital leaders".

21% said they would consider themselves 'digital leaders'. 40% said their organisations were not leaders – and so are classified as followers. The other 39% were neutral or unsure, and excluded from this analysis.

Latin American respondents were the least likely to report their organizations to be Digital Leaders – just 8%, compared to the average of 21% – and more likely to classify as Followers (56%, compared to 40% overall).

Digital Leader organizations are also more likely to be publicly listed companies than privately held or state-owned organizations, and are more likely to be larger organizations (i.e. those with over USD5bn in annual revenue).

When asked if they had "Increased their focus on digitalization over the past year", 95% of Digital Leaders and 59% of Followers said yes.

When asked if "digitalization has had a transformative impact on the organization," 80% of Digital Leaders and 40% of Followers said yes.

When asked if "Digitalization is critical for the organization's survival", 85% of Digital Leaders and 58% of Followers, said yes.

When asked if they understand why the company is digitalizing, 93% of Digital Leaders and 69% of Followers said yes.

When asked if they were Prioritizing improvement of data quality and availability in 2020, 90% of Digital Leaders and 55% of Followers said yes.

This indicates the digital leaders are committed to the company's digital transformation efforts, and it will take a high priority in their company, DNV GL says.

Other organisational attributes

Digital leadership turned out to be a strong "proxy" indicator for other organizational attributes.

Leaders (77%) are more confident about industry growth in 2020 than Followers (63%), and they have a similarly higher optimism about their own organization's prospects for the year ahead.

Far more Digital Leaders also say the overall prospects for their organizations improved in 2019 (72%) compared to Followers (54%).

Significantly more Digital Leaders (58%) than Followers (43%) are able to say that they would make acceptable profits even if the oil price averages less than USD50 per barrel in 2020 (Brent-WTI average).

Fewer Digital Leaders (38%) than Followers (47%) claim to be more focused on short-term than long-term strategies

More Leaders (77%) than Followers (63%) say that their cost-efficiency initiatives made since 2014 have become permanent changes

Leaders (92%) are more likely than Followers (76%) to increase/maintain spending on R&D (as well as almost every other spending/investment area) in 2020

"Leading digital companies seem likely to have a more innovative culture in place. They seem more open to new ideas, to talking with different people, involving other organizations," said Liv A. Hovem, CEO, DNV GL - Oil & Gas.

Liv A. Hovem, CEO, DNV GL Oil and Gas

"We are perhaps seeing organizations that have a broadly innovative approach, and digital is just one aspect of that."

The top three barriers to digitalization for Followers are a lack of required skills, an old-fashioned organization, and a lack of awareness among senior management.

Companies may have strategic reasons for choosing to be followers, including making a strategic choice to wait until others prove the value of new technologies.

Digital and carbon

Companies calling themselves digital leaders were also leaders in clean energy.

Digital Leader organizations are actively adapting to a less carbon-intensive energy mix (75%) at a far greater rate than Followers (50%).

More Digital Leaders are increasingly focused on energy opportunities outside of oil and gas (59%) relative to Followers (47%).

Leaders (81%) are more likely than Followers (64%) to be planning to invest in and/or develop a range of renewable energy sources

Attractive workplaces

Far more digital Leaders (75%) than Followers (50%) claim their organizations listen to and act on employee input to make it a better place to work.

Leaders and Followers agree that the industry is struggling to attract young employees (56% and 57%, respectively), but far more Leaders (74%) than Followers (43%) say their own organizations are attractive to young people.

This suggests that digitalization leadership (and these associated characteristics) could make organizations more attractive to the next generation of talent.

Collaboration

74% of digital leaders report that, in 2020, they will increase the scale of their collaborations with other organizations, compared to 63% for Digital Followers.

62% say they will increase the scale of collaborations with other organizations in the year ahead.

Where both align

In the survey, almost all respondents (92%) said they expect either to increase or maintain their level of spending on digitalization in 2020.

Two-thirds of Leaders (66%) and Followers (65%) agree that digitalization is not happening fast enough across the industry. High numbers say their organizations need to embrace digitalization to increase profitability (85% for Leaders; 73% for Followers).

Leaders (85%) and Followers (83%) agree that

the industry needs to develop new operating models to achieve further cost efficiencies. But only Leaders are actively building new ways of working that will help them thrive in a more data-driven, automated, efficient, diversified and sustainable industry.

Demand for data specialists

Among respondents, artificial intelligence and data specialists are the second-most in demand types of worker – and the number one for North America – from a list that includes all aspects of oil and gas operations.

Software developers are also in demand, ranked fifth overall.

Project managers, risk-management professionals, and subsea engineers round out the top five skills in demand for 2020.

DNV GL's annual survey of over 1000 senior oil and gas professionals "Outlook for the Oil and Gas Industry" compared attitudes of the young and old to the importance of digitalisation and decarbonisation. It looked at how companies could do better at attracting

DNV GL survey – comparing the young and old

DNV GL's annual "Outlook for the Oil and Gas Industry" survey compared attitudes of the young and old to the importance of digitalisation and decarbonisation – and looked at what it would take to keep attracting new graduates

In the analysis, people with under 10 years' experience were described as "Shorter Tenure" and people with over 30 years were described as "Longer Tenure".

The views of the Shorter Tenure group could give an indication of perspectives of future leaders, while the views of the Longer Tenure could represent the views of the "incumbents at the helm".

The Shorter Tenure group were more likely than average to be technical specialists or mid-level managers, although 23 per cent were in top level senior roles (C-suite, senior vice president, director, head of unit or head of country). By comparison half of the Longer Tenure group were in top level senior roles.

Importance of digital

Longer Tenure do not accord digitalization the same level of importance as do Shorter Tenure.

Many more Shorter Tenure respondents (74%) believe that their organizations need to embrace digitalization to increase profitability than do Longer Tenure (62%).

There is an even greater divergence around whether digitalization is critical to their organizations' survival, with 71% of Shorter Tenure respondents believing this, compared to just 57% of Longer Tenure respondents.

Shorter Tenure are also more likely to think digitalization is not happening fast enough across the industry (63% vs 49%) and that digitalization has already had a transformative impact on their organization (57% vs 39%).

These are significant differences, particularly when you consider that there are many people that buck the stereotype for their age group – from younger workers that lack any kind of digital aptitude to a range of older digital champions, DNV GL says.

Such large divergences suggest that there are fundamental differences in how these Shorter and Longer Tenure groups perceive the value, potential, and urgency around digitalization.

Divergence on decarbonisations

Shorter Tenure respondents are more likely than Longer Tenure respondents to want their organizations to move faster to reduce its carbon footprint.

They have also become more concerned, in the wake of climate change activism, about their organizations' environmental impact, and believe the industry should drive CCS technology adoption (rather than wait for regulations).

They are also less likely to feel personally aligned with their organizations' environmental policies.

This suggests that companies that have progressive attitudes to decarbonization may have greater success at attracting new talent.

"This makes some level of diversification into renewable energy a very important part of the story that energy companies tell to attract new talent," says Frank Ketelaars, regional manager for the Americas at DNV GL - Oil & Gas.

"It shows that there is a pathway where, at some stage, the company will move with the energy transition to a lower-carbon future, so people can feel they are involved in a positive shift for tomorrow, while also serving today's energy needs.

"Without this, it could be more difficult to convince people that our industry is responsible and committed to the energy transition."

However Hongtao Yan, deputy director-general of the China National Offshore Oil Corporation (CNOOC)'s East of South China Sea Oilfield Bureau, noted that the company faces "a shortage of workers like welders, cutters, painters and offshore maintenance workers. Not many millennials want to do this kind of work."

Attracting a new generation

The research suggests that progressive stances and tangible steps forward on both digitalization and decarbonization can potentially help attract and retain younger talent, DNV GL says.

But at the same time, all the universally applicable boxes need to be ticked, from remuneration to long-term progression opportunities.

"The younger generation are just as diverse as the older generation, so it's not like one answer fits them all, but I think many of them just want to have a job where they can learn and develop," says Liv A. Hovem, CEO, DNV GL Oil & Gas.

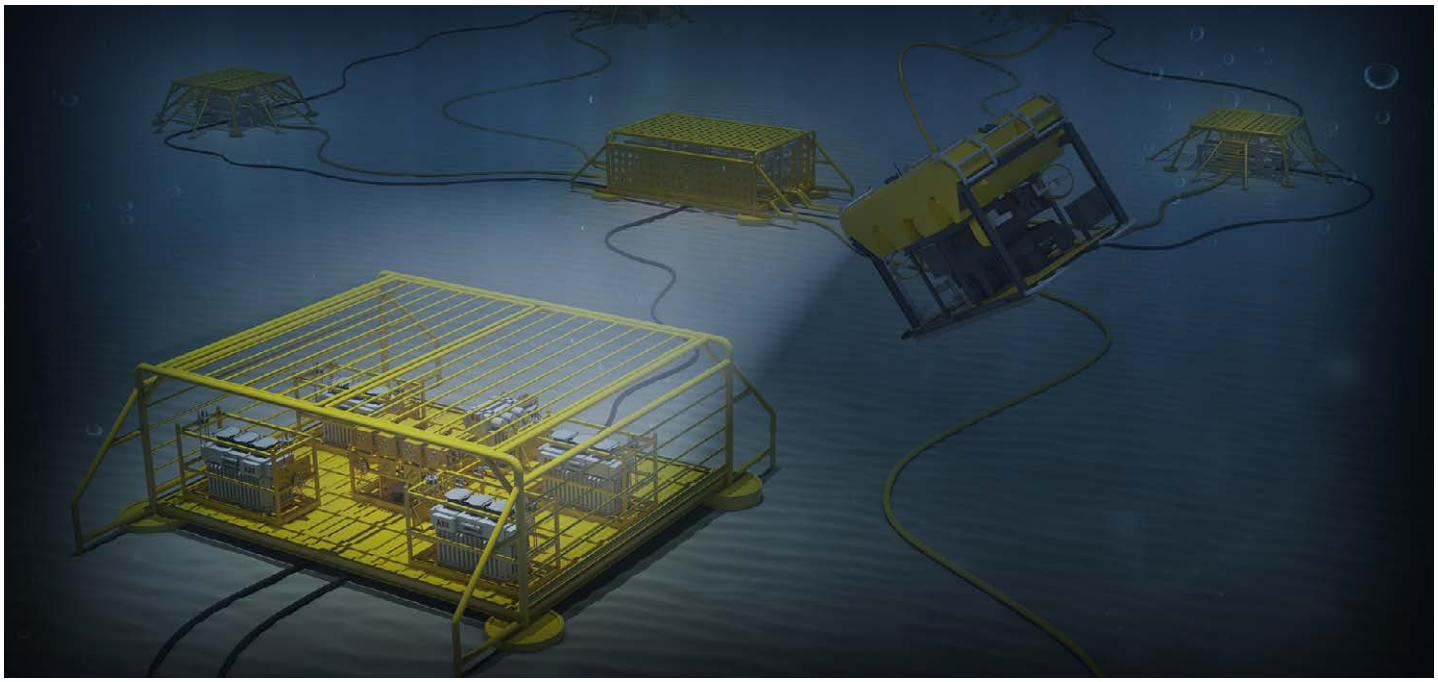
"I don't feel that they are reluctant to work for oil and gas companies per se, but they want to see their company driving towards decarbonization. It is important that a company is perceived as modern, up-to-date with technology, and aligned with social priorities."

More respondents from downstream organizations say their organization is attractive to young people (60%) than either midstream (55%) or upstream (49%).

Those from downstream organizations are also more likely to be Digital Leaders, and more likely to be actively adapting to a less carbon-intensive energy mix, which supports our hypothesis of these trends being key to attractiveness.

ABB's subsea power system – a game changer for subsea?

ABB's subsea power system – enabling transformation of power voltages to a wide range of outputs, and providing circuit protection, could open the door to many new subsea projects



How the ABB subsea power system will look like on the seabed

Power and automation company ABB has launched a subsea power system which enables power voltage to be converted on the seabed, and provide subsea circuit protection. It could open the door to many subsea development projects.

This is not the first time subsea transformers have been available, but until now, the only subsea transformers available have been relatively simple 'step down' equipment which converts voltage from one level to another. The subsea power system can do much more, and so supports more flexibility in planning and operating the field.

It includes a variable speed drive, which can adjust the power and frequency supplied to pumps and compressors, so you can adjust the pumping or compression speed to what you need. It also includes a switchgear, which protects equipment from damage by automatically shutting off power, like a fusebox in a house.

The system brings the vision of the 'subsea factory' much closer, making it possible to have a range of different standardised equipment on the seabed, without being restricted in the development by the need to be close to a power source, or only able to work with power at certain voltages.

The system has been tested to run at pressures equivalent to 3,000 metres depth, and separately tested to run for 3,000 hours in shallow seawater. This is considered adequate testing to declare the system reliable enough for installation in oil and gas projects.

"The main challenge for remote subsea operation is a reliable power grid," says Vitor Moritsugu, R&D engineer at ABB who has been leading the work on the subsea switchgear.

ABB, Equinor, Total and Chevron together spent $100m developing the technology in a "Joint Industry Project" with work going on since 2013, with over 200 engineers and scientists. The technology is now offered freely to any E&P company.

Why subsea power transforming

Subsea power transforming is necessary because of difference between the ideal voltage for subsea equipment (typically 24 volts for control systems or 400 volts for drives), and the ideal voltage for cables carrying power to the subsea (typically 132 kV).

The ideal voltage of the long distance power cables is high because the losses from the cable over distance are lower with a higher voltage.

With the combination of high voltage power cables to the subsea, and flexible power conversion subsea, you can both site the subsea equipment further from the power source, and use a range of different subsea equipment.

The comparatively low losses over distance with 132 kV transmission mean that engineers think it is viable to have a single power cable up to 600km distance, carrying up to 100 MW.

The system also means much lower costs of cabling. Without subsea power transforming, you need a separate cable from the power supply to the seabed for each voltage you require – so a 24 volt cable for control systems, a 400 volt cable for drives.

The switchgear distributes 11 to 33 kV to the motors driving the compressors and pumps, via the variable speed drives. It can support up to six feeders. It will automatically open (cutting power supply) if the power supply fails.

Equinor conducted a field development case which showed that the CAPEX savings could be over $500m, for a project involving 8 power consumers, such as pumps or compressors, linked by a single cable over a distance of 200km to other infrastructure.

Field development ideas

The system opens the door to new field development approaches.

You can site pumps and compressors on the seabed rather than on offshore platforms. This means that more suction power reaches down to the reservoir, because the pump is closer to the reservoir, there are less frictional losses.

It makes it easier to develop fields further away from existing infrastructure. Not all subsea fields are adjacent to an offshore platform.

It makes it easier to power a field using remote electricity sources which could be lower carbon than offshore diesel generated power – for example wind energy, or power generated onshore.

All of this may make it easier to develop subsea fields in general, which means that fields are developed which otherwise would not be, and more subsea fields which would otherwise use offshore platforms.

Where this could go

We can imagine an oil and gas field having all of its infrastructure on the seabed, with relatively inexpensive oil and compressed gas tankers arriving periodically to load, perhaps with separation onshore, and power generated by offshore wind turbines.

This could make it feasible to develop more 'small pools' such as in the North Sea, a big prize which the UK's Oil and Gas Authority is chasing.

Perhaps we could also see subsea compressors and pumps used for CO2 injection wells, reducing the cost of CO2 sequestration (although many projects plan to do all of the CO2 compression and pumping from onshore).

This isn't just for the majors - there could be opportunities for small / start-up E&P companies to set up in business based around this technology, developing small oilfields which are not viable to develop otherwise.

Another idea is using the power system for a ROV which stays continually on the seabed, with its batteries recharged periodically from a subsea charging station, and data sent to shore. So subsea support vessels are not required.

Any company can use the system, and purchase power from the electric grid – you don't need access to existing offshore power generation to run subsea equipment.

Here's another analogy. 100 years ago, all factories were powered by steam engines, with a single large engine, one long rotating shaft, and all of the other equipment taking 'power' from this. The invention of electric motors brought independent drive power systems, at variable speeds, to different parts of the plant, allowing much more flexibility and scope for efficiency.

Similarly the subsea equipment today must all run from a single power cable, and all run at the same voltage, unless there are multiple power cables or multiple "step down" transformers. Having subsea transformation brings in much more flexibility and scope for efficiency.

Parts of the world which could be interesting include the Norwegian side of the North Sea, the Gulf of Mexico, the Campos Basin offshore Brazil, and the Gulf of Guinea in West Africa, where there are potential deepwater projects.

Total and Equinor

"This is transformative technology, it allows us to put power subsea where we need it," says Jeremy Cutler, manager of Total's research centre in Stavanger. "It can open up unexplored areas of ultra-deep. We will be able to start with a clean sheet of paper. It opens up all sorts of vistas. This is an enabler; it is more efficient and cheaper. "

Dr Per Gerhard Grini, Manager, Subsea and Topside Technology, Equinor, says that the company could run a subsurface compressor for its Åsgard field which has 300m depth with this technology.

It fits with Equinor's vision of having all of its fields operated unmanned, and its vision of a "subsea factory", he said.

Equinor (formerly known as Statoil) presented the concept of a subsea factory back in 2012, as a standalone subsea production on the seabed, including pumping / compression, gas and liquid separation, and water injection.

More versatile availability of electric power could lead to the development of all electric actuators (components for opening valves), rather than using pneumatics (fluid pumped through the valve to open it), which is an extra complexity, he said.

Both Total and Equinor are interested in exploring the use of onshore generated energy, which can be cleaner (or zero CO2, such as hydroelectric).

Flexibility

Per Erik Holsten, Head of Energy Industries North Europe with ABB, says one of the most important reasons for developing the technology is to provide flexibility to go any depth or distance away. "It gives you opportunity," he says. "600km is enough to cross between the UK and Norway, or cross the Mediterranean, in certain parts of it."

Joerg Schubert, Global Head of Technology, Energy Industries with ABB, points out that most existing offshore platforms have their topsides fully utilised, so there is no space for any more equipment. The provision of power at the right voltage has been a key constraint on how subsea projects were developed.

Technical research challenges

The entire system operates at high pressure. This is easier to build than having a strong box around the components, which protects the components from the high pressure.

The pressure at 3000m is 300 bar, equivalent to 3000 tonnes per square metre of the enclosure surface. The system involves several hundred critical components, and they all needed to be tested to ensure they could work at this pressure – as well as understanding their limits and how they degrade.

A big technical problem was finding a way to remove the heat generated by the transformer and the variable speed drive. It is filled with oil, rather than water, which proves to be better at removing heat, as well as being an electrical insulator, with very low compressability. All the electrical and mechanical components had to be chemically compatible with this oil.

The research involved co-ordinating work in multiple countries. The power conversion module, power distribution module, and control module, is made in Norway; the reliability analysis was done in Poland; and power storage and actuator electronics was in Italy. The power cable was made in Sweden; the subsea transformer and electrical protection, and assembly of units, was in Finland; the chemical analysis and pressure testing for power electronics was in Sweden; the capacitors were made in Sweden and China.

The circuit breakers were made in Germany; controllers and variable speed drive made in Switzerland; the current and voltage sensors made in the Czech Republic. Software support was in India, VSD research support in Switzerland and power semiconductors in Switzerland.

The variable speed drive (VSD) is a significant focus of the project. It is rated at 9 Mega Volt Amp (MVA), and typically controls a subsea compressor's motor with 6 to 7 kV. Two units in parallel can run a load of 18 MVA.

The VSD has a number of diagnostic sensors to track the performance of the load and the performance of the drive.

A big problem with VSDs is the heat they generate, which can degrade the system. It needs to be designed so that heat can be efficiently dispersed to surrounding sea water.

New methods for packaging insulated-gate bipolar transistor (IGBT) and rectifier chips were developed, which would work in the high pressure oil environment.

To improve reliability, the system has in-built redundancy around modules. So there is a back-up control system module which can be immediately brought on if the first one fails, and back-up power circuits.

BCG – how to make a successful digital twin

For a successful digital twin project, you want to carefully consider where it can provide the most value, develop use cases, proof of concept and minimum viable product, and then scale up – rather than just try to digitalise everything, says Boston Consulting Group (BCG)

How do we make our digital twins projects more successful? Boston Consulting Group has some ideas

When building a digital twin, 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 – then developing "proof of concept" and a minimum viable product – and then scaling up, Boston Consulting Group said in a recent report.

For example, a digital twin might be used for flow assurance, 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.

Why digital twin

A "digital twin", or digital model of an asset, can be used to see how a process or machine is working, create an analytical what-if model, or a predictive what-will model.

Digital twins can enable automatic improvements and decision making—for example, by using an algorithm to alter valve settings.

It will usually be built of a mix of engineering data, sensors, life cycle information, and digital models.

Some digital twins use 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. For example, optimisation at a system or plant level.

As an example, an oil and gas supplier decided to use digital twin technology to transform its offering. The company wanted to move from selling equipment and time, to a more service-oriented business model based on equipment uptime and performance.

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.

Developing use cases

At an 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.

By ensuring that the focus is on demonstrating value as quickly as possible, you can avoid getting bogged down in protracted IT projects.

You can build support within the organization around a few early success stories and leverage lessons for future use case developments.

Companies often decide to mature most of their 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.

In one example, an international oil company wanted to screen its asset portfolio to find use cases for digital twin technology that would generate significant value.

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.

Proof of concept

After prioritizing the digital twin use cases that have the most value, the next step is to develop a Proof of Concept (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.

Minimum viable product

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.

Scaling up

Changing the way people work is typically more than 50% of the effort of developing a digital twin.

When scaling across an asset portfolio, prepare early and determine the implementation sequence by considering how to deliver the most value and which assets have similar work processes, stakeholders, and technology requirements.

Ensure continuity 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 development 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 conditions change.

To monitor value creation, companies should establish and track simple KPIs. Furthermore, proper governance mechanisms should be put in place to ensure further development of successful digital twins and termination of poorly performing ones. Communicating success stories broadly throughout the organization will build momentum and justify funding future digital twins.

In one example, 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.

Extensive work was done to optimize the rollout sequence and engage with the respective 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 operator's goal was to increase throughput by 2% to 4%. KPIs were implemented to monitor value creation. Current progress indicates that the organization is ahead of its target.

Common reasons for failure

There are typically three reasons why oil and gas companies don't get as much value from digital twins as they could do, BCG says.

Companies prioritize use cases for digital twins on the basis of what the technology can do, rather than what generates the most value. The greatest value might come from finding ways to reduce capital expenditure, getting to first oil faster, accelerating production, reducing operating expense, and HSE improvement.

Companies often don't get "the needed buy-in" and commitment from the people who use it.

They underestimate the extent of the changes to the ways people work that are necessary to realize value.

How suppliers can use digital twins

Suppliers of equipment can use digital twins to both broaden and deepen their offerings.

To be successful, suppliers need to focus on how use cases add value for operators and remain flexible so that they can tailor their offerings to operators.

To illustrate the difference, 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.

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.

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.

Case study – Aker BP and Cognite

When exploration and production company Aker BP needed an open technology platform for digital twin data orchestration, it turned to Cognite.

The company's solution offers a decoupled architecture that separates data management from applications.

The platform enabled Aker BP to securely share asset- and process-specific information with a global provider of pumping equipment.

Using Cognite's application programming interface, this pumping equipment supplier integrated its systems with a digital twin platform operated by Aker BP.

The supplier was then able to use real-time contextualized data derived from Aker BP's operations and IT systems to improve its service delivery.

Specifically, the supplier's access to Aker BP's streaming information, and its integration with the operator's enterprise resource management system, allows it to predict pump performance and guarantee equipment uptime, enabling the company to shift to a novel performance-based contract. A feedback loop covering Aker BP's design, engineering, and maintenance functions also helps the supplier strengthen its products and offering.

Cognite helped transform the traditional transactional supplier relationship into one that is more open, effective, and service oriented.

The supplier's use of Aker BP's digital twin platform has already led to a significant reduction in manhours and maintenance. Longer-term projections show a 30% reduction in maintenance work, a 70% reduction in shutdowns, and a 40% increase in pump availability.

The full report from Boston Consulting Group is available free online if you google "Creating Value with Digital Twins in Oil and Gas".

MEMS for onshore seismic make big progress

Micro-Electro-Mechanical Systems (MEMS) devices for onshore seismic recording are making big progress in reducing noise and power consumption, leading to an increase in take-up, says Sercel

Micro-Electro-Mechanical Systems (MEMS) devices for onshore seismic recording are making big progress in reducing noise and power consumption, says seismic technology company Sercel.

The latest MEMS devices are capable of operating at lower than 15 Nano-g per square root of Hertz, resulting in a dynamic range of 128dB.

This compares to 40-45 Nano-g per square root of Hertz for previous generations of MEMS and is equivalent to the quietest ambient noise detectable anywhere on Earth.

Power consumption on the latest single-sensor devices has been reduced to 85mW. This makes them easier to deploy on high density surveys.

MEMS background

MEMS (Micro-Electro-Mechanical Systems) are basically very small devices made using microfabrication techniques, with components between 1 and 100 micrometres (0.001 to 0.1 mm), making devices of 20 micrometres (0.02mm) to 1mm.

MEMS are used in inkjet printers to put ink on papers; accelerometers in cars and game controllers, smart phones and digital cameras, and to protect hard disks on laptops which accidentally fall. They are also used in microphones on mobile phones and laptops.

The first digital seismic sensors based on MEMS accelerometers were introduced in the early 2000s.

These small and highly-accurate devices promised significant performance benefits over traditional analogue geophones, prompting an expectation in the seismic sector that MEMS would quickly become the technology of choice.

Since then, MEMS-based digital sensors have established a foothold, but analogue geophones still account for the vast majority of market share. The historical reliance on geophones for data acquisition means that many operators have been reluctant to move away from a technology that they know and understand.

But MEMS-based digital sensors manufacturers have continued to invest in research and development, and the latest MEMS devices offer performance levels that could not have been conceived even ten years ago.

Digital fidelity

While the response of geophones is damped below their natural frequency and distorted above their spurious frequency, MEMS sensors offer linear and flat amplitude and phase responses from DC to 800 Hz in the acceleration domain. Their specifications are not affected by temperature, ageing or manufacturing tolerances, making the signal recorded accurate in both phase and amplitude on the entire seismic bandwidth of interest. The preservation of amplitudes has been recognized for amplitude versus offset applications.

The coil-free design makes the sensor insensitive to electromagnetic noise, and the sensor distortion is much lower than that of geophones. This digital fidelity is viewed as a significant benefit for high trace density, single receiver surveys.

Low noise floor

Much progress has been made in lowering the noise floor of MEMS sensors, improving the detection of low frequencies and weak signals such as those that come from faraway targets or from micro-seismic events.

The latest devices have been developed to reach a target specification of 15 Nano-g per square root of Hertz through a variety of techniques linked to mitigation of all internal electronic and mechanical noise sources without any increase in power consumption.

These days, MEMS sensors achieve a significantly lower noise floor than previously available designs, achieving -10dB and thus a higher dynamic range in the region of +10 dB, providing ideal conditions to record low frequencies down to 1Hz.

Also, recent research shows it is possible to develop MEMS accelerometers with a noise floor below New High Noise Model down to 0.1Hz and showing only a slight increase down to 0.001 Hz, opening up new possibilities for below hertz signal recording.

3 component recording

3 component (3C) acquisition has a proven track record of success in complex geologies.

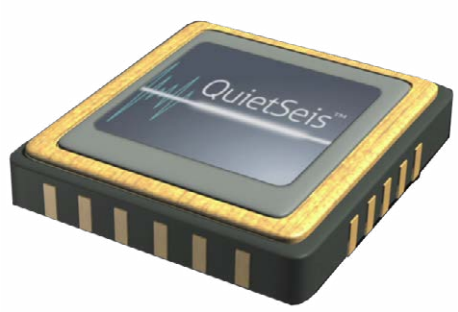
From an operational perspective, the 3C MEMS channel is omni-tilt and compact, and removes potential errors when connecting geophones to three digitizers.

The same sensor can be used for the three components, while geophones must be compensated for gravity when operated horizontally.

The MEMS tiny size allows for a correspondingly small housing form-factor, thus enabling an efficient rejection of parasitic signals, such as ground-roll induced rotations.

The compactness of the 3C sensor also favours optimal coupling to the ground – a paramount factor for the proper recording of horizontal components.

Another significant benefit of 3C MEMS lies in the excellent vector fidelity it provides to



seismic measurements. Indeed, good MEMS accelerometers are fitted with a feedback loop that enables the measurement of static signals, such as the Earth's gravity.

Thanks to this feature, 3C MEMS sensors can be easily factory-calibrated by using a very accurate gravitational acceleration reference, and consequently, the manufacturing orthogonality tolerances of the three axes can be compensated for.

Operational benefits

Historically, it has always been considered that a configuration of MEMS-based digital sensor units is more expensive than a field digitizing unit connected to a string of geophones, due to the higher density required.

But the smaller physical size of MEMS-based sensors provides many operational benefits.

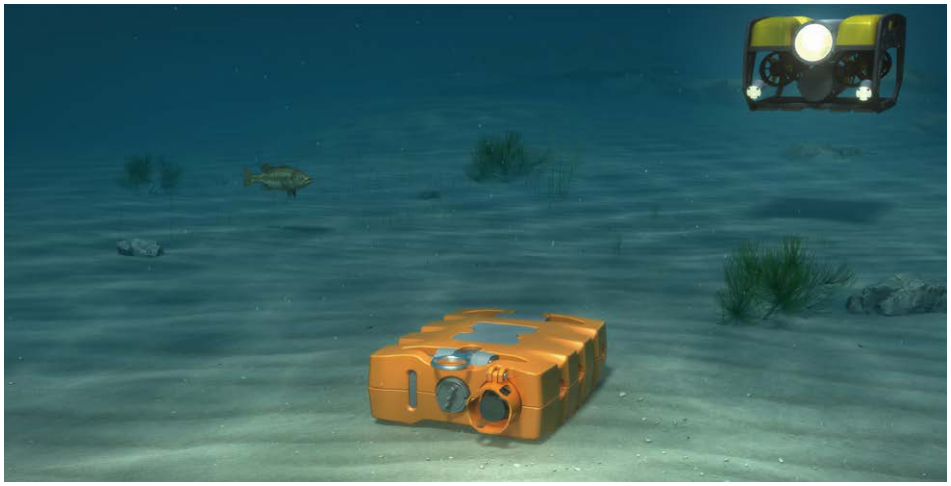
For geophone strings, a lot of effort is required to transport, deploy, retrieve, maintain and repair large quantities of equipment – in addition to the staff needed for these tasks and associated costs such as accommodation.

The use of MEMS-based digital sensor units, on the other hand, provides savings in each of these areas.

Low power and costs

The steady growth in popularity of MEMS-based devices has also delivered manufacturing economies of scale, which has in turn driven down the price. Also, a single sensor's power consumption has been reduced to 85mW, which is providing cost benefits for large-scale, high-density deployments.

These benefits have seen MEMS-based sensors start to break down barriers and achieve greater market acceptance.



This article is based on a white paper by Nicolas Tellier, chief geophysicist with Sercel, "Moving over to MEMS - Assessing the Analog to Digital Trend in Seismic Data Acquisition."

Maxar – How satellite imagery and radar is helping in E&P

E&P companies can use satellite imagery and radar in exploration, to monitor the earth's surface for change, to monitor infrastructure in operations, and to monitor CO2 emissions. Deborah Humphreville from Maxar presented some of the interesting developments.

Deborah Humphreville from Maxar

Following big improvements in the quality of satellite imagery and radar data available in recent years, companies are developing many ways to use it as part of oil and gas operations, including for exploration, monitoring environmental and construction change, monitoring infrastructure, and monitoring greenhouse gas emission.

She was speaking at the Finding Petroleum / Digital Energy Journal forum in London in November 2019, "How to digitalise exploration and operations".

Deborah Humphreville from Maxar explained some of the most interesting recent developments.

Something very new is attempts to try to detect greenhouse gas emissions from space – which could potentially show up companies which are flaring more than they should be, or which are less efficient in operations than they should be.

Uses of the data include analysing land use ahead of lease acquisitions, doing structural mapping, planning seismic surveys, analysing ground for subsidence, better understanding subsurface structures based on the shape of land at the surface, planning well sites, analysing potential for floods, planning pipeline routes, monitoring pipelines, and monitoring land disturbance.

It is used to provide advice during emergency response. "First responders have used satellite imagery for many years, such as to monitor wildfires," she said.

Ms Humphreville's background is as a geologist. She got involved in satellite imagery because she was interested in ways to "link surface and subsurface," she said.

Background

Satellite imagery was originally developed in the 1950s for defence and government intelligence purposes, and the first image analytics work was to look for aeroplanes in enemy territory. It is like a digital camera on a satellite.

Radar satellites are different, detecting objects and the shape of the earth from how they reflect radar waves. The first radar satellites were developed in the 1960s to try to detect metal objects – tanks.

This technology can also be used to monitor the shape of the earth, look for surface deformation or other change. Radar images can also see through clouds, something you can't do with optical imagery.

You can use radar combined with optical imagery, with the radar telling you about the shape of the earth, combined with optical images to tell you what it looks like.

Maxar has been operating satellites for over 20 years. One of its customers is Google, which uses the imagery in Google Maps. Its long experience differentiates it from the many start-ups launching constellations of small satellites today, which Ms Humphreville calls "toaster sats".

"We're looking to launch a new generation constellation in 2020 -2021 using the same tried and true optical technology," she said. "We can launch a number of satellites from what it cost us to launch one, 10 years ago."

"We're trying to do what we can to make spatial analytics available to the end user in an easier format.

Hopefully it will become part of the mainstream of analytics in the future."

Satellites in exploration

In exploration, the shape of the earth's surface (gathered from radar satellite) can be used to help understand the subsurface, if the dips and folds on the surface match those on the subsurface (shown on seismic).

The satellites might detect oil seeps on the surface, as an indicator of reservoirs below.

Optical imagery can "see" through 30m of clear water. Sometimes it is possible to track different kinds of benthic organisms in water. These sometimes show patterns relating to oil reservoirs below, because certain organisms form faster in the presence of tiny amounts of oil in the water.

One challenge is integrating satellite imagery data with subsurface modelling software. It doesn't necessarily need to involve integrating the digital imagery itself, which involves massive files. "Instead you can just bring in the information which is useful into subsurface software. Data can be brought into geo software as a skin – just the elements you need. You do all this computation and reduce the data down to an Excel table."

One company is working out ways to extract insights from geospatial data and just import those into subsurface software, she said.

Operations

In oil and gas operations, satellite imagery can be used to detect any change happening to the earth, or to monitor equipment located far away from people who can monitor it on the ground, such as pipelines.

Pipelines often run East to West, while satellite imagery is collected North to South, because this is how satellites fly around the world. So lower resolution imagery might be better for pipelines then high resolution because you have more of the pipeline in one image, she said.

Pipelines can run thousands of kilometres through different terrain, so there can be different effects happening in different areas.

You can set up an alerting system to be warned if there are any signs of oil spilled.

The satellites can be "tasked" to collect data if there is something of high interest occurring, such as a hurricane which should be closely tracked.

Many companies, particularly in the Middle East, use satellite imagery to monitor vegetation along pipelines and roads, and to prove they are "maintaining the environment".

It is important to differentiate persistent and temporary change in satellite data. For example, the image might just be changing due to the seasons, and not making any permanent changes.

The agriculture sector is already using satellite imagery to understand whether a certain crop is causing permanent damage to the soil, or if it could be grown year after year, she said.

Ms Humphreville showed an illustration of the colour of land in the Permian Basin (USA) slowly changing from 1989 to 2018. There is a "strong difference in spectral properties that persists for 3 dates," which indicates a change with high confidence, she said.

Companies use the different resolution satellite data together. For example thy can use the 10m (larger scale) data from the Sentinel 1 and 2 satellites to look at larger areas of the world quickly and see where any big change is happening, then use the higher resolution (30 and 50cm pixel size) data where there is something special to look at.

Ms Humphreville showed an example of monitoring change over a well pad, starting with low resolution data, and bringing in high resolution data to look at changes more closely.

Without necessarily knowing what the change means, you can see what kind of facilities the change is occurring near, such as well pads, facilities, pipelines, storage tanks and separation tanks.

Satellite images of the same point over a period of time can be used to track the history of a certain piece of land or property.

Satellite imagery can be used together with other remote sensing tools, such as CCTV cameras or sensors.

Satellite imagery has been used in environmental clean-up work, to monitor how the environment has changed following a spill. This could be used as part of legal cases.

It can be used to automatically identify water pools, to map mosquito habitats, including to monitor mosquito carried diseases. "We can't look at a disease or a virus – but we could see the root of that, which was mosquitos," she said.

CO2 monitoring

An interesting area of development is monitoring for CO2 and methane emissions. These can be monitored by satellite in similar ways to how they can be monitored on the ground, such as with infra-red cameras spotting the different radiation signature of air with higher greenhouse gas content.

Ms Humphreville showed an image of a leak spotted by aerial survey. Another survey identified 6bn cubic feet of methane emissions, she said.

Operators can "high grade" what leaks to be fixed first and how to spend funds. "Methane was leaking from places in the asset that they weren't aware of."

OFS Portal – digitalising the supply chain internationally

OFS Portal, a company based in Houston, reports that it is growing the international reach of its system for handling invoices electronically, and associated systems for electronic transactions. Put together, it makes it easier for oil and gas companies to digitalise their international supply chains.

OFS Portal, a company based in Houston, reports that it is growing the international reach of its system for handling invoices electronically, and associated systems for electronic transactions.

The system can be used by oil and gas companies to digitalise their international supply chains, handling and managing transactions, documentation and other communications with suppliers.

It is looking to build its 'footprint' with suppliers and operators in Europe, Asia and Africa, since its market penetration in North America may now have reached its limits, said Chris Welsh, CEO.

He was speaking at the Finding Petroleum / Digital Energy Journal forum in London in November 2019, "How to digitalise exploration and operations".

The company worked on its first Chinese integration in November 2019.

Work to improve digital engagement with suppliers is starting to pick up after the oil price downturn, with around one new operator joining a week.

The benefit to suppliers is that they can use the system to quickly integrate with the oil and gas operators which work with OFS Portal. "They sign the supplier agreement once, and they can transact with more than 400 customers, over 45 different e-commerce platforms, in 50 different countries," he said. These 400 customers and 45 e-commerce platforms have also signed the agreement.

The 45 e-commerce platforms include some which are oil and gas specific, like Oildex, and others which are multi industry, such as SAP Ariba and Tradeshift.

One company, Wellbore Integrity Solutions, will be using the system to transact immediately with customers in 50 different countries. "They wanted to tap into a model that was already established," he said.

When a supplier integrates with an operator for the first time through the system, they can typically see a 10 day reduction in "days of sales outstanding" (average days invoices are unpaid). "There's a big benefit from the supplier to engage digitally," he said.

The company handles invoices in accordance with the Petroleum Industry Data Exchange (PIDX) electronic invoicing and e-commerce standard, and works closely together with this globally adopted open standards body.

Chris Welsh, CEO, OFS Portal

It has systems to ensure invoices go securely where they need to go, as well as managing associated documentation, such as the confidential "price books" and catalogues which oil service companies develop for individual clients.

Every operator is aiming to digitalise its purchasing, but some companies have got further with it than others, Mr Welsh said.

OFS Portal was founded in 2000, based in Houston, and is owned and funded by Baker Hughes, Basic Energy Services, Halliburton, Schlumberger, Select Energy Services, Total Safety USA, Weatherford and Wellbore Integrity Solutions.

Digitalising the supply chain

The broader aim is to help "digitalise the supply chain". This can include defining what best practise means in digital integration, covering the lifecycle of the procurement process, from issuing the purchase order to receiving the payment. This dovetails with the supplier's processes from receiving the order to receiving the cash.

It provides "interoperability agreements", with standard rules for how companies engage digitally, using standards, content syndication and data ownership.

It can provide a gateway into multiple procurement platforms. There are a number of specialist procurement companies with cloud hosted offerings, for example offering online tools to work out the best route for trucks to go through multiple well sites in the Permian Basin, collecting water.

OFS Portal also develops its own software tools. For example, on the operator's side, there are tools to alert people when a supplier has uploaded a new price book to the operator's system, so the operator can use it to improve the accuracy of invoicing and payment.

OFS Portal also provides tools for suppliers to manage the "catalogues" they create for individual customers.

Operators try to keep purchasing under closer control by asking suppliers to provide "price sheets" for regularly used items and services, which are then used for all the company's purchases by its staff.

They are then used to drive out "rogue buying", when staff arrange purchases independently. Money spent setting up price sheets can deliver 10 per cent return, OFS Portal calculates.

Over the last 6 months, the number of operators demanding catalogues from suppliers has increased 50 per cent, Mr Welsh said.

Complex services communications

There are many communications involved with the procurement process, including purchase orders, invoices, submission of price catalogues matched to contracts. Many of these are for complex, multi-faceted services.

The communications involved with these between buyer and seller can be hard to configure in software systems designed more for manufacturing and trade, such as Coupa and Tradeshift, Mr Welsh says.

OFS Portal provides tools for handling these communications which are geared to the needs of the oil and gas sector.

As a result, 80 per cent of all invoices from OFS Portal's service company managers in North America are now sent digitally, Mr Welsh says.

OFS Portal is also looking at setting up blockchain based procurement systems, as a shared neutral place for data. This could make it easier for data from sensor systems and SCADA systems to be gathered together and directly "piped" into transactions as needed.

Other invoicing systems

Some oil majors have their own projects to engage electronically with suppliers, for example BP has a worldwide project called "Backbone" and Chevron has a project to move all of its procurement to a software system called "SMART" by online procurement company GEP.

Some South American companies have regulations that all invoices must be electronic, because that is seen as the best way to minimize fraud and aid tax collection.

Governments are getting more involved in

e-invoicing. For example in Italy, e-invoicing was mandatory from January 2019, the Italian Revenue Agency to automatically collect details of e-invoices, before it provides the e-invoice to your customer, in a system called "Faturra PA". The invoice has to follow certain government standards.

There is a European standard called PEPPOL for communicating with public buyers. In Norway, "all the operators are going to start rolling out PEPPOL as an industry standard".

Data standards

OFS Portal uses e-commerce standards from the organization PIDX (Petroleum Industry Data Exchange) and works closely with PIDX. PIDX has been developing standards for 35 years, going back to the days of Electronic Data Interchange (EDI), moving to XML in 2000, and now developing standard APIs (Application Programming Interfaces)for cloud to cloud integration.

PIDX standards are designed to dovetail with government standards, where they apply.

Security

Data protection and ownership management is a major part of OFS Portal's work. If a supplier provides confidential pricing and catalogue data to a customer through OFS Portal's systems, there needs to be a legal agreement guaranteeing that it will be kept confidential by the customer.

OFS Portal can facilitate the legal agreements, providing a standard contract, so the agreement only needs to be signed once to connect multiple suppliers and buyers.

Analytics

Oil and gas companies often want to do a great deal of analytics on their purchasing, such as to analyse all of their spending around a specific well, and how it compares with other wells. They often identify specific areas of their spend they want to keep under closer control, a process called "category management"

This is easier to do if they are transacting electronically with suppliers, because they end up with accurate data about all their spending in a structured format.

Sometimes companies will set a target of putting 80 per cent of their spend under careful control. They can achieve this by signing up with OFS Portal, because they might find that 70 per cent of their spending is with suppliers which are already OFS Portal members.

The other 20 per cent of their spend might be with a "long tail" of thousands of suppliers where they have just a handful of transactions a year. The effort of automating this processing is probably not worth doing, because the value of having the data analysed is not so great.

End to end digital

Oil and gas companies are increasingly seeking "end to end digital", with direct integration of multiple software systems.

For example, you could have a software system managing data about levels of water in waste water tanks at a well head which connects to a system which orders a road tanker service to collect and dispose of the water. Another system creates documentation and makes the payment.

To support this, OFS Portal and PIDX are developing standards for software Application Programming Interfaces (APIs).

For example, at some point in the future, we might see 60% of future transactions sent as electronic documents via XML, and 40 per cent via direct software integration over API.

"We need to understand how that's going to work for oil and gas with this "infinite connectivity" model that's emerging for us all," he said.

Geologix – oil operations analytics which are easy to understand

The most useful analytics for oil and gas operations might be tools which give people insights into what is going on, in a way they can understand easily. Julian Pickering of Geologix explained how to do it.

In oil and gas there are many digitalization solutions being developed which are "extremely expensive, incredibly complex, and our clients don't really understand what the business value of them is," said Julian Pickering, CEO of Geologix Systems Integration, and a former domain lead for digital drilling and completions at BP.

"Data analytics has become a bit of a buzzword. Digital oilfield, digital transformation, big data, all these different titles. Fundamentally it's about the same thing, acquiring data and using that data to make better decisions."

"Don't be afraid of data analytics. [but] I think the industry has gone slightly off course – becoming too techy."

To illustrate, Dr Pickering has a client in Kazakhstan with a very remote well site. If this client could be given a digital model which would help understand how the well systems are operating, the client might appreciate it. But if someone tried to show them "augmented reality" they could get shown the door, he said.

Dr Pickering has been reviewing papers about digital energy and analytics for the Society of Petroleum Engineers event ATCE 2019. About 95 per cent of papers come from universities and research organisations. Some of them are very complicated. "I'm on the verge of whether I can understand what they are talking about," he said.

An illustration of using technology which is fit for purpose, rather than over-complicated, is Dr Pickering's IPhone7. "It was cheap, it does what I need, it makes phone calls, allows me to access my e-mail, I can do what I need to do on it. I can identify with it a bit more than spending hundreds of pounds on the latest phone," he said.

Enhanced visualisation most useful?

The background is that oil and gas companies want to extract maximum value from their declining assets, and avoid unplanned downtime, in order to maintain profitability. They are finding processing getting more and more complicated, while the experts in their workforce are retiring.

Technology can help them manage these complicated assets, incorporating knowledge management.

But the digital systems need to be presented in a way that people can easily understand the value proposition. The systems also need to be reliable, so people trust it, and genuinely helpful in providing insights into operations, he said.

It is also important that the operators understand how the digital systems work. "Very few people are happy to use systems where they have no idea what's going on," he said.

To illustrate, Dr Pickering said he would not yet be confident in an autonomous car, because although he is an automation expert, he does not have a deep understanding of how the autonomous systems make decisions.

The analytics system also needs to give operators sufficient time to take action.

Taking all of this into consideration, perhaps just giving operators "enhanced visualisation" – better insights into what is currently happening – would be most useful. Perhaps the industry will come around to this idea once it has got over the hype of big data and data analytics, he said.

Geologix Operations Advisor

Following this philosophy, Geologix has developed a software tool called "Geologix Operations Advisor" (GOA), which aims to give operators insights into factors such as decreasing performance of process equipment. For example, compressors, pumps, heat exchanges and control valves. It provides information which is not normally easily available, but easy enough for the customer to understand how the data was generated. An example is given below.

It can base the analytics on what it can actually see happening, not a digital model of the plant and the assumption that everything is working exactly according to the digital model, as many other tools do, Dr Pickering said.

The data can be put together to make a "structured asset model".

Using the data, GOA can generate smart alerts, modelled around something useful to a person. So for example it would not just say a certain temperature reading has gone up 2 degrees (as a control system would), it would say it is predicting fouling in the heat exchanger, and it is worth cleaning it because otherwise it will cause the plant to trip.

It can also tell you how urgent something is. If the bearings in a compressor are starting to wear, "that's pretty high urgency stuff." But if a heat exchanger is starting to foul, there is time to backflush the exchanger to fix the problem.

Julian Pickering, CEO of Geologix Systems Integration

A knowledge management system sits behind these alerts, containing recommended practice on how to resolve a certain problem. The recommended practices for handling a certain problem might be written down by the operator. Having that expertise immediately available can be particularly valuable at times when there are not many staff around, such as 2am on a Sunday night, Dr Pickering said.

The GOA visualisation fills a gap between the 2D drawings of industrial processes which everybody uses (on paper or software drawings), and 3D "digital twins" which are now becoming more available in the oil and gas industry.

Dr Pickering uses the term "2.5D" to mean a 3D representation of something on a flat screen which someone can 'walk around'. Actual "3D", in comparison, can mean a 3D visualization you see on a headset, with different images for each eye, so you actually see the object in 3D.

Gas compression example

Dr Pickering presented an example of how the Geologix Operations Advisor (GOA) software can work.

Consider a basic gas compression system at a well head. The gas is compressed to a target pressure and temperature (normally 80 degrees C) for export or re-injection to the reservoir. But if the gas export line exceeds a certain tem-

perature, the system automatically switches off for safety reasons (known as a 'trip'), which in the example given was set to 100 degrees C.

A common problem is that people do not have much time to fix any problems – just a few hours between warning of a problem and the trip.

When gas is compressed, its temperature goes up, so it needs to then be cooled to reduce the temperature. It is cooled by flowing it through a heat exchanger, which has a series of metal plates, with liquid on the other side of the plates to cool it down (like a house radiator in reverse).

It is very difficult to see what is going on – the devices are very large, running under high pressure, with a number of flow channels. They can be instrumented externally (to monitor for temperature) but almost impossible to add instruments internally, such as to monitor for fouling and flow.

The cooler's effectiveness is blunted by fouling, basically muck building up inside the pipes. As the muck builds up in the second stage cooler, more cooling fluid is needed, so the control valve to release the cooling fluid is automatically opened up further. Eventually, the valve cannot be opened any more.

This passes the problem onto the third stage cooler, which also has to work harder. But the gas export temperature still doesn't show any problem, because the output gas is at 80 degrees.

But eventually the second cooler is also pumping cooling fluid at the maximum, and the fouling continues to build up further, but there is no further means of keeping the output gas at 80 degrees, so the temperature rises until it reaches 100 and the system shuts down.

Meanwhile the fouling may have built up so much that it takes a few days to unblock, and production from the whole system needs to stop.

You could use software like GOA to see a flow diagram of the equipment (created from the database), combined with real time flow data. It could be considered a digital twin, with detailed data about all of the vessels, pipework and instruments. Software like GOA continually puts all of the available data into a structured data model so it can understand what is going on.

Warning about fouling is available much earlier. This means the operator has time to back flush the system (change direction of flow) to clean it out.

"It is not just a simple matter of putting new extra instruments on the process, these are analytical things that you can't measure," he said. "There is an agglomeration of a number of different measured points to give you this information."

"But there is no complex logic, the operator can fully understand what is going on. The interpretation is based on the physics of the process.

Although the sensors cannot see the fouling directly, they can infer from the data that a cooler is 50 per cent fouled and needs backflushing before it gets any worse.

Equipment can be colour coded red or green indicating if there's a problem. It is "showing information in a way we've never done it before."

The software also shows "we don't need lots of expensive and cumbersome equipment to look at the 3D world," he said.

The data is light enough to run on a handheld tablet computer, by someone actually walking around the plant. An analogy is a surgeon who can look at a person and look at data from the sensors the person is wearing at the same time. "The level of awareness is transported to a whole new level."

Sorting out data after a takeover

UK data management company Flare Solutions helped an oil major to organise 4 petabytes of data owned by a company it had acquired. Dave Camden, director, told the story of how it went.

UK data management company Flare Solutions recently undertook a project to help a large oil company sort out the data owned by a company it had acquired – 4 petabytes in total.

The data had been gathered over 20 years, comprised around 300 million unstructured files, stored in a number of locations.

The project involved going through the data, trying to retrieve the most useful parts of it and make it available to the company, archiving some data and deleting other data. Because of the scale of the project, it involved a large number of automated tools.

Some of the data was also urgently needed – people wanted to be able to work on the data before the data sorting project was completed.

The basic steps were first to make a searchable index of the 300m items, so people in the company could have a look themselves to see if there was something useful in there. The second step was to add labels to this index, and classify it into "information to be sorted out first", "archive", or "delete". A third step was to actually move the data to new systems. A fourth (lower priority) step is to add additional tagging to the files.

A lot of the sorting was done by "tagging" information, according to a set of standard taxonomies (data structures).

Flare also wanted to ensure that its system would be useful in the future.

Making a searchable index

The first step to making a searchable index of the data was to find out where the data actually was. This was done by scanning the hard drives to find all the information stored on them.

Because of the large volumes of data, and low performance of the disks being used, it was easier to analyse files directly from the disk unit, rather than access it across the network.

The scanning process pulled off file names, folder attributes and file locations, but not the content of the file itself.

There were many different disk systems,

David Camden, Director, Flare Solutions

and a challenge bringing all the information from them together in one place so it could be visualized.

The project team decided not to use checksums (a means of checking for errors). "To try to do checksums on 4 petabytes would take literally years. Although it is desirable to do this on small data sets, not really feasible on large data sets," he said.

The file data was put through a quality con-

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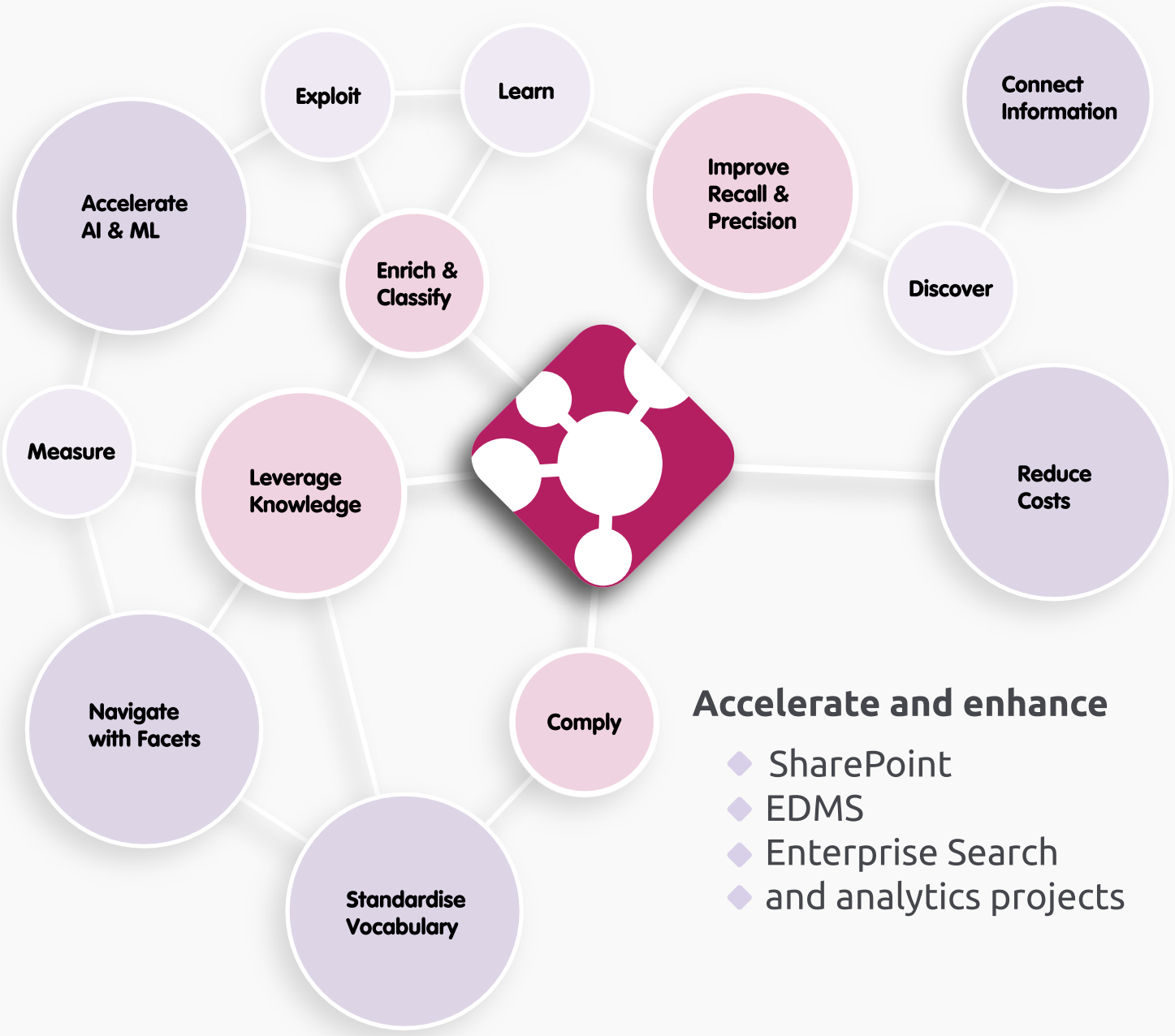

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trol process to try to weed out the unwanted files.

A "folder search" system was developed, which, rather than bring up files which might be useful to someone searching, would tell you which folders contained files which looked like they might be useful, so you could look more closely there. This way it was possible to search 300m items in a second, something which was impossible on the original systems, he said.

The difficulty with getting results as a listing of files was that a search like "Angola assets" would bring up hundreds of thousands of results, he said.

Flare was able to monitor the progress of its data organising project, so it was able to see what proportion of all the data has been planned for migration, archiving and deletion, and what was left.

Moving data to new systems

The high priority data migration was completed over 4 months.

Actually moving the enormous data volumes to a new file storage system was "really difficult", he said.

The data was moved on enormous 20 terabyte drives, copying onto a new 4 petabyte shared drive. (1 petabyte = 1000 terabytes = 1m gigabytes).

The new disk had 40m files on it, not as much as 300m on the old disk but still "a significant amount of information," he said.

Some data was transferred to different company offices, where it could be combined with other data sets they already had about certain parts of the world.

There's an audit record of what happened to each of 300m original files, he said.

Although the data was stored on disks, the project would be very similar if the data was stored in cloud servers. "Data lakes are really file systems in the sky – but have the same issues as dealing with home grown disks," he said.

"If you had to move 4 pb of data from one cloud provider to another, how long would that take – not a simple task."

Virtual folders

The company decided not to re-organise the file structure, but instead create a 'virtual folder' system, based around a standard folder format the acquiring company used. So files could appear to be in the standard folder format, whilst actually being stored in the original format. This could be achieved by giving the files meta data tags, with a mixture of automatic and manual methods.

This means that users can see all of the files in the company standard structure, but also have access to files in the original structure if they want to (for example in case the tagging process has missed something).

Further tagging

Now, more work is going on to add more tags to the data, for example about assets or countries it refers to. The tagging is based on searching for reference keywords, and a set of taxonomies (data structures).

This means that it can be searched in different ways, with results visualised in different ways. For example you can search for data on carbonates in Brazil and find, for example, information on limestone in the Campos Basin.

It may be possible to develop analytics / AI based automated classification methods. But for that to work, the computer needs to be able to understand what a document is about, which is difficult, he said.

Flare is exploring ways to use machine learning to study documents which have already been classified manually, to see if it might be possible for a computer to be trained.

Flare is developing ways to model the standard documents made in the exploration, drilling and well completion processes. Then you could tag a document as to where it sits in a certain process. You could also bundle documents together, if they were all created as part of a certain process. "It gives you a lot of consistency," he said.

It is also looking at developing custom views of the data, for people in specific roles who have specific information needs. "There is more of that coming up as metadata gets increased," he said.

Big projects

There are big technical challenges associated with working with enormous data volumes. "The native system just doesn't hack it – too slow and inflexible," he said. "Moving information physically from one system to another, no matter what connectivity you've got, can be extremely difficult. It can take a lot of time. Dealing with big networks, big systems, is really hard."

When trying to classify or tag the data, you can often find yourself with tasks which may only take a few milliseconds each time, but you have to do millions of operations the time becomes prohibitive..

"You want to do the fastest, simplest things you can initially, simple searching/matching, just make it work. Then use more complex methods, progressively. Things that take longer to analyse, do them later."

"Also, recognise that you'll never have the time to do 100 per cent of the information that you've got. "

It s important to develop progress metric systems, so you can see how work is proceeding, and if it is on schedule.

Some people argue that if files have enough metadata, folders are unnecessary. Mr Camden disagrees with this. "Folders are an integral part of the way humans think about things and there are folder structures that are really hard to capture in matadata. Navigating through folders can be useful. As long as you don't try to make a folder structure that's too big. People will get lost in it," he said.

"There is a definitely a place for folders, but they have to be augmented with metadata and smart searching. Don't rely on folder structures alone."

Data Overload

With such huge numbers of items it's easy to get overloaded when you search. Apart from the 'folder search' already mentioned, there are other strategies you can adopt.

It can be useful to develop better prioritisation systems for search results, and help people work with folders, rather than files, so manage the amount of detail people need to work with. "You don't want to do a search and get millions of results, you can't do anything with it," he said.

"Many things come in chunks of tens of thousands. Projects themselves can be dealt with as a single object and searched in that way," he said. That way, "you can reduce the number of objects in your system quite dramatically,"

Many files are linked to applications and can only be read with a certain software package, and should not appear in a search. "There's a lot of stuff on disks that users don't care about, only applications care about, and it gets in the way of users," he said. "Our system 'hides' these files to prevent overload".

Graph database

Flare has its own technology called SIRUS which converts data to a graph database, enabling data to be viewed in terms of connections,

Having a graph database system for viewing data "is a huge enabler in this case, a technology which really made this possible," he said. "It would be quite difficult to get this degree of performance any other way."

InEight – using software to better "package" projects

Project management software company InEight Inc. is developing better ways to break down construction projects into "packages" using digital technology – so they can be easier to manage, including making sure there are no obstacles to each work package before it begins

Project management software company InEight Inc., based in Scottsdale, Arizona, is developing improved ways to package construction projects into chunks with the help of digital technology.

The idea is that each "package" can be managed much more easily because it is a limited size – including making sure that construction workers have everything they need before actual work starts, and any risks have been eliminated as much as possible.

Breaking projects down into packages is not a new concept, says Paul Self, EVP planning and delivery with InEight. But the company has developed a more structured way to do it using software. It "puts a bit more rigour into how you take the best practises and implement them on a project," he says. These best practises are commonly known in the oil and gas market as Advanced Work Packaging (AWP).

Projects can become enormously complex, so it is very difficult to manage all the different components in someone's head, or in a computer system. So the idea of packaging is breaking a project down into components which are small enough to be understood fully.

Each package can be split into an engineering package, a procurement package, and a construction package, with everything planned before work starts. Each work package has documents, estimates and cost controls attached. The discipline leads (who are not planners or schedulers) can more easily review each package separately, to check they cannot foresee any problems.

This means that the actual work can take place in a constraint-free environment. People have all the materials they need, the documents / approvals they need, and everything else they might need, such as scaffolding, in place before the work starts.

InEight has 300,000 users worldwide, with support for a number of oil and gas customers and their contractors, sub-contractors and engineers.

Companies can take a hard rule that they won't start detailed planning of the work package until the primary constraints are "released". Working free of any constraints also has safety benefits – people will have everything they need to do the job properly at a reasonable working pace.

A study by the US Construction Industry Institute showed that better work packaging systems can improve productivity of work done by 25 per cent. In a test of two identical projects, the contractor with AWP (Advanced Work Packaging) installed at a rate of 2.6 hours per linear foot, the contractor without AWP installed at 3.4 hours per linear foot. The use of AWP led to reduction in total installed costs of 10 per cent.

It also makes outcome much more predictable. There is also a morale benefit – a more productive team is usually happier, Mr Self says.

If the construction is built entirely according to the digital plan, then the digital model will more accurately reflect what is actually built. This means that the software systems can be more useful during construction. It also means that the data can form an accurate "digital twin" of the project which can be used during operation.

How packaging works

A typical Installation Work Package (IWP) is 500 to 1000 hours of one team's work (8-16 days of work for an 8-person team). It is typically 1-3 weeks long.

The InEight packaging process begins with the "end" and works backwards. So you start with a picture, often a 3D model, of how you envisage the project should end up, and then break down the work of getting there into small packages.

An analogy to this could be making a Lego model of whatever you are constructing, and then taking it apart brick by brick, and writing Lego building instructions starting with the last page.

Each package is designed to finish with everything in place which is needed for the subsequent package. You know exactly what this is, because your subsequent package has already been designed.

Then you can ensure that each package of construction work has everything in place before people start constructing, and all the planned work packages will lead you to your desired end point. You get a good idea of what the obstacles might be along the way because you have already planned ahead in detail.

This is opposite to traditional project planning, which goes from left to right, analogous to building with Lego starting with just a pile of bricks. You start building without knowing what obstacles you might come across in the later stages.

Some companies find it useful to tie together the "commissioning sequence" – the order that equipment is switched on when the plant is started up – with the construction sequence. You usually commission a plant according to a certain sequence; you can build the plant in the same way.

Decommissioning work can also be planned in work packages in a similar way. The starting point to creating packages could either be the end (having nothing) or the point of "cessation of production".

Not all of the project can be planned in packages. Some elements need to be planned while looking at the whole project at once, including the overall design, the documentation for the whole project, the planning tools which work out the sequence of work, and tools to support execution of the work as it is done.

The InEight software has analytic tools to determine the feasibility of different approaches to the project, based on previous experiences. "It helps the organisation see if the way they sequence the work is actually feasible, based on how they historically executed similar projects".

The company calls it "augmented intelligence", using computer tools to support human judgement. "We're serving up the information to the expert user in a way that makes it far faster and more accurate," he said. "Human collaboration and intelligence are a huge and important element to this; you can't lose this as part of the planning process."

The InEight software makes packaging easier to do. Many packaging projects have been done "in spite of the technology", with planners struggling to gather the information needed from different software packages, Mr Self says.

Linked software modules

The packaging tools connect with other integrated software modules which InEight provides - project cost management, connected analytics, planning / scheduling / risk, capital and contract management, document management, virtual design + construction, field execution management, safety / quality/ commissioning.

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