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Frac to the Future; Oil's Digital Rebirth

The Oil & Gas industry has at last seized on the promise of digital and is poised for a step-change in efficiency over the next five years. Digital technologies will reduce the cost of production by almost 10% globally while increasing recovery rates by the same amount. Though deflationary for oilfield services in general, upstream digital could be a >\$30bn market in five years, a ~6x increase from today.

North America Oilfield Services & Equipment*

U.S. Software*

European Integrated Oil & Refining*

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Executive Summary

The Digital Age is finally dawning for Oil & Gas. We are witnessing the early stages of the transformation of an industry ripe for reinvention and keen to woo back ESG-conscious investors. A combination of new technologies, emerging business models, and eager C-suites is enabling this change. We see a market poised to erupt over the next five years.

The power of Digital is immense: small improvements in each phase of the well lead to big gains in efficiency, creating an estimated \$150bn in value to Producers. The Digital Services market is taking shape; a fascinating mix of Big Tech (cloud), OFS (Big 3), and technology start-ups. With Oil & Gas under pressure as never before, Digital provides a lifeline to improved efficiency, better FCF profiles, and higher ESG ratings. Digital not only makes hydrocarbons more competitive with other energy sources, it makes them safer, cleaner, and less wasteful. With apologies to those predicting the imminent death of hydrocarbons, Digital is breathing new life into an industry desperate for change and a return to relevance.

We have identified almost \$150bn in value that can be extracted, which could also put pressure on oil prices. Over the next five years, we estimate Digital can lower the cost of production by more than \$3 per barrel, offering Producers' improved returns and a lower FCF breakeven. We expect the Digital Services market to grow to more than \$30bn annually from less than \$5bn today, while we estimate a \$25-30bn opportunity for the cloud providers.

A golden opportunity for Oilfield Services to regain relevancy. The Big 3 in Oilfield Services (SLB, HAL, BKR) are each uniquely positioned with relationships, technology footprints and Digital experience. As an emerging high-margin, low-capital revenue stream, Digital could be almost 20% of EBITDA in five years, potentially re-rating these names. Despite limited disclosure, we believe Schlumberger is best positioned in the near term. Halliburton is perhaps a few steps behind, but Baker may have the greatest upside of all, though it's the hardest to quantify. Outside of the Big 3, Apergy has the most Digital exposure as artificial lift has seen the greatest adoption to date.

There are consequences. Increased efficiency and performance translates into reduced upstream capital investment, which is broadly deflationary for the Oilfield Services sector. OFS companies need Digital to offset structurally declining revenue from traditional services. On a macro level, Digital flattens the global cost curve, which in turn may put a ceiling on oil prices (caveat being the Permian), while also making oil more competitive as an energy source.

Why now? O&G investors are rightfully skeptical after hearing about the promise of Digital for years. However, the last 12 months has seen a dramatic shift in adoption, with numerous announcements of cloud and digital-platform partnerships that we think are just early signs of things to come. As the cost of acquiring and storing data has plummeted, advances in software architecture and programming have created a diverse array of applications that address almost all upstream activity. Having widely achieved proof of concept, value creation over the next five years hinges on scalability as Digital moves beyond discrete applications to organization-wide implementation.

This report presents a comprehensive analysis of the Digital opportunity for Oil & Gas, delving into the enabling technologies, cutting-edge applications and various market players. We go beyond the marketing and rhetoric to quantify the potential value creation from Digital, breaking down the financial impact at each phase of the well lifecycle. Not only do we drill down into the unique offerings of the major Oilfield Services companies, but also highlight many of the Digital Innovators; start-up tech companies which are marrying domain knowledge with data analytics capabilities.

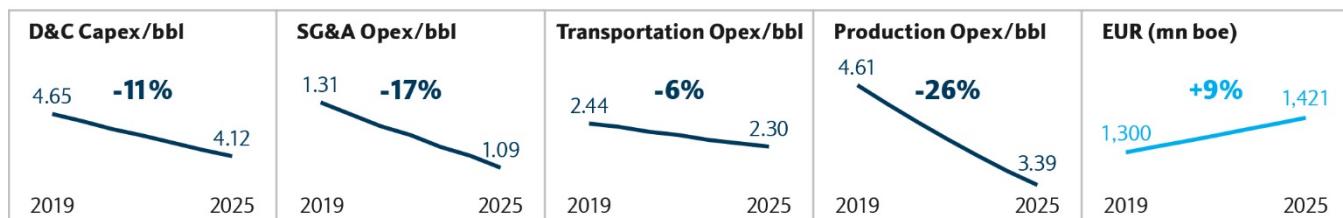
What is the market opportunity?

Over the next 5 years, the Digital Services industry is expected to grow to more than \$30bn annually from less than \$5bn today as Producers benefit from an estimated \$150bn in value creation.



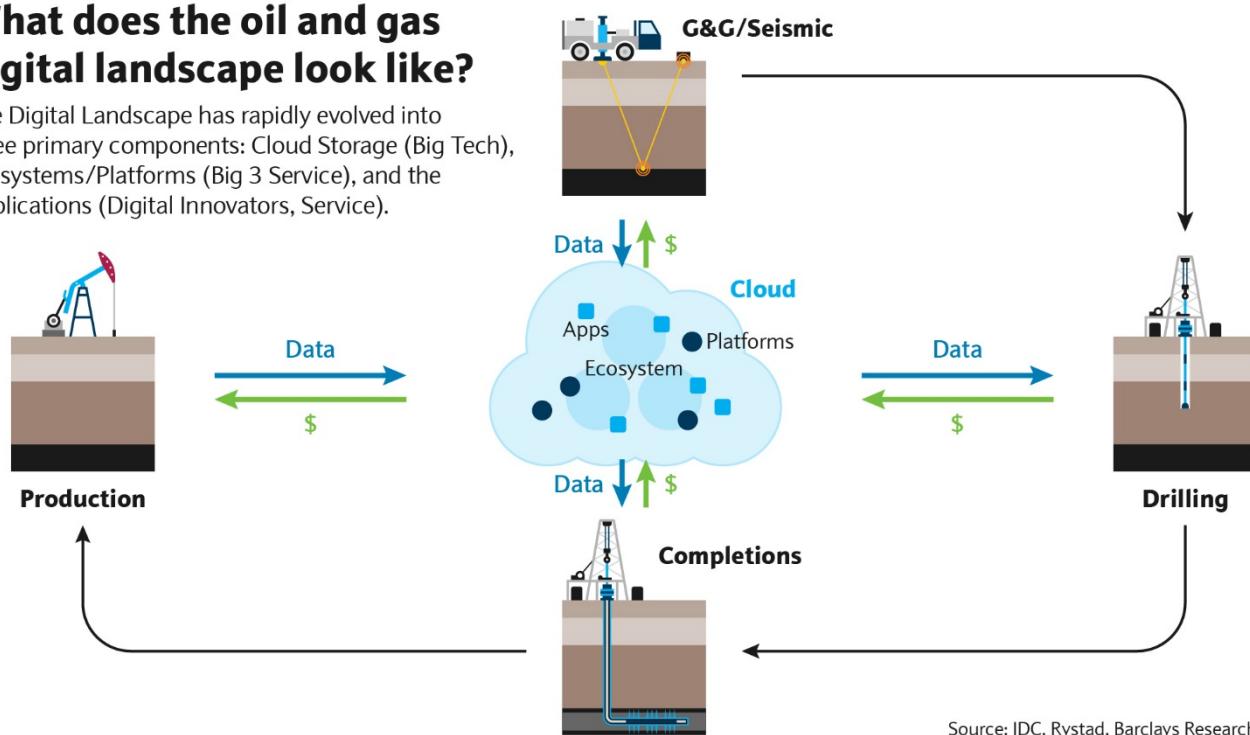
Where do savings come from?

Small improvements add up to material gains, improving returns for Producers and lowering the FCF breakeven. Digital impacts virtually every aspect of upstream activity, not only reducing costs through greater efficiency, but also increasing hydrocarbon recovery.



What does the oil and gas digital landscape look like?

The Digital Landscape has rapidly evolved into three primary components: Cloud Storage (Big Tech), Ecosystems/Platforms (Big 3 Service), and the Applications (Digital Innovators, Service).



Source: IDC, Rystad, Barclays Research

Who are the winners & losers?

Winners	Benefits	Consequences
Select Oilfield Service SLB, HAL, BKR, APY	More Competitive Oil & Gas Industry Closes the productivity gap, improved capital efficiency, lower cost of production	Traditional Oilfield Services Deflationary for more commoditized services as Producers can do more with less
Producers E&P and Integrated Oil		Ceiling on Oil Prices Flattening of the global cost curve
Big Tech Cloud Providers MSFT, AWS	Improved ESG Metrics Smaller footprints, less waste, increased safety of operation	Adopt or perish Those who don't embrace digital will be left behind
Digital Innovators Technology start-ups	Emerging Digital Market Higher margin, higher multiple industry for digital services built on software, hardware and new equipment	Potentially delays the energy transition Digital widens the economic gap with renewables, could slow down transition.

Why now?

A step change in enabling technologies	An industry ripe for disruption	Evolution of software business models
<ul style="list-style-type: none"> Cloud computing Sensors and measurement Edge computing, software architecture Programming capabilities O&G c-suite level acceptance 	<ul style="list-style-type: none"> Lower oil prices putting spotlight on industry efficiencies Producers under pressure to deliver FCF, capital discipline ESG increasingly important to investors Service companies eager to develop new markets 	<ul style="list-style-type: none"> SaaS: faster innovation, better performance, more flexibility, recurring revenue streams vs. on-prem Open Data: acceptance of the cloud, data is no longer siloed, benefits of collaboration Open Architecture Programming: increased reliance on 3rd parties in software architecture, "future proof" systems

Key players: who are the main beneficiaries?

- Big Tech:** Has made a big push into the O&G sector over the last 12 months, signing contracts with OFS companies and Producers. Wallet share shift in IT budgets from traditional infrastructure to the cloud makes the opportunity substantial.
- Oilfield Services:** From a revenue standpoint, the Big 3 of OFS (Schlumberger, Halliburton, and Baker Hughes) and Apergy have the most to gain over the next 3–5 years. Could represent a re-rating opportunity down the road.
- Digital Innovators:** The most exciting development has been the astonishing growth in emerging digital technologies, most of which have only existed for a few years. Could be consolidation targets over the coming years.
- Producers:** Leveraging a combination of external and internal solutions, there is an opportunity to reduce costs and increase production. The majors are the big prize, and have the most to potentially gain.
- Industrial Companies:** More of an enabler of digital than a player, providing hardware that allows machinery to operate independently. Certain Industrial companies do compete on the software/digitalization side, to a degree.

PART I

A Guidebook to the Future of Digital Oil & Gas

About this Report

This is how Barclays sees the Digital Age evolving in the oil and gas industry. From our seat covering the Oilfield Services sector, we are uniquely positioned to evaluate and opine on the influence of Digital across the oil and gas landscape. The diverse set of companies we follow is collectively exposed to virtually every aspect of oil and gas operations, from deepwater to shale, from the Middle East to West Texas, from geomechanics to rotating equipment, from private E&Ps to the largest National Oil Companies.

The intention of this report is to highlight the most influential technologies, the best-positioned companies, and the opportunities and challenges as Digital becomes accepted as an integral part of the oil and gas business.

Digital is an extremely broad topic; not everyone has the same definition. Furthermore, we acknowledge not having captured every technology, nor have we highlighted every company that will benefit. After spending the past six months researching this topic, we are continually finding new angles where Digital can be applied. But we have also run into many roadblocks. Transparency in oil and gas is poor to begin with and many companies are reticent to provide details. In other words, this report represents our best efforts, but there is much we don't know yet. It's a dynamic topic that we plan to continually revisit.

An Introduction

The Digital Age is upon us. The concept of digitalization within the oil and gas industry is not new, but despite all the excitement and promise, there has been precious little to show for the hefty R&D expense. So elusive has digital success proven that many investors now roll their eyes at talk of “Big Data” and “Digital Algorithms.” Frankly, we can’t blame them, given the extent to which progress has lagged the hype. But that’s all about to change.

While digitalization is still in its early days, it is starting to impact the numbers, and the potential it has to increase production, lower costs and improve returns is meaningful. It turns out the concept wasn’t just ahead of its time - its potential was also vastly understated. Over the next five years, we see the impact of Digital spreading throughout the oil and gas industry, with opportunities across all phases of the well lifecycle.

The next few years will be critical in shaping the digital landscape: the leading companies of tomorrow will be those investing today, taking advantage of evolving markets and the fortuitous convergence of technology advancements, evolving business models, and an industry ripe for disruption.

Multiple factors converge to make this a reality. Over the past six months, we’ve canvassed the oil and gas industry, developing a comprehensive understanding of how Digital is impacting the industry; the technology, the challenges, and the players on all sides. It was hard not to take notice when cloud providers such as Microsoft signed a plethora of contracts with both service companies and producers, so our initial line of research focused on the cloud and the opportunities technology companies see in oil and gas. This led us down the proverbial rabbit hole to explorations of the digital ecosystems being built for

various applications and the many start-up companies developing third-party applications, platforms, or technologies that can be integrated with open-architecture platforms.

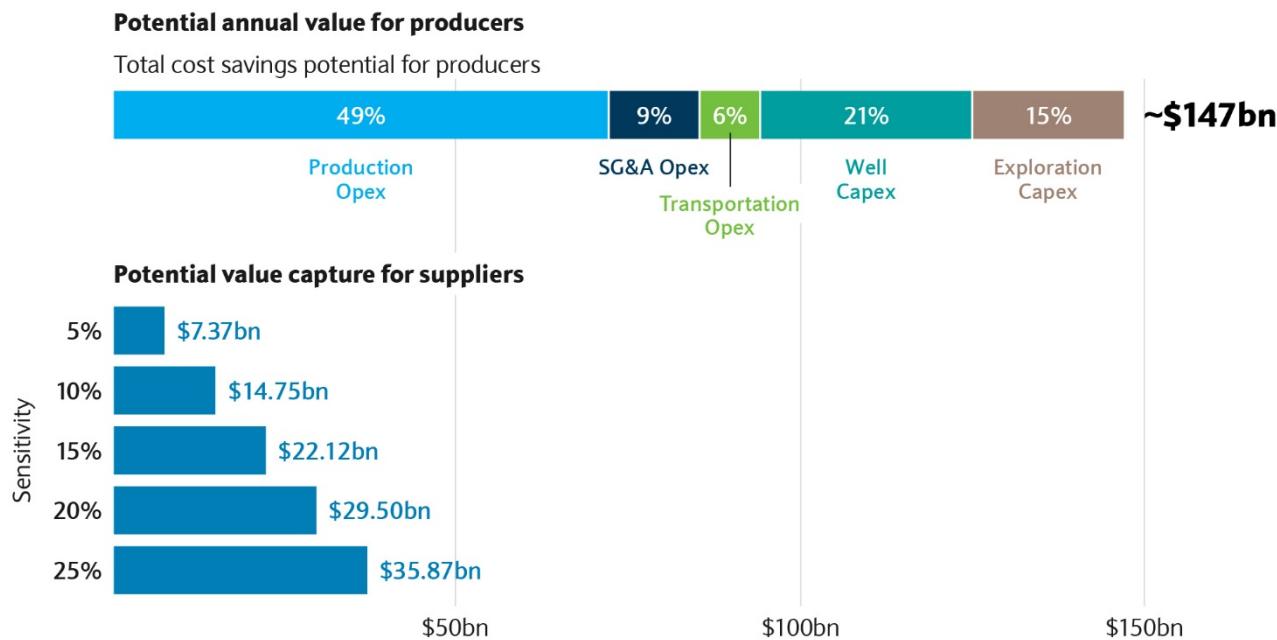
Our research reveals a much more vibrant, complex and opportunistic digital Oil & Gas market than most investors realize; one that is just now starting to emerge. Some of the change is as simple as integrating workflows across the organization and “un-siloing” data in near-real time. Other parts are complex, multi-dimensional topics that can be viewed from many different perspectives.

In this report, we identify a multitude of potential winners. But we also see significant repercussions: a step change in efficiencies across the lifecycle of the well would not only be deflationary to oil prices but also a negative for traditional oilfield services because more can be done with less (more production/less capex).

We estimate the annual addressable market for Digital Oil & Gas solutions could increase by 500% over the next 5-6 years. The purpose of this report is to define the digital oil and gas landscape by identifying each of the players, breaking down the digital opportunities at each phase of the well lifecycle, and highlighting the various technologies being employed. Within this framework, we estimate the amount of money being spent to use upstream digital applications currently is approximately ~\$5bn across the industry, though we note very few companies disclose the direct amount of spending.

In Figure 1 below, we show where we believe the total addressable market can go, and a sensitivity analysis based on different values captured by the suppliers of the digital products. Notably, this doesn't include the opportunity on midstream/downstream/LNG or for cloud infrastructure providers.

FIGURE 1
Total Addressable Market



Source: Rystad, Barclays Research

Our ~\$150bn estimate of the annual potential savings for Producers is predicated on limited disclosure, requiring a number of assumptions. In general, Oil & Gas companies are highly secretive to begin with, but we've noticed a striking lack of disclosure when it comes to Digital, in large part to protect competitive advantages in this emerging business.

Though Microsoft has identified Oil & Gas as a top growth market, it's embedded within its \$12bn cloud business. Among the large oilfield service companies, only Baker Hughes discloses revenue and operating income from its Digital Solutions segment, and only ~10% of that is under our definition of Digital in this report (the rest is from measurement and control hardware); Schlumberger spent ~\$350mn (Barclays estimate) on R&D for Digital last year; Halliburton has provided almost no digital disclosure in terms of numbers. Major oil companies use the word "digital" liberally, but have begun to speak about its potential more, referencing the use of both internally and externally built solutions (we think in-house focus has been on existing production). In US land (non-majors), EOG Resources and Occidental Petroleum are the leading users of Digital for unconventional development, also developing most of their capabilities in-house, but they do not disclose spending levels.

Over the next 3-5 years, we expect data management to steadily expand as the amount of data being captured grows exponentially. We think the greatest opportunity will be in providing digital services to major oil companies and independents in US land, where the marginal barrel globally resides. With an increased focus on capital discipline and reducing SG&A cost, as well as a finite amount of "Tier 1" acreage, producers will need to rely more heavily on external solutions providers as they recognize the challenges in building out and maintaining digital capabilities, such as hiring and retaining teams of software engineers to design applications.

Why now?

The Digital Age is making its mark on all parts of global commerce as the growing ability to store and process massive amounts of data (cloud) coincides with exponential increases in the amounts of data being generated. Artificial intelligence and machine learning tools can be used to analyze the data and help optimize operational efficiency. By most accounts, the oil and gas industry is late to the game, but it is rapidly catching up for a number of reasons.

- **A step change in enabling technologies.**
 - **Data storage and computing:** capabilities have dramatically expanded while cost has come down as MSFT, GOOG and AWS have built out servers to enable large scale cloud storage and processing.
 - **Sensors:** the cost of data acquisition through sensors has fallen precipitously, while the capabilities of sensors have greatly improved.
 - **Programming:** the capabilities of software engineers have dramatically increased in the area of data analytics, artificial intelligence, and machine learning.
 - **Edge computing:** allows real-time computation in remote locations, enabled by increased processing power.
- **An industry ripe for disruption.** The Oil & Gas industry has come to terms with a lower commodity price environment; many producers are rethinking business models to improve profitability, returns on capital, and free cash flow. This is especially true given the finite amount of Tier 1 inventory yet to be tapped and reduced potential for further savings from service cost deflation. Digital can enable improved efficiency across the lifecycle of the well: higher productivity, greater uptime of facilities, and lower cost of finding and developing hydrocarbons to remain competitive as renewable energy solutions become more economic with scale.
- **An emerging re-rating opportunity for services.** Larger diversified service companies (predominantly SLB and HAL) have been involved in Digital for more than a decade, but it has recently become a higher priority. As the traditional oil and gas services market

continues to shrink, Digital is one of the few areas with long-term growth potential. There is an opportunity for re-rating within the OFS sector because larger service companies can provide more of the digital tools that producers cannot build in-house.

- **Evolution of software business models.** One of the most critical trends of the past 10-20 years has been the broader industry shift towards subscription-based models (software as a service, “SaaS”) from software packages being sold direct to customers (via traditional licensing agreements for on-premises solutions; “On Prem”). The oil and gas market is just beginning to make the transition, which has coincided with broader availability and acceptance of open-source platforms that allow third-party or in-house software applications to be implemented on existing digital platforms (ecosystems), most of which are agnostic to the cloud infrastructure provider.
- **A means to improve ESG ratings.** Oil & Gas companies are particularly vulnerable to the growing ESG investing movement, and are looking for ways to counter the negative perceptions of hydrocarbons. Digital can improve ESG ratings through improved stewardship and better environmental outcomes through improved efficiencies, monitoring and reducing emissions, developing resources with smaller footprints, and improved safety as AI and machine learning remove employees from harm’s way.

Diverse set of players, plenty of opportunities to go around

The emerging Digital Landscape is creating a fascinating convergence of technology companies, oilfield service companies, and upstream producers, each bringing a different skillset to the table. A tremendous amount of data is being generated across the oil and gas industry, but to date, Digital has been more conceptual than practical, with limited examples of success. In fact, Baker Hughes’ CEO Lorenzo Simonelli believes only 2-3% of data being collected is actually being used - and that stream of data promises to grow exponentially in coming years.

Part of the problem has been the lack of defined roles in the digital realm. That was driven in large part by a lack of trust (hesitancy to share data) and a culture within O&G of developing solutions in-house in an effort to protect intellectual capital and competitive advantage. Whether it was a well design, a new completion technique or simply a new methodology of interpretation, collaboration was rare in the past. In some cases, this even became an issue intra-company, where historically the difficulty of sharing data often negated the incentives for co-operation. All of this led to companies attempting to build the necessary capabilities in-house, which has limited their effectiveness.

However, recently it seems as if the industry has turned a corner in terms of willingness to share data and use external solutions to extract value from it, as evidenced by increased cloud adoption and adoption of third-party (i.e. non-producer built) solutions. The result has been more defined digital roles and a greater opportunity.

Five main players across the O&G digital landscape:

- **Big Tech:** Over the past 12 months, Big Tech has made a big push into the Oil & Gas sector, signing contracts with both service companies and producers for cloud computing services. We often hear digital applications and platforms are “cloud-agnostic.”
 - Microsoft has been the most aggressive, saying that Oil & Gas is the #1 growth market for its cloud services and announcing a number of contracts with different service companies and producers.
 - Amazon Web Services is also making inroads but has made fewer public announcements.

- Google was early in the digital O&G space, but from what we've heard, this has begun to fade.

The question is, where does Big Tech go from here? Publicly, they deny having ambitions beyond the cloud, but we're not so sure.

- **Oilfield Services:** From a revenue standpoint, we believe the Big 3 of oilfield services stand to gain the most from Digital over the next 3-5 years, potentially resulting in a re-rating opportunity. Each of the Big 3 have created digital platforms (ecosystems) that rely on cloud computing to run a wide range of applications, both in-house and third-party.
 - Schlumberger is best positioned, in our view, having long ago established itself as the technology leader in the sector with an unrivalled understanding of the reservoir.
 - SLB and Halliburton have been licensing software to customers (producers) for more than a decade, partly derived from success in geologic seismic data interpretation (the original Big Data). They are now looking to build out their suite of offerings into other parts of production optimization, encompassing well placement, design, drilling, completion and production.
 - Baker Hughes is taking a different approach with more of a focus on asset optimization in midstream and downstream markets (for now), using sensors and the digital twin on rotating equipment (turbines, compression) to create predictive failure algorithms in order to improve uptime. A JV with C3.ai will help to improve analytical capabilities and reduce the time it takes to create new products.
 - Apergy currently has the highest digital exposure in our coverage universe with its optimization and predictive maintenance for artificial and midstream.
 - Another subset of OFS companies has digital exposure, though not to the same extent, including National Oilwell Varco (rig automation and predictive maintenance), Helmerich and Payne, and Patterson-UTI. For these companies the opportunity set is more discrete.
- **Digital Innovators:** The most exciting development has been the astonishing growth in emerging digital technologies targeting Oil & Gas, most of which have only existed for a few years and have seen an uptick in industry interest and adoption more recently. In many cases these are enabled by the cloud and open-architecture. We've identified a host of new software companies that have made impressive inroads by creating applications or platforms, many of which can be integrated with other platforms.

Outside the confines of larger corporations, emerging technology companies are nimble and responsive to customer demands, typically focusing on a specific digital tool including data normalization (SFile), well design (Novi Labs), geosteering (Rogii), completion optimization (Seismos), and production optimization (Ambyint), to name a few. As most of these emerging technology companies are backed by venture capital and private equity funds, they are unlikely to remain stand-alone as the digital landscape matures. Large oilfield service companies are the logical buyers (particularly if apps or technologies are already integrated with the Big 3 ecosystems) but this could also be a path for Big Tech to expand into the oil and gas digital domain.

Internal consolidation is another alternative if larger "third-party" technology companies become consolidators or if several start-ups merge to create a pure digital oilfield service company, both of which would command a premium multiple in an IPO scenario.

- **Producers:** Major oil companies (Shell, BP, XOM), have embraced the opportunity of Digital and built in-house capabilities primarily to focus on existing production to

identify inefficiencies. Through remote monitoring and increasingly sophisticated sensors, these large producers can quickly identify problems (i.e. issues with wellheads, valve malfunctions) and improve uptime across the system.

Exploration & Production companies (independents), on the other hand, have spent considerable time and money on big data and data analytics, though few outside of **EOG Resources** and **Occidental Petroleum** have much to show for their efforts. The complexity of building out the full software stack has proved too difficult and costly for most, particularly as investors are pushing back on SG&A costs and capital spending. However, there are still opportunities for producers to develop some of the solutions internally, but it is more financially sound to also leverage third-party solutions.

- **Industrial Companies:** Industrial companies such as **Rockwell Automation**, **Emerson**, and **Honeywell** provide automation and control technologies. (The hardware provided allows machinery to operate independently and can allow automation of tasks such as the control of speeds, the monitoring of sensor- and temperature-based specifications, and the converting of raw material into finished goods. Historically this has been controlled by central distributed control systems (DCS); however, improved capabilities and the proliferation of low-cost sensors has allowed for the beginning of software-controlled feedback loops (i.e. edge computing). Rockwell (through Sensia) and Emerson (through its Paradigm acquisition) also compete on the software/digitalization side of things. For more info see the following reports from our MI team: 1. *Emerson Electric Co. CEO Meetings: Digital Transformation well underway; Bottoming demand 1/12/2020* 2. *Rockwell Automation: CFO meetings: Subdued NT Demand; Competitive, IT position firming up, 6/30/2019.*

The Well of the Future will be heavily impacted by Digital across all phases of the life cycle

Impacts all phases of the well lifecycle

The development of oil and gas hydrocarbons is a complex process that begins with an understanding of the reservoir (the rock) before drilling and completion is carried out to facilitate production (upstream). The well flows over a number of years until it is no longer economic, during which time the produced hydrocarbons are transported over pipelines (midstream) and then processed or refined (downstream) prior to being delivered to the end consumer. We believe Digital will have a material impact on all phases of the lifecycle of the well, though to varying degrees. Some aspects have already begun to successfully adopt Digital, while other parts of the lifecycle have barely scratched the surface.

Phase 1: Geological & Geophysical: understanding the subsurface, where to drill the well.

Phase 2: Drilling: how fast to drill the well, placing the well in the optimal location.

Phase 3: Completions: bringing the well online, maximizing initial production rates, optimizing materials.

Phase 4: Production: higher production over the life of the well, improved surface efficiency, lower operating expenses.

Phase 5: Midstream/Downstream/LNG: improving utilization rates and throughput in pipelines, processing, and refining.

How do we define success?

The application of digital technology to the oil and gas industry is not a new concept, with the terms “big data” and “data analytics” being thrown around liberally for years. On paper,

the concepts made sense, with the promise of being able to extract more oil and gas at a lower cost. However, for all the talk, success stories have been few and far between.

For the digital market to grow meaningfully, service companies must continue to spend on digital product R&D and producers need to be willing to spend on digital applications.

Over the last few months, we've seen numerous successful proofs of concept, which has increased our confidence that the industry can see meaningful improvement in a number of areas over the next 5-6 years:

- D&C Costs reduction of ~11% (Only 2% annually)
- Estimated Ultimate Recovery: Increase existing EUR by ~9% (Only 1.5% annually)
- Add roughly \$3/bbl of cash flow through increased EUR and ~17% reduction in capex/opex (Exploration, Drilling, Completion, and Opex) per barrel of production.
- Improve utilization and uptime in upstream / midstream / downstream / LNG
- Internal benefit for OFS companies (using Digital on own operations/supply chain and integrated project work) means they realize 100% of the benefit

Who will be the winners of the Digital transformation?

As with any disruption to an industry, there will be winners and losers. With Digital now increasingly integrated within the workflow, there is an enormous opportunity for the providers of digital services. However, the most obvious early beneficiaries will be the consumers of Digital.

- **Producers: The clear winner of the digital age.** We estimate the net impact of Digital will be upwards of a \$3 improvement in cash flow per barrel produced. At the end of the day, producers will be able to do more with less. They will benefit from lower costs, increased production, and greater operational efficiency, all of which will lead to higher returns on capital (i.e. higher valuation multiples).

The value of Digital also comes from what it eliminates: fewer exploration dry holes, less development drilling, less frack hits and parent/child interference, and reduced downtime of equipment in production, midstream, and refining.

- **Select service companies: Either embrace Digital or be left behind.** The OFS industry has been steadily shrinking over the last several years, particularly in North America, where E&P capital discipline has driven down upstream spending. Assuming a flat-to-down oil market the next few years, Digital represents a promising new business opportunity (perhaps the last opportunity), that could potentially result in a re-rating thanks to a growing revenue stream from subscription software services.

Right now the best-positioned companies are the Big 3 (Schlumberger, Halliburton, Baker Hughes) and Apergy. Schlumberger, the incumbent, appears to have the edge right now with digital offerings from its Software Integrated Solutions falling into its Reservoir Characterization segment; however, Baker Hughes may have the most potential over the long term. There is still a significant growth opportunity for Halliburton with its Landmark segment, while Apergy has the highest current exposure. A second tier of OFS companies is investing in Digital, but its impact isn't as material yet (NOV, HP, PTEN).

- **Big Tech: Cloud demand will only increase from here.** With low-cost sensors becoming ubiquitous across all phases of oil and gas operations, the industry has only seen a glimpse of how big "big data" will eventually become. Although Google initially took the lead in the oil and gas industry, we believe Microsoft has become the cloud server of

choice for the industry. Right now, cloud providers are primarily providing the infrastructure as well as certain micro services. *The open-ended question is, where does Big Cloud go from here? Do they have ambitions beyond just the cloud? Could they look to acquire some of the applications that will be relying on cloud computing? We think that the answer is yes.*

- **Digital Innovators: The Oil & Gas technology start-ups.** Over the last several years, hundreds of technology start-up companies have emerged within the O&G domain. These companies typically have a narrower focus compared to OFS companies. Essentially, these are the content providers creating applications and platforms that focus on one or two components of the well lifecycle and that can be integrated with digital ecosystems. Backed by venture capital and private equity funding, we expect many of these companies to be acquisition targets in the coming years. The other potential is for consolidation and mergers, creating stand-alone digital O&G companies.

The downside of digital: a smaller OFS market and potentially lower oil prices

From the standpoint of the Oilfield Services equity analyst, there's a certain existential dread attached to writing about how this digital transformation will impact the coverage universe. The more digital applications are embraced, the less relevant traditional services become. This digital transformation could mean lower levels of traditional services for parts of our coverage universe. Another concern is what it could mean to oil prices if the cost curve flattens globally and the cost of the marginal barrel of production (Permian) meaningfully falls.

- **Highly deflationary to the oilfield services industry.** The ramp up in oil prices to over \$100/bbl in the prior cycle, combined with the emergence of deepwater and shale development, created a considerable amount of oilfield inflation in the system. In contrast, the past 5 years has seen a great unwind. Though OFS pricing has fallen precipitously in recent years, with too much capacity chasing too little work, Digital threatens another step down to OFS demand as it addresses inefficiencies across the lifecycle of the well. Digital allows producers to do more with less, the capex or opex dollar will be able to go further than it has in the past. **That means demand for traditional oilfield services (rigs, pressure pumping, directional drilling) will be structurally lower.**
- **Could it place downward pressure on longer-term oil prices?** As digital applications become more prevalent over the next several years, we anticipate a step change in efficiencies across the oil and gas landscape. Not only will drilling and completion costs fall, but Digital will facilitate the industrialization of US shale as the industry wrings out efficiencies by perfecting multi-well pads, optimizing completion techniques, drilling wells faster without deviation, and minimizing parent/child and interference issues.

However, the question for US land (the Permian especially) becomes: to what extent these gains will be offset by shrinking Tier 1 inventory? We are arguably in the fifth year of cored-up drilling programs due to the reset lower in oil prices, which could provide an offset to the increase in EUR.

Offshore platforms will be smaller, relying on remote operations with fewer personnel. Existing producing fields will be optimized through artificial intelligence, while downstream and midstream operations will see increased utilization as predictive failure methods decrease equipment downtime.

The cost of the marginal barrel of oil production (i.e. the Permian) could decrease with the adoption of Digital, which could in turn flatten the cost curve. It could be a negative for oil prices, but that is not a given.

- Does Digital become a requirement for OFS and could this go the way of commoditization as well? Over the next several years, we expect E&Ps to pay up for these services, particularly as they see improvements in EUR and cost. However, as Digital proliferates throughout the industry and investment ramps up, instead of a premium service it is possible that some digital processes become absorbed into standard operating procedure. This would imply lower margins over the longer term as more companies introduce competitive digital solutions. We do not see this playing out across the entire industry, but there are definitely certain places where digital applications will be the norm as opposed to a differentiated value-add solution. We anticipate that more highly differentiated and value-add solutions, such as DELFI (SLB), iEnergy/DecisionSpace365 (HAL), and BHC3.ai (BKR) can have long-term success, though it won't be without its challenges.
- Digital could delay the global transition to renewable energy. Beyond increasing production and lowering costs, another reason for oil and gas companies to adopt Digital is to take advantage of how it can assist in positioning firms within an ESG investment framework. (*Oil in 3D: The Demand Outlook To 2025, 5/7/19*) Recognizing the oil and gas industry is in the cross-hairs of a world seeking a reduction of its reliance on hydrocarbons while also remaining relevant with investors, Digital makes operations safer (fewer personnel), cleaner (more efficient production, better monitoring of emissions/spills), and smaller (reduced footprints). At the same time, the adoption of Digital could delay the timing of the energy transition towards renewables. Over the last several years, the cost of solar, wind, and electric vehicles has fallen, while reliability has increased as the underlying technologies have improved and matured. **In other words, the economic gap between renewables and hydrocarbons has closed; however, digital technologies in oil and gas could work to widen that economic gap again, potentially slowing the adoption of renewables.**

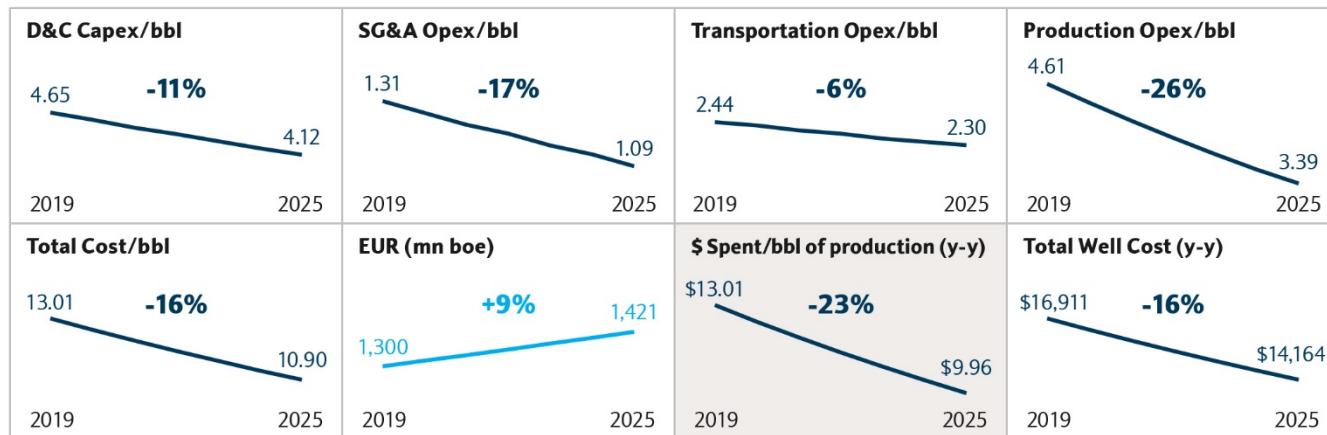
PART II

The Investing Opportunity of Digital

Sizing the Market

Over the next 5-6 years, we estimate Digital can help bring cost per barrel produced down by more than \$3. Keeping in mind that cash flow per barrel for E&Ps is roughly \$20-25/bbl, this implies an increase of nearly 7% in E&Ps' free cash flow per barrel.

FIGURE 2
Cost Reduction and Production Uplift Assumptions



Source: Rystad Ucube, Barclays Research

Importantly, these assumptions imply small changes annually. But when you look at the aggregates over a longer time horizon, the results will be meaningful:

FIGURE 3
Annual Cost and Production Assumptions

	2020	2021	2022	2023	2024	2025	Total
D&C Capex	-2%	-2%	-2%	-2%	-2%	-2%	-11%
SG&A Opex	-3%	-3%	-3%	-3%	-3%	-3%	-17%
Transportation Opex	-1%	-1%	-1%	-1%	-1%	-1%	-6%
Production Opex	-5%	-5%	-5%	-5%	-5%	-5%	-26%
EUR	2%	2%	2%	2%	2%	2%	9%

Source: Barclays Research

For this analysis, we did not include Facilities Capex, Tax Opex, and Abandonment Opex, nor did we include Exploration Capex because of the significant differences in offshore vs. onshore exploration. While onshore exploration activity is likely to remain flat, offshore exploration spend will have to increase over the coming years and will come close to reaching its 2013/2014 peak level (more on that below), though the increase will be somewhat offset by benefits from using Digital.

Basis for assumptions:

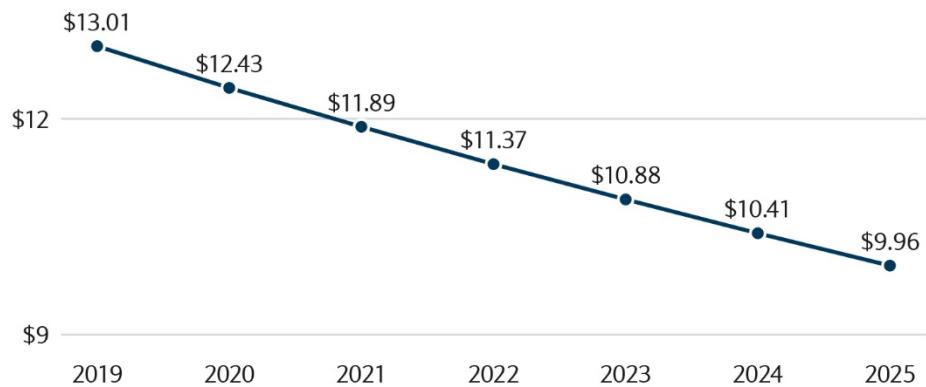
- **D&C Capex/bbl:** Automated drilling can reduce drill time and improve accuracy. Real time frac monitoring can optimize completions with a lower mix of materials done at reduced pump times (see EOG/OXY commentary). **Assume a decrease of 2% annually.**
- **SG&A/bbl:** reduction of headcount from the use of Digital, increased productivity from transition to more work on high-value tasks, benefits of remote monitoring, faster planning of wells. **Assume a decrease of ~3% annually.**
- **Transportation Opex/bbl** (upstream from production/processing to point of sale): a little unclear, but there is an opportunity on optimization of processing (DCP Midstream) utilization and predictive maintenance on compressors. **Assume a decrease of ~1% annually.**
- **Production Opex/bbl:** Remote monitoring/labor efficiency savings for artificial lift, optimization/reduction of chemicals, reduced workover and maintenance costs, reduced electricity costs, compression. **Assume a decrease of ~5% annually.**
- **EUR:** Increased discovery, increased recovery, production uplift from frac optimization (Seismos claims that in some cases it has helped customers increase production by over 100%), Shell, per its 11/26/19 investor presentation, was able to optimize well locations to uplift estimated EUR for Bonga North by 10%. **Assume an increase of ~1.5% annually.**

FIGURE 4

Reduction in capex & opex could bring cost per barrel down by nearly 20%

Opex & Capex per bbl of production

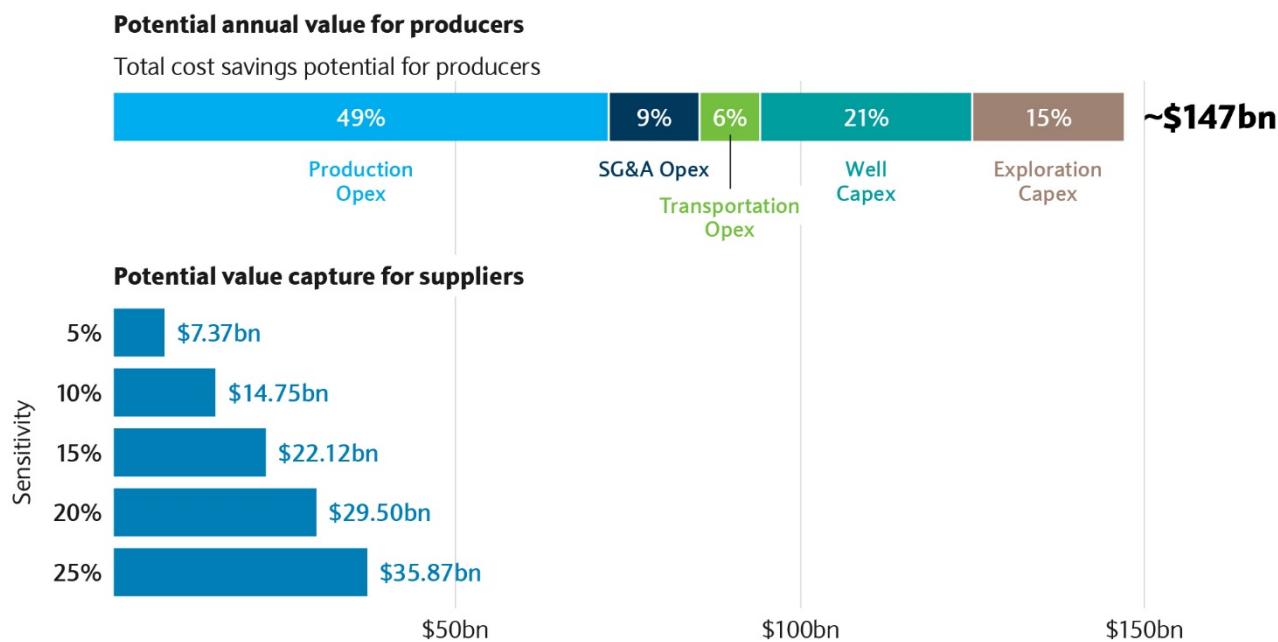
\$15



Source: Rystad, Barclays Research

Based on 2019 global spending numbers using the aforementioned assumptions for each bucket, we estimate that the total addressable market can reach ~\$150bn annually (full breakout below in Figure 5). We believe that the suppliers of these technologies can capture somewhere between 10-15% (sensitivity shown below).

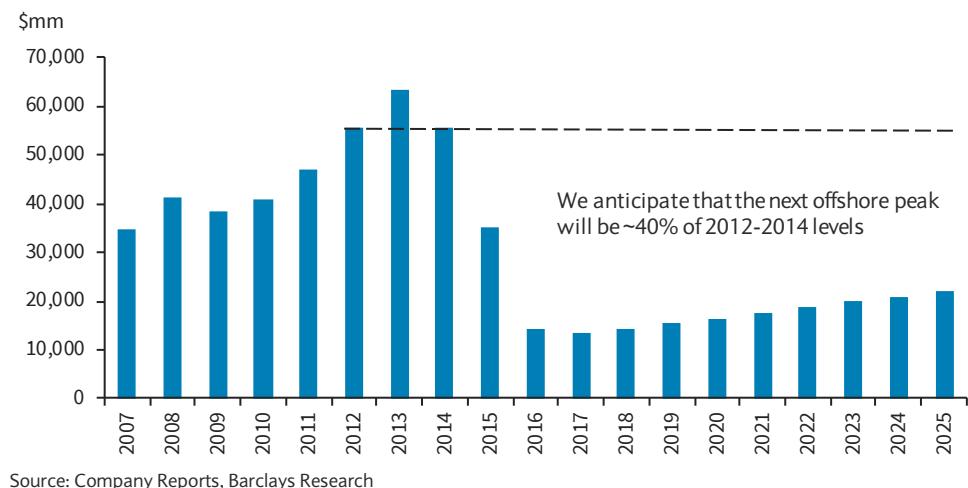
FIGURE 5
Value breakdown for producers and suppliers



Source: Rystad, Barclays Research

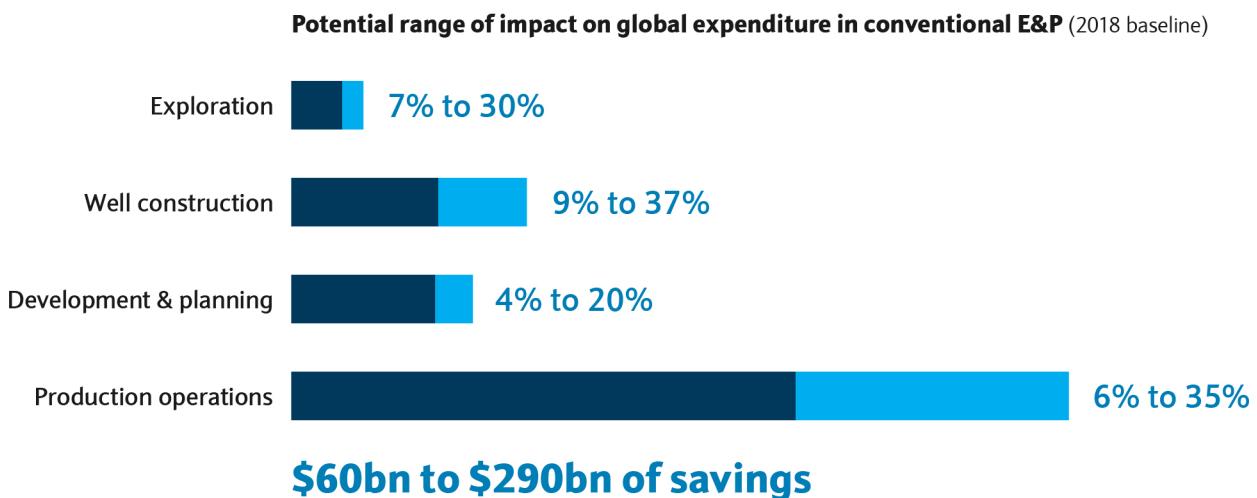
Another component of value creation will be exploration spend, particularly for the offshore companies. An analysis of the companies shows that historically they've written down almost two-thirds of the costs incurred. While we are at a trough level of exploration and should see an increase over the next 5 years, the next offshore peak in 2025 is going to be substantially less than the prior peak. In order to come up with an estimate for offshore exploration, we took aggregate exploration spend from ~40 of the largest O&G companies worldwide (in terms of offshore spend). Assuming that rig rates today make up ~50% of total offshore exploration spend, we adjusted 2012-2014 average exploration spend to today's rig rates (~55%). We then assumed that the next peak will be ~70% of this adjusted prior peak spend, and found the potential savings from the use of Digital is ~30%. For onshore exploration spend, we assumed that there could be ~20% savings from the use of Digital.

FIGURE 6
Offshore exploration cash costs incurred, ~40 largest companies that report ASC232



Taken as a whole, our conclusions help to narrow down the wide range of outcomes that Schlumberger has presented when talking about the impact of Digital.

FIGURE 7
SLB Digital Market Opportunity



What Digital means for OFS earnings estimates

Digital impacts a number of different players; below we lay out how we see it broadly impacting the different groups. The most direct impact will be for the service companies creating new products with recurring revenue streams; the producers, which will see benefits from higher production at lower costs; and the cloud providers, where increased transition from on-prem to public cloud will drive growth.

FIGURE 8
Digital Opportunity Breakdown

	Impact
Oilfield Services	
SLB	We estimate that by 2025 digital can represent ~16% of total company EBIT
HAL	We estimate that by 2025 digital can represent ~22% of total company EBIT
BKR	Opportunity a little more opaque with 10-15% stake in C3.ai
APY	We estimate that by 2025 digital can represent ~22% of total company EBIT; highest exposure in the shorter term
Other	NOV, HP, PTEN all have digital arms they are beginning to build out
Producers	
E&Ps	Additional FCF of ~\$3/bbl from decreased costs and increased EUR
Majors	Similar to E&Ps, but will also benefit from the use of digital in refinery and processing
Big Tech	Increased use of cloud computing or processing and microservices
Industrials	Most of the benefit from increased automation, some are entering more upstream (Paradigm, Sensia)

Source: Barclays Research

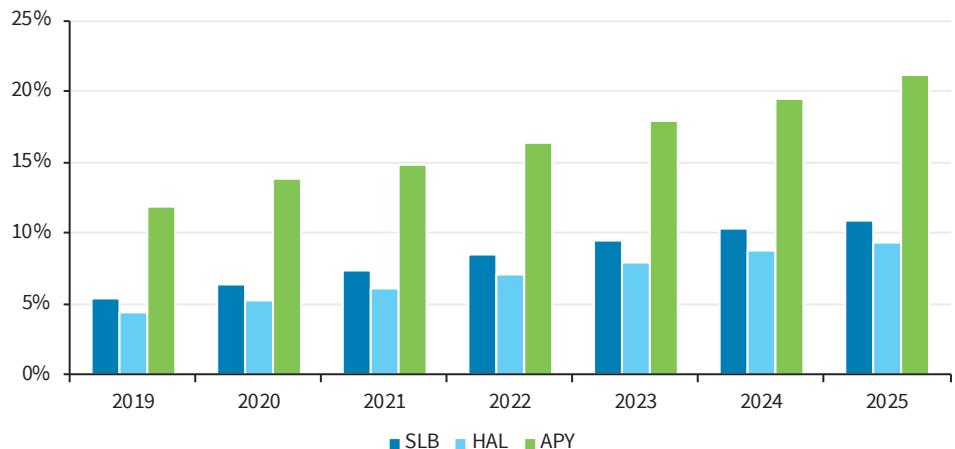
Oilfield Services Exposure

The opportunity for OFS companies to benefit from Digital comes in a few different forms: First, and most obvious, the direct profitability that can come from more asset-light, higher-margin business. Second are the opportunities internally on the cost side. Digital can be applied to inventory or supply chain management to help improve business functions; or it can be used on integrated performance-based projects to help optimize results. Lastly, it could lead to potential margin expansion as the largely recurring revenue stream becomes a bigger part of company financials.

To us, this is not by any means a winner-takes-all type of market. There can be multiple winners, and even multiple companies working with the same producers thanks to open-architecture environments. What is vital is demonstrating to E&Ps the value that the offering can deliver, continuing to invest to make technologies better (and prevent commoditization), and working as an industry to enable the use of technology across companies (for example, Open Subsurface Data Universe, Open Earth Community).

Unfortunately, disclosures are limited on the business impact that Digital currently has for the Big 3. Early indications to us are that **SLB** and **BKR** are well positioned, but **HAL** has also been investing resources in digital technologies for years. While **HAL** focuses on upstream and **BKR** focuses more on midstream/downstream, **SLB** has solutions that address both. The impact on Schlumberger and Halliburton's financials is more obvious, while Baker Hughes' benefit from its joint venture is a little bit more complicated and could take more time to come to fruition. **APY** will benefit and this is easily quantifiable as the company discloses sales from its digital segment. Other companies that have less exposure include **NOV**, **HP**, and **PTEN**.

FIGURE 9
OFS % of revenue from digital (Barclays estimates)



Source: Company Reports, Barclays Research

- **Schlumberger:** We estimate that current digital revenue for SLB that falls into its Reservoir Characterization segment was ~\$1.55bn in 2018 and will be ~1.8bn in 2019 (roughly 5% of total company revenue). Unfortunately, there is limited disclosure but what we do know is that more than half of R&D (~\$700mm companywide in 2018) was spent on digital, it is margin-accretive for the company and has been for 10+ years, and it could double over the next several years (we see even more upside to that). Software is now being sold via a SaaS model, which should come with improved margins and recurring revenue. As the sales mix shifts to more software (recurring sales of software being used) from what we suspect could be a little bit more service-heavy in the near term (installation, transition to cloud from on-prem) profitability should improve and help drive Reservoir Characterization margins higher. Assuming double-digit growth peaking at ~20% and margin expansion from ~25% to ~30% over the next 5 years, digital can represent nearly 11%/16% of total company Revenue/EBITDA in 2025. We used a comp set of Enterprise SaaS companies for a multiple for Digital and historical Schlumberger multiples for the rest of the company.

We found that on a Price/Sales basis there is meaningful upside to SLB's current share price and some longer-term upside vs. our 12-month price target. Looking at EPS impact, we think that EPS from Digital can approach ~\$0.75 in 2025.

FIGURE 10
SLB illustrative SOTP analysis

2025 (EV/Sales)								
	Revenue	Multiple	EBIT	D&A	EBITDA	Implied	EV	
Other	37,400	2.5x	6,539	(3,051)	9,590	9.7x	93,499	Net Debt
Digital	4,529	6.0x	1,291	(249)	1,540	17.6x	27,171	Market Cap
Total	41,928	2.88x	7,830	(3,300)	11,130	10.8x	120,671	Shares Outst.
								1,396
								Share Price
								53.00

Source: Company Reports, Barclays Research

- **Halliburton:** For Halliburton, replicating the above exercise is even more difficult, given that we don't have a starting point of R&D costs or Landmark margins relative to company margins. Landmark Solutions falls into Halliburton's D&E segment. Given that companywide D&E EBIT margins are currently ~9% vs. SLB Reservoir Characterization margins of ~21%, it is likely that HAL's digital segment accounts for a smaller portion of HAL's D&E segment (which is larger than SLB's Reservoir Characterization). We

replicated the exercise we used for SLB and assumed that currently Landmark Revenue is 55% of SLB's SIS, which is a slight haircut to Spears & Associate's proportional estimate. We also used the same growth rates / EBIT margins that we used for SLB.

What we found is that there is meaningful upside to HAL's current share price. Looking at EPS impact, we think that EPS from Digital can approach ~\$0.45 in 2025.

FIGURE 11
HAL illustrative SOTP analysis

2025 (EV/Sales)									
	Revenue	Multiple	EBIT	D&A	EBITDA	Implied	EV	Net Debt	8,888
Other	24,318	1.6x	2,507	(1,483)	3,990	9.8x	38,909	Market Cap	44,965
Digital	2,491	6.0x	710	(137)	847	17.6x	14,944	Shares Outst.	876
Total	26,809	2.01x	3,217	(1,620)	4,837	11.1x	53,853	Share Price	37.00

Source: Company Reports, Barclays Research

- **Baker Hughes:** Of the Big 3, it is hardest to project an impact over the coming years for BKR. BKR does have a large Digital Solutions segment; however, Digital Solutions isn't really the correct word. The majority of the revenue (more than 90%) in Digital Solutions is from Measurements and Controls (hardware). Predix software was included, and there is still a software component to the business unit, but BKR began its transition away from Predix in late 2018 and the contribution has begun to roll off.

We consider Measurement & Control to be more of an enabler of digital than an actual digital solution. As a reminder, BKR took a board seat and a minority stake in C3.ai, which was valued at more than \$2bn in May 2019, according to PitchBook.¹ The real long-term potential for Baker Hughes in digital stems from this JV and its investment. In general, most of the revenue from BHC3 will remain within C3. As part of its minority interest, Baker will see revenue streams in the form of commissions and services work associated with software sold from C3 as well as hardware and equipment pull through for products. The four primary benefits are:

1. **Sales model with C3.** Baker will get commissions and services work associated with software that is sold by C3, which will flow through its Digital Solutions segment. The commissions and services could be 10-20% of the value of the software contract.
 2. **Hardware and equipment sales pull through.** There should be some pull through sales of hardware and equipment. Early on, the biggest opportunity is on sensors and lift products, and as the model evolves there should be an opportunity on compressors and RSS, among other equipment types as well.
 3. **Internal productivity.** Baker Hughes will also pay a licensing fee to C3 to apply its AI suite across the Baker Hughes organization to improve reliability and efficiency. The licensing fee is materially less than the \$60-70mm that they were spending annually on digital capabilities.
 4. **Value of investment in C3.ai.** BKR's minority stake should increase in value as C3.ai does. This is the most uncertain of the benefits, but has a lot of potential depending on what happens to C3.ai in the future (IPO, acquisition). The size of BKR's stake is undisclosed but we note that in the industry one board seat has historically equated to around a 10-15% stake.
- **Apergy:** A potential dark horse as regards benefit from the increased use of Digital. Apergy actually breaks out top-line sales from Digital Products, which falls into its

¹ <https://www.cnbc.com/2019/05/14/c3-2019-disruptor-50.html>

Production & Automation Technologies segment. We estimate that in 2019 Digital Products will represent ~12% of total company revenue; the highest proportion of any OFS company (not including BKR's Measurement & Control) right now. We also know that right now it is accretive to PAT margins (PAT EBITDA margins ~21.5%). Further adoption of Digital on APY's full suite of artificial lift products, plus the conversion of what are currently Asset Integrity proof of contracts into actual recurring contracts, could create a recurring high-margin revenue stream.

On a SOTP basis there is some long-term upside, but less than for SLB/HAL. Looking at EPS impact, we estimate that EPS from Digital can approach \$0.75 by 2025.

FIGURE 12
APY illustrative SOTP Analysis

2025 (EV/Sales)									
	Revenue	Multiple	EBIT	D&A	EBITDA	Implied	EV	Net Debt	548
Other	1,127	2.5x	164	(104)	268	10.5x	2,817	Market Cap	4,074
Digital	301	6.0x	78	(18)	96	18.8x	1,804	Shares Outst.	78
Total	1,428	3.24x	242	(122)	364	12.7x	4,622	Share Price	38.00

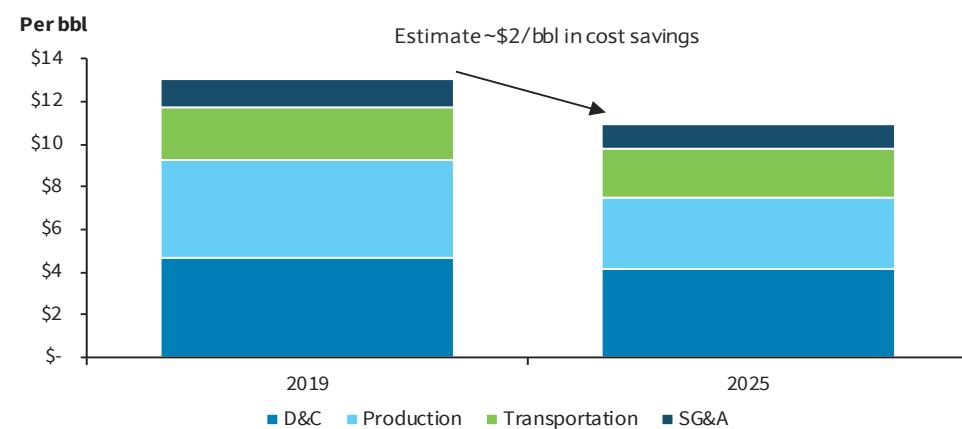
Source: Company Reports, Barclays Research

Note: These are APY standalone numbers; does not include impact of announced combination with Ecolab's Upstream Energy Business

How Digital impacts costs and performance at each phase

Below, we set out how we are justifying our assumptions. So far we have seen numerous examples of proof of concept, and what follows is an extrapolation assuming increased adoption and scaling of digital solutions at organizational levels. In many cases, we think there is further upside above what we are proposing. Cumulatively, the impact is material.

FIGURE 13
Well Cost Change from 2019 to 2025



Source: Rystad, Barclays Research

Phase 1: Geological & Geophysical

Understanding the subsurface and identifying a potential hydrocarbon reservoir is the first step in the lifecycle of the well. Then producers must use that data to help map and plan the optimal well and completion design. A significant amount (some estimate more than 80%) of the value of the well is determined by making the correct choice about where and how to drill. Digital applications can help producers optimize the processes of locating and planning

wells. Digital can also speed up the process with some of the major geophysical surveys historically taking months to process. New approaches to interpretation can reduce cycle-times, with machine learning already being credited with higher resolution outcomes, with fewer outliers in times that can be hundreds of times faster.

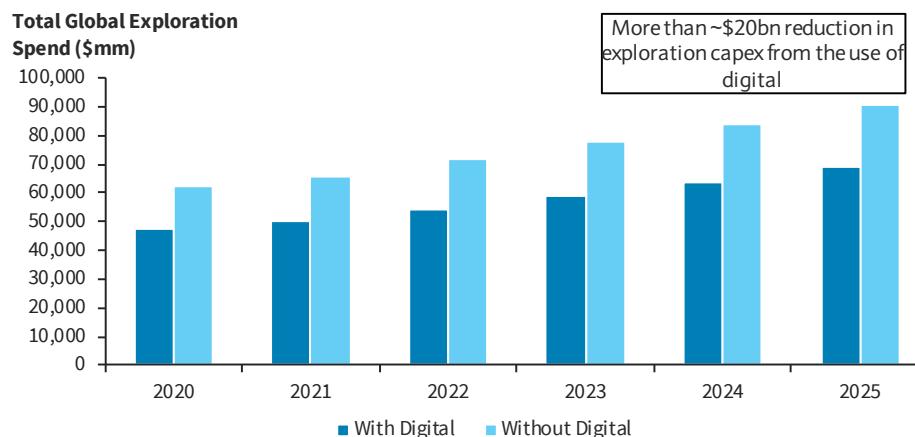
Potential cost savings: Better and faster planning of the well, fewer dry holes drilled, reduction in development drilling.

Improved performance targets: Faster interpretation of the reservoir, increase rate of success in finding oil and gas, finding additional reserves, fewer “dry holes”.

How it impacts ESG metrics: Fewer subsurface disturbances, such as exploration wells offshore, if oil can be found more effectively. The multi-client model for seismic data is a pure digital data sharing business, advance recently by cloud storage, which reduces dramatically the amount of offshore activity needed to investigate the sub-surface.

Examples of success: We've seen a big reduction in SG&A from E&Ps as they reduce headcount. Digital will help bridge the gap with faster well planning (i.e. fewer engineers needed). OAG Analytics told us that a customer was able to go from drilling 50-100 test wells to 5-10 because of the increase in accuracy. Total has said that AI changes the workload for engineers, and it has allowed engineers to transition from splitting time spent on high value tasks and time spent on routine tasks from 50%/50% to 80%/20%.² Petrobras actually has the long term ambition targeting a 100% discovery chance factor, which would mean no exploratory wells are necessary.³

FIGURE 14
Savings from improved exploration efficiency



Source: Rystad, Barclays Research

Phase 2: Drilling

Drilling makes up ~10% of the cost of an onshore well for US land. Companies have cited the goal of reducing drilling costs by 10-15% from the use of Digital at the rigsite, with additional opportunity as drilling operations are optimized. Automation can be done on the surface and downhole. Geosteering and other technologies help to place the bit in the optimal location, which reduces the “ellipse of uncertainty,” keeping the well closely aligned to the drilling plan.

Potential Cost Savings: Decreases number of drilling days, decreases number of workers on the rig.

² Total Strategy & Outlook Leveraging new technologies presentation September 25, 2018

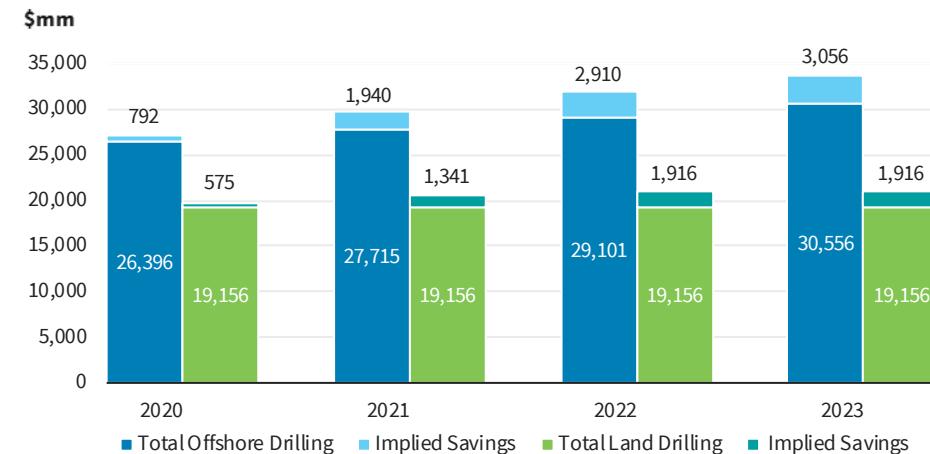
³ Petrobras Day London December 6, 2019

Improved Performance Targets: Reduces error in drilling results, especially important in pad drilling (parent/child and frac hits). Hazard avoidance.

How it impacts ESG metrics: Fewer personnel on the wellsite increases safety.

Examples of success: Equinor has the publicly stated goal of reducing drilling costs by 15% from the use of the NOVOS operating system. It has reported a 10% reduction in costs. NOVOS along with real-time data from NOV's wired drill pipe was used in land drilling to reduce the time it took to drill a particular section by 25%.⁴

FIGURE 15
Savings from Digital use on land and offshore drilling



Source: Spears, Barclays Research

Phase 3: Completions

Completing a well is the process of extracting hydrocarbons from the rock. With shale, there is still a lot of trial and error. The transition to pad drilling over recent years has introduced the importance of monitoring frac interference between wells. New technologies give the ability to understand fractures in real time, providing the opportunity to test new completion methods and optimize designs.

Potential cost savings: Eliminates unnecessary stages, reduction of materials (chemicals, sand), avoidance of frac hits.

Improved performance targets: Increases initial production rates, helps to reduce well interference.

How it impacts ESG metrics: reduction of chemicals, less time spent pumping lowers emissions.

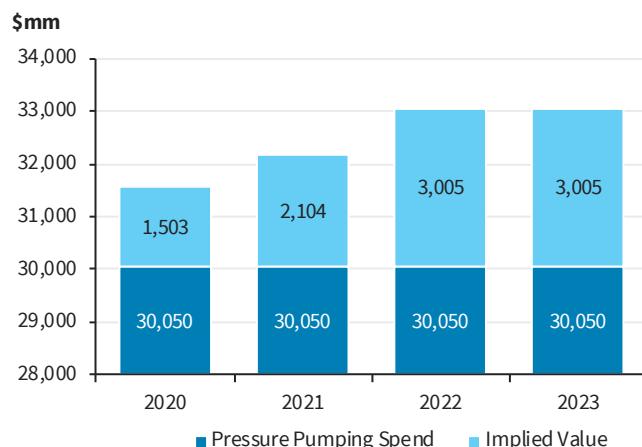
Examples of success: EOG made real-time adjustments and was able to reduce pump times by 10% from the use of real-time data from pressure pumping operations.⁵ OXY uses on average 28% less proppant compared to the other top operators without sacrificing quality of results.⁶

⁴ NOV SPE/IADC White Paper, "Performance Impact of Downhole Data from Wired Drill Pipe and Downhole Sensors"

⁵ EOG Resources Earnings Conference Call August 2, 2019

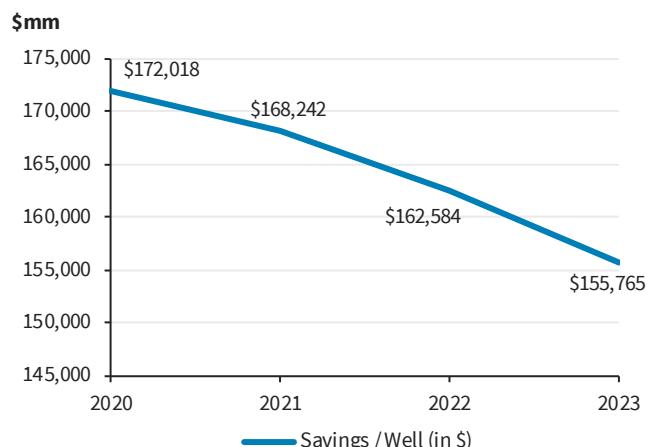
⁶ Occidental Petroleum Earnings Conference Call August 12, 2019

FIGURE 16
Savings from reduction in pump time (real time data)



Source: Spears, Barclays Research

FIGURE 17
Savings from use of less proppant (optimization of design)



Source: Rystad, Barclays Research

Phase 4: Production

Of all of the different phases of the well lifecycle, production has seen the furthest uptake already. This phase has provided proof of concept that Digital presents an opportunity to mitigate the impact of base declines. This is particularly important in North America, where E&Ps are hesitant to spend, but want to increase production.

Potential cost savings: Decreases opex through reduced chemical use and less workover costs, and increases uptime of facilities. Remote monitoring reduces opex, and enables smaller facilities offshore which can lead to lower capex spent on facilities.

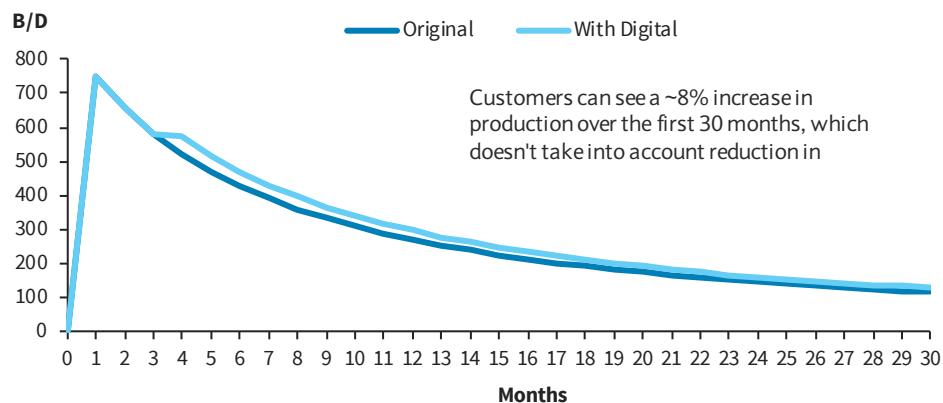
Improved performance targets: Production uplift from optimization and higher uptime.

How it impacts ESG metrics: Allows leaks to be identified quickly, reduces footprints of operations, remote operations require fewer personnel.

Examples of success: Ambyint reports that a customer in the Bakken realized a 6% production uplift, 48% decrease in workover costs, and 10% decrease in electricity costs with a full payback one month after implementation. Apergy cites the potential for a 10-15% increase in production and 25% reduction in operating expense. Remote operations allowed Equinor to build a smaller offshore production platform, resulting in 30% less capex and 50% less opex.⁷

⁷ Equinor Earnings Conference Call February 6, 2019

FIGURE 18
One well benefit from artificial lift optimization, first 30 months producing



Source: Barclays Research

Note: Assumes 10% benefit during Gas Lift, ESP, and Rod Lift.

Phase 5: Midstream/Downstream/LNG

Harder to quantify, but another opportunity.

There is additional opportunity in Midstream, Downstream, and LNG; however, it is more difficult to value. For Midstream, throughput on pipelines can be optimized and leaks failures can be remotely monitored and detected. Refineries are immensely complex systems that are affected by a lot of different factors. Digital can be used to monitor and optimize not just individual parts, but also the system as a whole, for example through the creation of “digital twins”. Scaling it across assets provides a big challenge, but also a big opportunity.

Total’s stated goal is an impact of ~\$500mm/year on Midstream/Downstream from revenue, availability, and costs coming out (vs. ~\$1bn per year impact on Upstream). Shell cited an increase in production of 1-2% from the use of Digital on an LNG asset.⁸ Based on limited spending data, this is a little bit harder for us to put a number around, but there is an opportunity here as well.

Potential cost savings: Increased upfront costs (more maintenance spending), but lower full cycle costs (extended life of equipment), remote monitoring and inspection.

Improved performance targets: Decreases non-productive time (NPT) through improved equipment uptime and preventive maintenance, higher utilization rates at refining and LNG facilities, increased pipeline throughput through optimization of compression, improved identification of leaks.

How it impacts ESG metrics: Identification of leaks, increased efficiency.

Examples of success: DCP Midstream optimization efforts drove capacity from 365,000 to 400,000 bpd resulting in “tens of millions of potential margin opportunity.”⁹

⁸ Royal Dutch Shell P&T Open House Presentation November 26, 2019

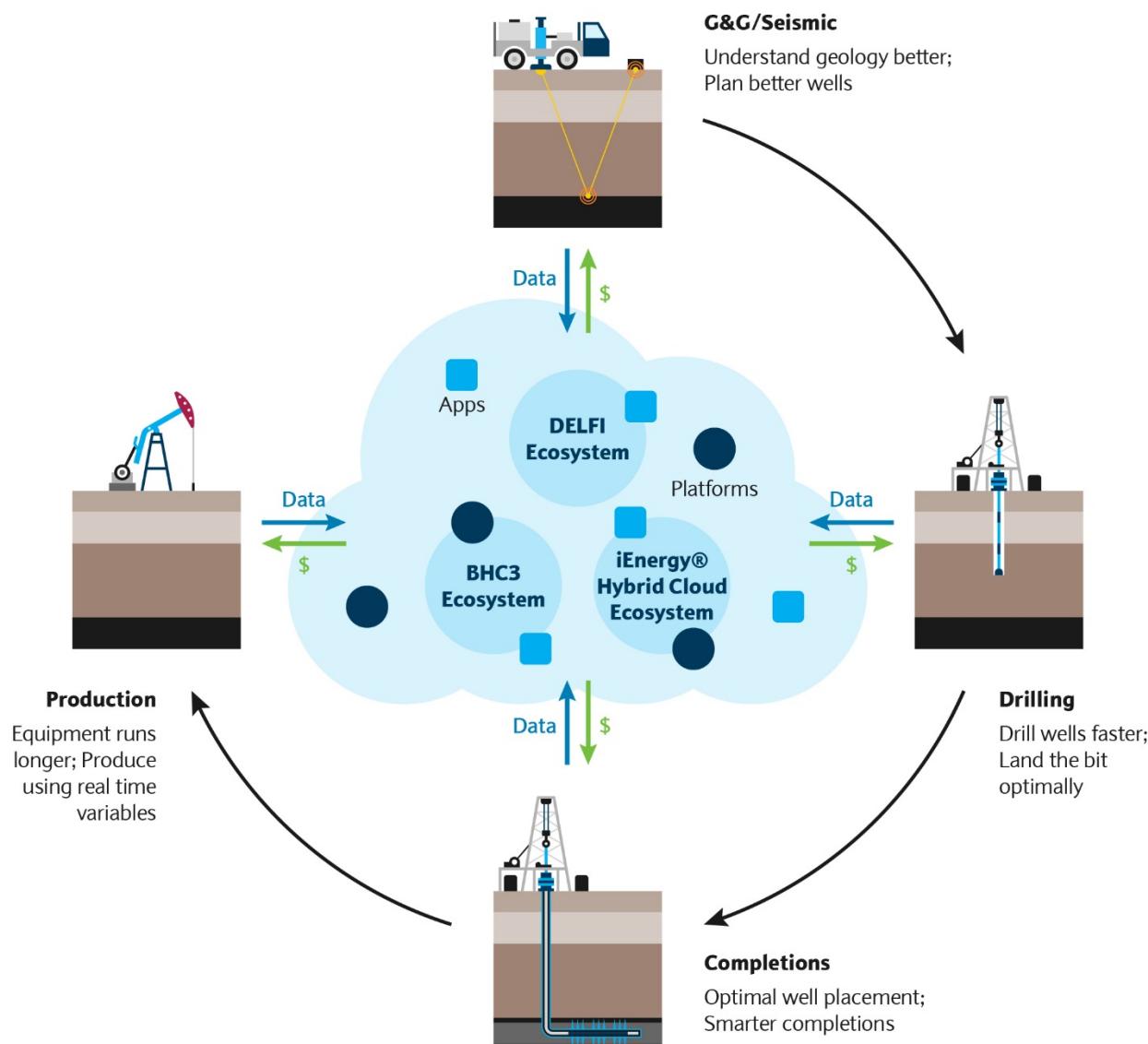
⁹ DCP Midstream LP Earnings Conference Call May 8, 2018

PART III

Defining the Oil & Gas Digital Landscape

The Oil & Gas Digital landscape has only recently come into view. Before now, it was more conceptual, centered on the use of big data and algorithms to improve operations, but largely dismissed by oil and gas investors as having few practical applications and limited success. In many respects, the concept was ahead of its time, but that is changing quickly. The digital landscape has now taken shape as roles have been defined, technology is enabling more applications, and clear proofs of concept have emerged across the hydrocarbon lifecycle.

FIGURE 19
Digital Landscape



Defining Digital

Before describing the Oil & Gas Digital landscape, we first need to establish our definition of what we mean by Digital. The term “digital” is extremely broad and can interpreted to describe a wide range of applications. In fact, it can be difficult to determine where exactly Digital begins and ends. Our definition of Oil & Gas Digital is the use of technologies, data analytics, artificial intelligence, and machine learning across the lifecycle of the well, which includes finding hydrocarbons (geological & geophysical), drilling and completing new wells, production from existing wells, and delivering hydrocarbons to consumers (LNG, pipelines, refining). This definition does not include back office applications, supply chain management or tracking devices. While these applications have been shown to improve operations and reduce costs, we view these as ancillary benefits to producers, as they do not directly impact the physical hydrocarbons.

Three Primary Components of the O&G Digital Landscape

The digital oil and gas landscape is a vast, complicated network of interconnected technologies designed to wring out efficiencies across the well lifecycle. Digital comes in many forms, some of which address a specific task, while others create a comprehensive environment designed to improve workflow on an enterprise-level scale. On a basic level, we believe the digital oil and gas landscape can be simplified into three primary components: the cloud; ecosystems and suites; and applications, platforms, and other technologies.

The Cloud. As low-cost sensors generate increasingly massive amounts of data across all parts of the well lifecycle, that data needs to be stored in an accessible, centralized location. For instance, as a well is being drilled, data is generated about the rate of bit penetration, vibration and torque, along with geologic data such as conductivity and porosity, all of which is captured at hundredths-of-a-second intervals.

To be able to use this data for machine learning, storage is critical, forming the backbone of digital applications. Until recently, much of this data was held on internal servers, but it is now migrating to cloud storage from providers such as Microsoft, Google and Amazon Web Services.

Before the data can be stored, it needs to be “cleaned” and configured into a uniform data set, which is particularly important when pulling in and comparing against older data sets and data from different sources. While producers have become increasingly comfortable with storing data on the cloud, a public/private hybrid cloud may be a solution for some.

It’s not surprising, therefore, that completions has turned out to be somewhat of a digital laggard considering the success of Digital is entirely dependent on the quality and breadth of the data. On the other hand, much of the data from drilling and working assets (turbines, compression, etc.) is collected and owned by the service companies, forming a rich data set on which to build artificial intelligence and machine learning capabilities.

The Ecosystems. Digital Ecosystems (also referred to as “Suites” or “Environments”) sit on top of the cloud, located within the network of the customer on which the various Digital Applications and Platforms are integrated. Ecosystems are centralized places where platforms and applications can be interconnected.

Different types of data can be ingested and integrated from any provider. Essentially, it is a collaborative technology environment to connect workflows, data, platforms and applications. New structures have been designed to provide customer flexibility to utilize different types of platforms and applications, whether it is built by the ecosystem provider, internally by the customer, or by a third party.

Schlumberger (DELF) and Halliburton (iEnergy® Hybrid Cloud) previously operated a type of closed digital ecosystem for 10+ years, while Baker Hughes had been trying to develop its own (Predix) but decided to instead form a joint venture with C3.ai because they would have otherwise “missed the market” (their words, not ours).

The next generation of ecosystems is being sold through software as a service (SaaS) subscription-based models, are cloud-agnostic, and designed to be open-architecture, allowing for the incorporation of third-party technologies.

Platforms, applications, and other technologies. The most substantial innovation in the Digital Oil & Gas landscape is being generated among the multitudes of platforms, applications, and technologies being developed for specific or sometimes multiple functions across the lifecycle of the well. Whether in G&G/seismic, drilling, completions, production, or midstream/downstream/LNG, companies have been able to develop software and technology to address specific problems, and many of the companies have AI/ML capabilities in their DNA.

While diversified service companies have invested to develop numerous platforms, applications and technologies internally, some of the most impactful innovations are being developed by third parties, many of which have ties to the oil and gas industry, being spearheaded by former employees of service companies. Focuses include optimization of well spacing and completion planning, drilling software to increase ROP, completion hardware and software to optimize fracking operations, and AI and machine learning applied to artificial lift equipment to increase production. In most cases platforms, applications, and data points from new technologies can be integrated with ecosystems.

Framework of an AI/ML Platform or Ecosystem

Barriers to full internal development:

- Complexity of building
- Brittleness
- Future Proof

The concept of using big data to create an algorithm to perform a specific task or function is not new. Over the last several years, a number of producers have touted their ability to harness the power of data to reduce costs, increase production, and improve operations. In fact, more than a dozen E&P companies at the Barclays Energy Conference in 2017 mentioned big data and data algorithms in their presentations.

However, at the Conference this past September, it was mentioned by only a handful of E&Ps. Why? Because it's one thing to apply algorithms to a specific task; it's an entirely different challenge when applied across a field, a region, or even an organization. As we discuss in Part V, we can point to numerous examples of digital success in all phases of the lifecycle of the well, but scaling this up to an enterprise level is a sophisticated, dynamic process that is well beyond the capabilities of most producers.

Though some inroads can be made by hiring a team of data scientists, true digital success can only come from utilizing a digital platform or an ecosystem, which is comprised of two critical elements:

Data Management: big data is about to get a lot bigger. Despite the talk of big data, the oil and gas industry hasn't seen anything yet. The proliferation of low-cost sensors, decreased cost of computing power, the rapidly increasing speed of data transmission, and the desire to measure practically every function across the lifecycle of the well will create an exponentially larger data stream, while natural language processing (NLP) can help make use of old, unstructured data.

Utilizing a hyperscale cloud for data storage is a prerequisite, but it only solves part of the problem. The key is being able to aggregate, integrate, and process multiple sources of data into a unified system. Data comes in many forms, including enterprise information systems (ERP, CRM, SCADA), sensor IoT networks (real-time drilling data, production rates, vibration

rates), or from external sources (geology, terrain, satellite imagery). Normalizing all this data with a unified structure is the first step before feeding it into ML algorithms.

The Software Stack: model-based architecture must be open source & microservices-based to be “future proof.” Building a software stack to create an AI system has been a critical component in the evolution of software programming and system engineering.

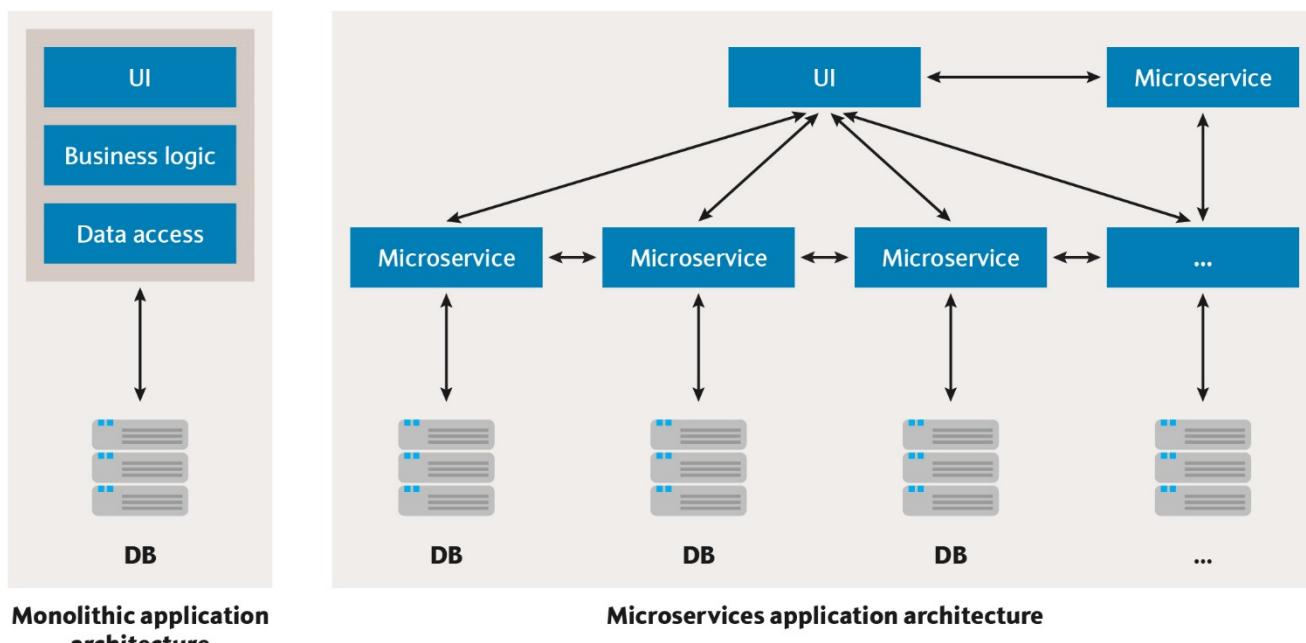
For more than 50 years, software has been designed using *structured programming* techniques that rely on sub-routines to perform certain repeatable processes such as macros for performing calculations, regressions, or other basic functions. Structured programming has since evolved into the technique of *modular programming*, which separates these functions into independent, interchangeable modules.

An AI suite or platform is also modular, with the output from these various applications being combined and applied to specific problems using advanced processing techniques. The *software stack* integrates the network of programs and applications, many of which are available from third parties for free via open-source networks, to create the backbone for the overall system, a complicated task that connects various functionalities and ties together discrete software packages.

Aside from the complexity of the system, arguably the biggest risk is obsolescence - the rapid pace of innovation requires continual upgrading of the software stack. Therefore, it's critical for the architecture of the software stack to be modular, ensuring the ability to be easily switch modules out when the capabilities of a new software application supersede the incumbent. Simply put, in order for a software stack to be “future proof,” it cannot be built internally, because the pace of innovation is too fast for any platform or suite to keep up.

An example of this software development change is how cloud-native applications are being engineered. The industry is moving away from structured/monolithic applications that cannot be easily changed. Instead, there is a move towards a microservices/container framework that combines proprietary and open-source components. In addition, different parts of the “stack” can be changed or swapped out for a new technology without disrupting the application as a whole. With the ability to swap in new or upgraded modules as the technology changes, applications are being built to be “future proof.”

FIGURE 20
Microservices Architecture



Source: Barclays Research

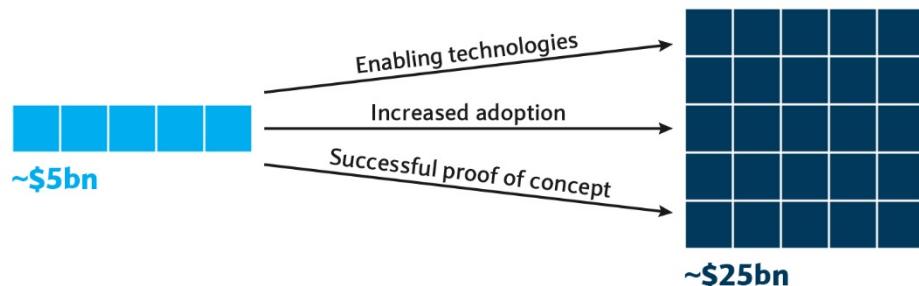
For additional information on enabling technologies, see the Appendix at the end of the report.

PART IV

Who will capture the growing digital revenue pie?

Over the next 5 years, we believe the addressable digital market for upstream oil and gas will increase to an annual level of greater than \$30bn; a six-fold increase from our current estimate of less than \$5bn.

FIGURE 21
Potential digital market expansion



Source: Barclays Research

Notably, this estimate is only for the upstream and does not include the Cloud. For the cloud, we think the market opportunity will increase to ~\$25-30bn from \$2-3bn today (detailed in Figure 22).

The following analysis on p.33-34 is provided by Dave Anderson and Raimo Lenschow. Raimo Lenschow¹⁰, who is Barclays' U.S. Software analyst, provides his views on the software industry's intersection with Digital in the Oil & Gas sector.

Cloud Providers

Oil and gas represents a massive opportunity for the **Cloud Providers**, given that it has been one of the slowest industries to adopt Digital. Microsoft, which has made announcements with Equinor, Exxon, Chevron, Halliburton, and Schlumberger, among others, told us that O&G is a top priority and that it will continue to increase investment in the space.

Based on our research, we believe that Amazon and Microsoft are the leaders right now in the oil and gas space, with MSFT having become more aggressive over the last 6-12 months. Google, on the other hand, seems to be less enterprise-focused right now.

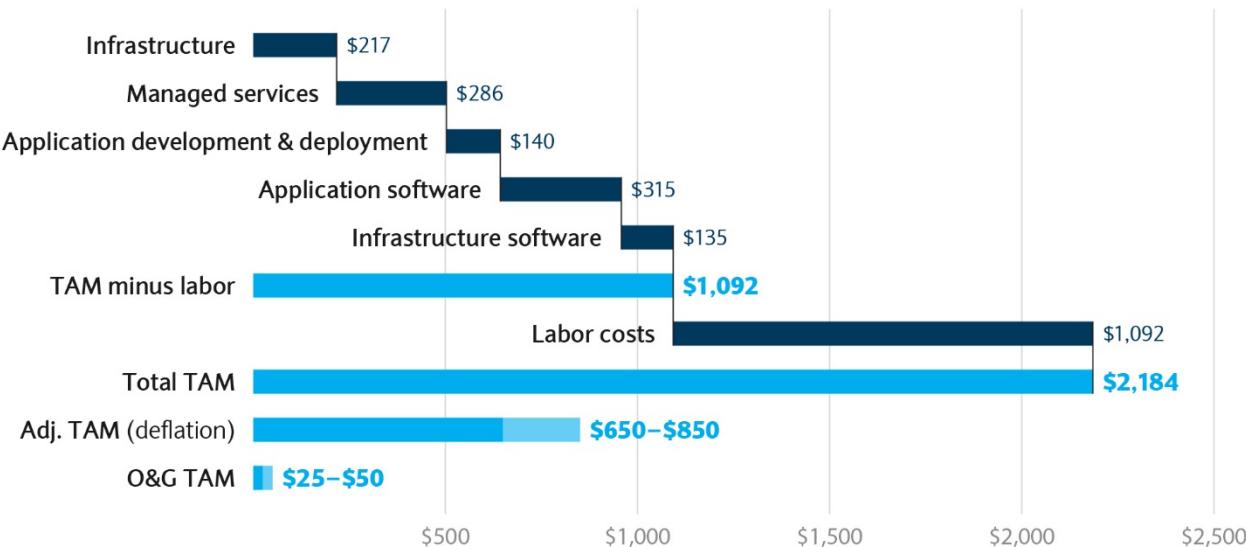
Up to this point, providing infrastructure and some analytical capabilities has been the focus for cloud providers. However, we believe they are keeping a close eye on trends and developments in the industry, which is still in the very early stages of digital adoption, posing a potential threat to OFS companies and Digital Innovators. Given larger balance sheets, more scale, and higher software capabilities, we do believe it is a space that cloud providers could enter, should they choose to, whether it be via organic investment or consolidation.

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Cloud providers are interested in this market because there is a wallet share shift in IT budgets away from traditional on-prem infrastructure/applications to the cloud. This provides a large addressable market for offerings such as Azure and AWS. In order to estimate this market, we (1) added up different parts of IT budgets that could be outsourced to the public cloud (server infrastructure, managed services, app development etc.), (2) assumed that labor costs make up 50% of total IT budgets in line with the software industry standard (this doubles the TAM), and (3) assumed a deflationary multiple of 0.3x – 0.4x, which is typical in the space.

Since public clouds gain economies of scale from resources and staff, enterprises will likely pay less for their current IT footprint. As we have seen with computing and storage costs declining, falling IT costs usually lead to increased usage. This leads to a \$650-\$850bn TAM for all industry verticals and \$25-\$30bn from the Oil & Gas industry specifically (O&G represents 3-8% of Global IT Spend).

FIGURE 22
O&G Industry Represents \$25-50bn TAM for Cloud Vendors (\$ in bn)



Source: IDC, Barclays research.

A Golden Opportunity for Oilfield Services

Four companies stand out:

- **SLB:** The incumbent
- **BKR:** Hard to quantify, but may have the highest long-term upside
- **HAL:** Early mover, significant amount of growth upside
- **APY:** Highest exposure in the near term

The large oilfield service companies are uniquely positioned in the emerging digital environment, and it couldn't come at a better time. After struggling through a 5-year downturn while the industry recalibrated to lower oil prices, Digital represents a promising secular growth opportunity that can leverage the relationships, technical capabilities, and established infrastructure of the Big 3 OFS companies.

Each of the Big 3 have been involved in Digital for almost two decades through legacy positions in seismic interpretation and reservoir analysis, providing the foundation for new digital platforms and ecosystems. As we noted above, digital applications will ultimately prove deflationary to traditional oilfield services segments, so there is an opportunity for the Big 3 OFS companies to replace this lost revenue through a growing share in digital applications; a revenue stream that is higher-margin, less cyclical, and accretive to valuation.

Viewed another way, the emergence of Digital across the oil and gas industry is a binary path for the Oilfield Services sector: the leaders in Digital will thrive with new growth opportunities, while the rest will be relegated to fighting over a shrinking OFS market.

The Big 3 have an early advantage as incumbents with an existing digital footprint. In contrast to most producers, programming software and implementing digital technology has been a part of the DNA of large diversified service companies, which have been developing digital applications for more than a decade.

In oil and gas, seismic data sets were the original Big Data, requiring leading-edge processing capabilities to model complex reservoir formations and locate hydrocarbon deposits. Schlumberger's WesternGeco and Halliburton's Landmark business lines were the leading software solutions for reservoir modelling and have provided the foundation for each company's broader digital offering.

These on-prem software suites have since been replaced with SaaS models that incorporate internally and externally developed cloud-based systems, creating ecosystems and applications that can span the entire lifecycle of the well. For many years, the diversified service companies were the first (and only) movers, allowing each to establish inroads and aggregate data for different producers, solidified by longstanding relationships with the major producers. However, the strength of this incumbent position is being challenged because producers have vastly improved their own digital capabilities in recent years, just as a multitude of competitive offerings have come online.

Competitive threats coming from two sources: start-ups and cloud providers. Although a handful of producers are building out digital capabilities internally, we view companies like EOG Resources as outliers; among the few that have consistently dedicated the necessary time and resources to the issue.

Large integrated producers (Shell, BP, ExxonMobil, etc.) also boast digital capabilities, but the focus has generally been limited to improving efficiencies of existing production (field management, optimization of equipment). Having been core customers of OFS companies for decades, there is an enormous opportunity to expand these relationships into digital offerings. Of course, incumbency and relationships only extend so far. As with any emerging business, there are many entrants going after this growing revenue pie.

The biggest competitive threat in the near term is from start-up software companies, which have been rapidly developing digital applications to address various parts of the well lifecycle, including direction drilling (geosteering software), completions (microseismic mapping), and production (artificial lift optimization). However, because these providers are generally offering discrete applications, we think the Big 3 have the advantage of scale, having already built out ecosystems and integrated platforms that can incorporate their own or third-party software applications with a SaaS model that provides the best structure for capturing future value.

Longer term, we think biggest threat may come from the cloud providers themselves. Microsoft, AWS and Google have aggressively competed for share in providing cloud storage to oil and gas companies, but have largely avoided software solutions across the life of the well. While the cloud providers don't directly compete with the large OFS companies right now, they do offer various types of "microservices" that provide the building blocks of automation, artificial intelligence and machine learning. Despite public denials, we think the risk is that the tech companies could directly compete with the large OFS companies in the future.

Woeful disclosure on digital activity hinders measurement. For all the promise of Digital, this is still a trend at its infancy. While we are convinced the digital transformation has moved beyond the "proof of concept" phase and customer adoption is accelerating, the business models continue to evolve and few companies are willing to provide much insight into the size and profitability of their digital businesses.

Because historical disclosures from the Big 3 are now essentially irrelevant (given the transformation of their businesses), our views on the respective digital offerings have been formed through conversations with the companies, examining customer relationships, and analogous data points. This is a highly competitive arena, so every customer accolade of an application or platform is inevitably bookended by criticism that it isn't robust enough or another technology is superior.

There's only one way to settle this: the Big 3 need to start disclosing more.

- Until then, we believe Schlumberger will be the digital leader over the next several years, having invested heavily in its digital ecosystem, leveraging its incumbent position with many of the largest global producers and building on its unmatched expertise in reservoir analysis.
- We view Halliburton as a step or two behind SLB. Competing in many of the same markets and applications across the life cycle of the well, it's far from an unsurmountable gap in light of HAL's digital infrastructure.
- Longer term, we believe Baker Hughes may have the greatest opportunity of all with its partnership with C3.ai, bringing AI/ML to the midstream and downstream market, while SLB and HAL are focused on upstream applications.

Below we've summarized important parts of each of the Big 3's digital offerings. There are more details in later parts of the note, including a breakdown across the lifecycle of the well in Part V and a full company write-up in the Appendix.

Schlumberger: Best positioned in the near term

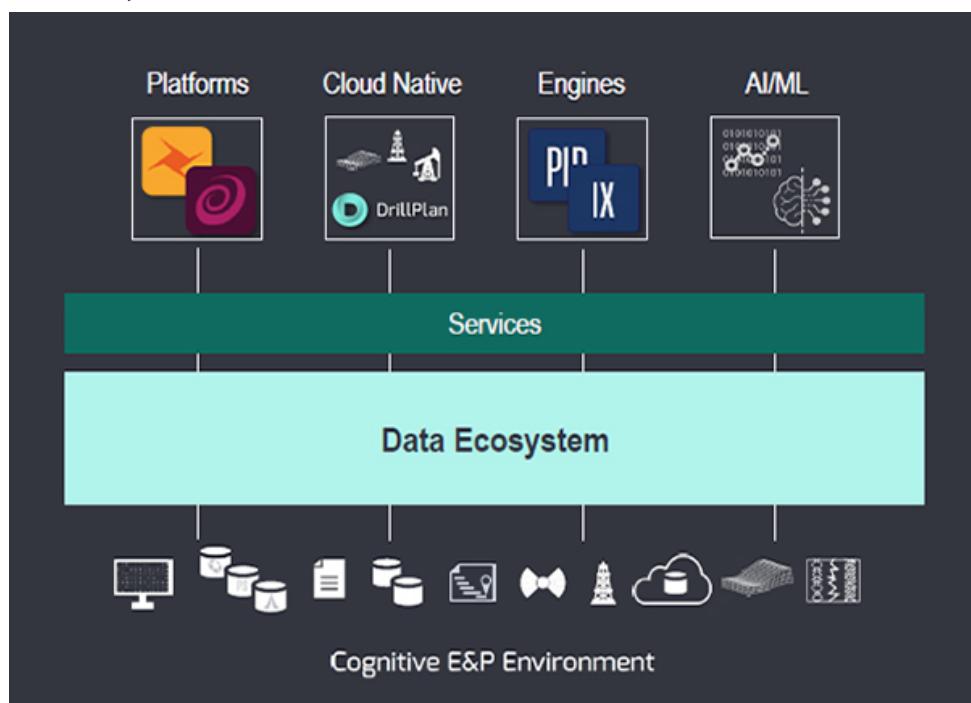
At the Barclays CEO Energy Conference in September 2019, Schlumberger's Olivier Le Peuch gave his first speech as the new CEO of the company, in which he declared Digital as the first key initiative for his tenure and ultimately, the future of oil and gas. Management has been dedicating considerable resources to Digital over the last several years (50% of R&D spend allocated to Digital; R&D was ~\$700mm in 2018), building out a team consisting of more than 1,000 software engineers/data scientists.

We believe SLB is the leader in Digital today with its DELFI operating system, a cloud-based E&P environment that has the ability to connect people, data, and applications across the lifecycle of the well and is the focal point of Schlumberger's offering. A product like DELFI can increase collaboration by connecting planning and operations through a holistic workflow that incorporates all relevant data and is accessible across geographies. DELFI has three "suites" (subsurface, drilling, and production), allowing data to be shared and integrated across different phases of the well to extract additional value.

DELFI customers have the ability to use SLB-built, internal, or third-party applications and/or platforms, allowing customers to choose the combination of applications from providers that is right for them. SLB has completed the process of moving some of its old platforms and applications such as Petrel onto DELFI, while also releasing new cloud-native applications as well (details in Part VI).

Management announced that it open-sourced and contributed DELFI data ecosystem to the Open Group OSDU forum in an effort to increase collaboration and adoption within the industry. This is advantageous for Schlumberger, because if oil companies go towards Digital and bring data into OSDU, all of the data will work with SLB's applications and services.

FIGURE 23
DELF1 Ecosystem Pictured



Source: Company Presentation

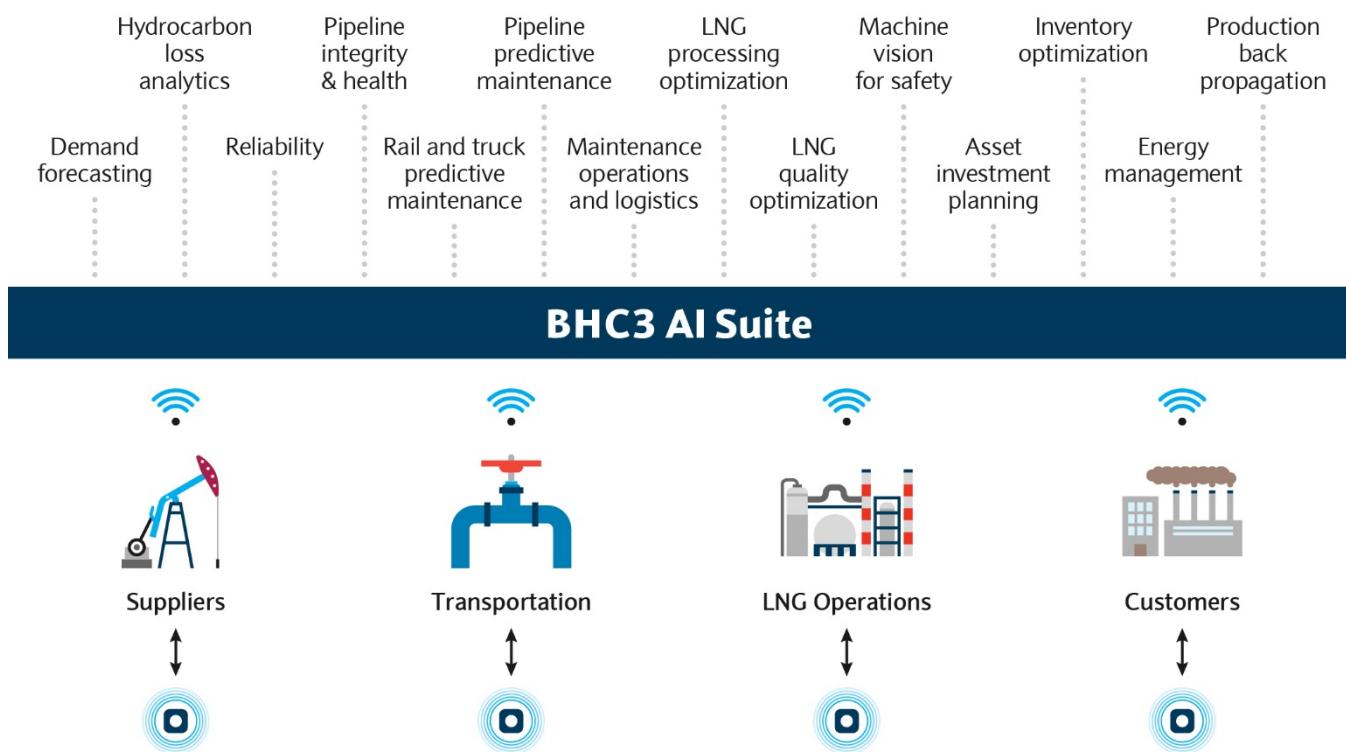
In late September at its SIS Forum, SLB made a flurry of announcements regarding its digital offerings, including a collaboration with Chevron and Microsoft to develop cloud-native solutions on DELFI ([SLB: Busy Week of Digital Announcements Signifies Progress on New Strategy, 11/21/19](#)). On 8/20/19, Woodside Energy announced it would undergo an enterprise-wide deployment of DELFI.

While DELFI primarily targets upstream production optimization, Sensia, which is SLB's joint venture with Rockwell Automation is more focused on asset management. Sensia will leverage automation and software capabilities to control and optimize equipment for production, midstream, and downstream. Other digital opportunities for SLB include edge computing opportunities (including the rig of the future), the reservoir product line portfolio (introduced ORA intelligent wireline in September), and WesternGeco (now more asset-light).

Baker Hughes: Potentially the biggest prize...but further down the road

This past June, Baker Hughes entered into a joint venture agreement with C3.ai, the world's leading provider of enterprise-scale artificial intelligence applications, taking a minority stake. Named BHC3, we believe this deal will have a profound effect on the digital landscape, marrying the domain expertise and relationships of Baker Hughes with the leading technologists and proven enterprise scale of C3.ai. Founded in 2009 by Tom Siebel, a Silicon Valley entrepreneur who pioneered customer relationship management (CRM) software systems, C3.ai has spent more than \$600mm to build an AI platform on an industrial scale. In this partnership, C3.ai are essentially the technologists, while Baker Hughes provides the domain expertise and relationships to expand the joint venture with teams of subject-matter experts to co-locate with clients.

FIGURE 24
BHC3 Midstream AI Suite



Source: Company Website, Barclays Research

C3.ai has had success with a number of large customers, including Enel (Italian multinational energy generation and distribution), ENGIE (French multinational electric utility), and 3M (Multinational Conglomerate) and recently won a contract with the U.S. Department of Defense that will provide predictive maintenance on over 4,000 aircraft. From an oil and gas perspective, the company's most significant contract is with Shell, signed in September 2018.

Although Shell has been an early adopter of Digital, it has struggled to scale up its internal digital platform. With a focus on optimizing its midstream and downstream operations, Shell believes digital applications can wring out efficiencies throughout the processes, targeting increased throughput and higher utilization rates through predictive maintenance. Over the next several years, BHC3 will be rolling out a series of applications targeting predictive maintenance, production optimization, and drilling risk and productivity on an enterprise level.

Pricing for the services is based on an annual SaaS subscription license for the software based on number of developers and a run-time fee based on the number of CPU hours each application is used. C3 will receive the majority of the revenue, but there are four benefits for BKR:

- Sales model with C3.** Baker will get commissions and services work associated with software that is sold by C3, which will flow through its Digital Solutions segment. According to Baker Hughes, the commissions and services could be 10-20% of the value of the software contract.
- Hardware and equipment sales pull through.** There should be some pull through sales of hardware and equipment. Early on, the biggest opportunity is in sensors and lift

products, and as the model evolves there should be an opportunity in compressors and RSS, among other equipment types, as well.

3. **Internal productivity.** Baker Hughes will also pay a licensing fee to C3 to apply its AI suite across the Baker Hughes organization, improving reliability and efficiency companywide. The licensing fee is materially less than the \$60-70mm that they were spending annually on digital capabilities.
4. **Value of investment in C3.ai.** BKR's minority stake should increase in value as C3.ai does. This is the most uncertain of the benefits, but has a lot of potential depending on what happens to C3.ai in the future (IPO, acquisition, etc.).

In its financial disclosures, Baker Hughes reports a segment called "Digital Solutions", though most (more than 90%) of the business is related to measurement and control hardware and a smaller portion is from its legacy position with GE's Predix. BKR began its transition away from Predix in late 2018 and while there is still a software component to the business unit, the contribution has begun to roll off. Although the digital revenue from the BKC3 partnership will be limited over the next several years, it may have the greatest longer term opportunity with few competitors in the midstream and downstream markets.

Halliburton: An early mover, but opportunity less clear with limited information

Halliburton groups Digital into three buckets, aligned with how they are addressing their customers' objectives. One is Reservoir, designed to improve understanding of the subsurface to reduce uncertainty, improve exploration success and recovery. The second is Drilling (including wells engineering and operations). And the third is reservoir-centered Completions and Production, aimed at lowering cost/bore while maximizing recovery.

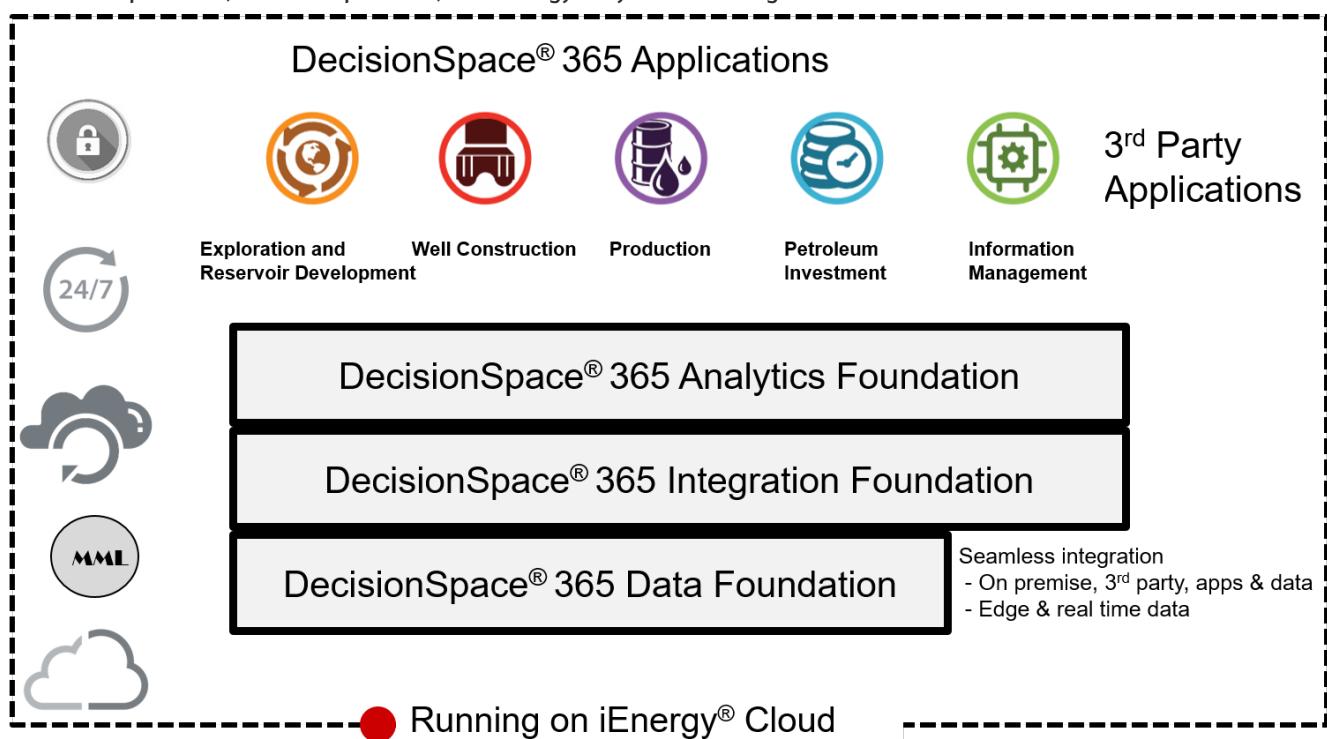
Halliburton's digital solutions are sold through its Landmark product service line. Landmark was purchased by HAL in 1996 for more than \$550mm and while it likely looks very different now, this is the source of the company's digital DNA. Halliburton pivoted to the cloud more than three years ago, and introduced iEnergy® Hybrid Cloud, a digital ecosystem designed to run on all available clouds, allowing customers to deploy, integrate, and manage various types of digital applications in the upstream oil and gas workflow.

Similar to Schlumberger's DELFI ecosystem, iEnergy® Hybrid Cloud allows customers to integrate platforms, applications, and workflows across the organization relying on Halliburton solutions, internally built solutions, or third party software. The software is open architecture (as opposed to open sourced) so that the software stack and non-software capabilities that create the foundation of the ecosystem are essentially plug and play. That means any part of it can be replaced seamlessly as software innovates, which provides important optionality to the customer.

Running on iEnergy® Hybrid Cloud, Halliburton's solutions include DecisionSpace 365, which is Halliburton's suite of digital E&P SaaS applications targeting Geosciences, Well Construction, and Production. At its Landmark Innovation Forum and Expo (LIFE) conference in August of 2019, the company introduced ten new intelligent cloud-native applications on DecisionSpace 365 including Scalable Earth Modeling, Full-Scale Asset Simulation, and Real-Time Control – Edge among others. Other important parts of HAL's software offering include Neftex Insights, a sub-surface model of the planet, and ARIES economic planning software.

FIGURE 25

Halliburton OpenEarth, DecisionSpace365, and iEnergy® Hybrid Cloud Figure



Source: Company Website

Halliburton's digital offering extends beyond just software and into the re-design of equipment for both subsurface and surface applications. Marrying together the interconnectivity of hardware, sensors, software, and system capabilities, engineers can work together to address specific challenges, improve efficiency and increase EURs.

According to the company, all digital technologies, software and services are assessed against the same investment criteria and customer requirements as other decisions. HAL has also developed several new hardware technologies that are paramount to its strategy of having a full scale asset solution. These include the iCruise (intelligent rotary steerable solution), edge technologies that run on the rig, Prodigy (automated frac), Intelligent Completions, and Summit (ESP monitoring). Additionally, Halliburton's digital offering not only creates value for its customers, but it can also create value internally by improving the reliability of equipment and increasing asset turns.

FIGURE 26

There has been a dramatic increase in the number of Digital announcements from the Big 3

OFS Company	Date (2019)	Other Company	Other Notes
SLB	Feb 18	Rockwell Automation	Joint venture to create Sensia
SLB	May 5	N/A	IriSphere: Continuous Resistivity Look-Ahead-While-Drilling Service
SLB	May 12	Google	Selects Google as a Preferred Cloud Provider
SLB	Aug 20	Woodside	Enterprise-wide deployment of DELFI for Woodside Energy
SLB	Aug 22	N/A	Contributes DELFI to Open Group Open Subsurface Data Universe Forum
SLB	Aug 26	N/A	TerraSphere: High-Definition Dual-Imaging-While-Drilling Service for Oil-Based Mud
SLB	Sep 13	IHS Markit	Strategic collaboration on the GAIA digital subsurface platform
SLB	Sep 16	Microsoft	Selects Microsoft as a Preferred Cloud Provider; Deploys Solutions in the DELFI Environment
SLB	Sep 17	Microsoft, Chevron	Three-party collaboration to accelerate digital transformation, development of cloud-native solutions
SLB	Sep 18	N/A	Ora: intelligent wireline formation testing platform, enabling real-time decisions in a cloud-native environment
SLB	Sep 26	TIBCO	Integration of TIBCO Spotfire and TIBCO Data Virtualization technologies into DELFI
HAL	Apr 29	N/A	Elect frac sleeve; hardware, firmware and software work in tandem to convert sleeve into a useable downhole solution
HAL	May 6	N/A	Scalable mobile technology for managed pressure drilling system
HAL	Jul 17	N/A	3D reservoir mapping LWD capability
HAL	Aug 27	N/A	Released 10 cloud-native applications on DecisionSpace 365
HAL	Sep 30	N/A	Automated directional gamma service MWD technology
HAL	Oct 1	PTTEP	Selected HAL Landmark for joint development of new well design workflow to automate D&C engineering processes across lifecycle
HAL	Oct 28	Repsol	Multi-year agreement to provide cloud-based master data management solution for E&P activities (SaaS model)
BKR	Jan 28	N/A	LUMEN: Ground & Drone-based advanced methane detection and reduction system
BKR	Jan 30	ENOC	Co-development of VitalyX, a real-time lubricant monitoring system with conversion into actionable insights
BKR	May 8	Topaz Energy	Long-term agreement to use VitalyX
BKR	Jun 5	N/A	Announces first inspection technologies customer solutions center in Silicon Valley
BKR	Jun 24	C3.ai	Joint venture to bring BKR's O&G expertise and C3.ai's AI software suite together
BKR	Sep 3	N/A	SureCONNECT: downhole intelligent wet-mate system that enables real-time productoin monitoring asnd control of completion system across the wellbore
BKR	Sep 10	N/A	Orbit 60 series: Announces the next-generation platform for condition monitoring
BKR	Sep 11	C3.ai	Release of first AI application: BHC3 Reliability
BKR	Nov 19	C3.ai, Microsoft	Announce alliance, move data management, storage, and compute onto Azure, development of enterprise-wide deployment of AI apps on BHC3 AI Suite

Source: Company Reports

The Digital Innovators: Proof of concept in hand, but scalability now the challenge

The universe of digital start-up companies in Oil & Gas has thrived over the last several years as programming expertise from Silicon Valley has made its way into an oil patch desperately in need of a technological rejuvenation.

These Digital Innovators are typically funded by private equity and venture capital funds, many of which are led by entrepreneurs that have developed digital solutions by marrying oil and gas with software-domain expertise to address unique problems across oil and gas operations. Although annual revenue is only in the tens of millions in many cases, we've identified dozens of companies with new technologies that have moved beyond the proof-of-concept stage.

The Digital Innovators can be broken down into three categories: software designers, hardware focused technology, and data aggregators. Software-focused innovators have created applications and platforms that tend to focus on addressing discrete functions such as well planning, geosteering, and artificial lift optimization. They typically follow the SaaS model and have been designed to run independently on cloud infrastructure or can be integrated into OFS ecosystems (which provides OFS companies a look at some of the competition and other solutions in the market).

The more hardware-focused innovators have coupled oil and gas domain expertise with leading edge technology and software to provide real-time insights to different parts of the well lifecycle, often concentrating on completions. A prime example is microseismic technology, which allows for a better understanding of hydraulic fracture patterns and has given the ability for real-time (or close to it) mapping of fractures in the subsurface. As pad drilling on unconventional reservoirs proliferates, such technologies can help reduce well interference and “frac hits” along with optimizing current and future completion schedules.

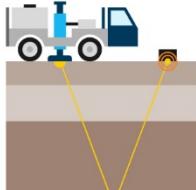
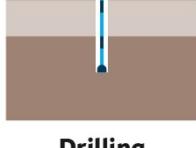
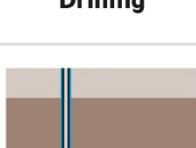
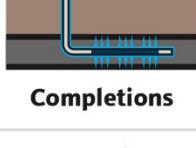
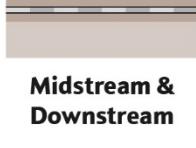
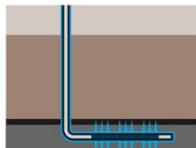
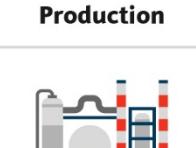
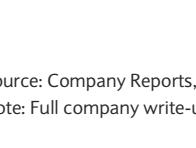
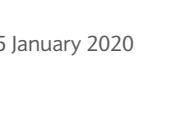
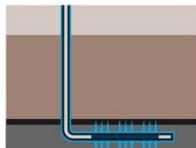
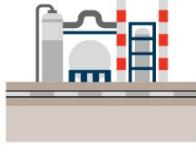
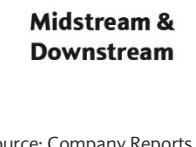
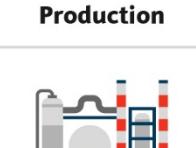
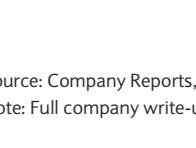
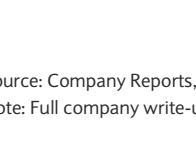
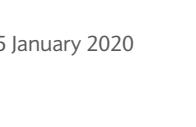
Lastly, a number of data-centric innovators such as Enverus, IHS Markit, and RS Energy have aggregated public and non-public data that can be provided to producers. Some of these companies have expanded their offering and capabilities through acquisitions as well as internal development, and we anticipate they could continue to be consolidators in the space.

Once the Digital Innovators start to achieve scale, consolidation is likely to follow. It's far too early to name the winners and losers among the Digital Innovators – this is a nascent industry that has come a long way in just a few years. Though we have seen many of these innovators reach proof of concept, the challenge going forward is figuring out how to scale up these technologies.

In contrast to the Big 3 OFS companies seeking to implement digital ecosystems on an enterprise level, the customer base for the Digital Innovators tends to concentrate on smaller E&Ps, often targeting a specific well or addressing an individual issue. As E&Ps start to adopt some of these digital applications organizationally, the next step is for these innovators to build out their companies (with programmers, engineers, equipment) and scale up.

As their presence builds over the next few years, we expect a wave of consolidation driven by three factions: 1) Larger OFS companies filling out and expanding ecosystems and platforms with new technologies, 2) Cloud providers looking to capture more of the oil and gas digital-revenue pie, and 3) Internal consolidation as Digital Innovators form partnerships with each other to create independent integrated platform solutions.

FIGURE 27
Digital Market Table

	Schlumberger	DELF1 E&P environment across the lifecycle of the well
	Halliburton	iEnergy® Hybrid Cloud that targets upstream functions
	Baker Hughes	BHC3.ai suite targeting more midstream/downstream functions
	Schlumberger	Petrel, GAIA, Eclipse and DrillPlan
	Halliburton	DecisionSpace365 apps, Neftex, EarthStar
	CGG	Primarily functions as data provider
	OAG Analytics	Provides AI for pre-production, helping customers design wells
	Novi Labs	Automating well planning through software and data accumulation
	Petro.ai	Housing and analyzing data across the lifecycle of the well
	Beyond Limits	Coupling conventional AI and symbolic logic in well planning
	ResFrac	Physics-based model to integrate reservoir simulation and completion design
	Sfile	Structuring/normalizing data to deliver actionable insights
	Schlumberger	Rig of the future, DrillOps
	Halliburton	Digital Well Program, iCruise, LOGIX, Baralogix, Cerebro
	National Oilwell Varco	NOVOS (operating system)
	Helmerich & Payne	FlexApps (operating system), MOTIVE, AutoSlide MagVar, DrillScan
	Patterson-UTI	Cortex (operating system), Superior QC bit guidance
	Precision Drilling	AlphaAutomation technology
	Rogii	Geosteering software provider for drilling more accurate wells
	Corva	Platform and applications to help optimize drilling and completions
	Halliburton	Improving completions with Prodigy™/Gohfer
	Well Data Labs	Cleaning and structuring frac data in real time
	Seismos	A plug and play modular subsurface intelligence platform
	Deep Imaging	Real-time fluid tracking to detect subsurface problems
	Reveal Energy Services	Mapping fracs at a fraction of the cost
	Schlumberger/Rockwell	Sensia joint venture to improve connectivity of assets at the wellsite
	Halliburton	ESP monitoring and production optimization
	Apergy	Production and maintenance optimization across artificial lift suite
	Ambyint	Optimizing artificial lift operations through AI and physics based models
	Schlumberger/Rockwell	Sensia improving connectivity on midstream and downstream assets
	Baker Hughes	Predictive maintenance and asset optimization
	Apergy	Predictive maintenance on compressors/engines
	DCP Midstream	Monitoring major field assets with its Integrated Collaboration Center
	Beyond Limits	Looking at the refinery on the device and system levels
	SparkCognition	Using AI and ML for predictive and prescriptive analytics

Source: Company Reports, Barclays Research
Note: Full company write-ups in Part V& VI

The Producers: Believers in the concept, still learning how to implement

As with any service or technology, it's the customer that matters. Over the last several years, there have been countless examples of integrated oil companies and independents (E&Ps) believing in the power of Digital to improve efficiency, reduce cost and increase recovery rates. We are convinced the concept of Digital has been broadly accepted at the C-suite level of these companies and is now starting to filter down through senior management to the operations level.

It's not only about controlling costs in a lower oil price environment, but also reflects the clear need for the energy sector to address its material productivity gap to the wider economy as well as the recognition that the most efficient businesses are also likely to be the most sustainable. For large-cap integrated oil companies (IOCs), we see at least a \$60bn potential gain from closing the productivity gap alone.

A number of producers have been early adopters of Digital, many implementing their own internal digital programs with varying degrees of success. However, as these companies are learning, while it's one thing to use Digital on a specific task, building out digital capabilities on an enterprise scale and maintaining that technological edge creates an entirely different set of challenges (and a big opportunity for services).

Over the last several years, producers have generally implemented Digital in two distinct ways:

1. **US E&Ps utilized big data and data analytics in onshore drilling and completion activity.** Many E&P companies tried to build out teams of data scientists and new technologies, but most failed. Not only is this not in the DNA of the E&P company, but investors balk at the R&D spend required. EOG Resources is the outlier, and we're not convinced they can keep up with the pace of software innovation.
2. **Major IOCs digitizing existing production to optimize field operations.** The IOCs have seen capex per barrel of production fall 50% and opex per barrel fall by 30%, partly a reflection of efforts to standardise and simplify the cost base, but also from the digitization of producing fields. By installing sensors and measurement systems across a producing field, the IOC can then monitor performance to enhance efficiency and reduce downtime.

US E&Ps: Very few can go it alone

Over the last few years the number of E&Ps talking about the potential for Digital has declined as they confronted the challenge of building out digital capabilities in-house. So what happened? The inherent complexity of building an integrated offering, including creating and maintaining the software stack, requires significant capital, time and expertise.

Whereas Schlumberger and Halliburton have been developing their digital ecosystems for more than a decade, this skill set isn't generally part of the E&P DNA. That is not to say that E&Ps do not have internal resources devoted to the development of software and technology; all of the majors – EOG, OXY, Aker BP, and COP – have at least a degree of digital development internally (it ranges across the spectrum). However, given the newfound requirement for capital discipline, leaner organizational structures (i.e. less SG&A spend), and diminishing marginal efficiencies from service-cost deflation, self-sourcing, and pad development, we believe that E&Ps will turn to external solutions to capture the next leg of efficiencies. In our opinion, this is especially true for small- to medium-sized E&Ps, both public and private, that simply do not have the resources to develop full solutions internally; though we think they will retain some flexibility to develop some solutions internally.

EOG: More than 100 custom in-house built apps

Occidental: OXY Drilling Dynamics helps to improve drilling rates and lower well costs

EOG Resources: Uses proprietary software and data on well geology, spacing, lateral placement and production history to create a unique completion design for each well. Data collected enables EOG to make real time adjustments that have reduced pump time by as much as 10%. EOG also uses software in order to balance drilling speed and steer to stay within its precision targets. EOG maintains its own data warehouses and has a suite of more than 100 internally developed custom applications.

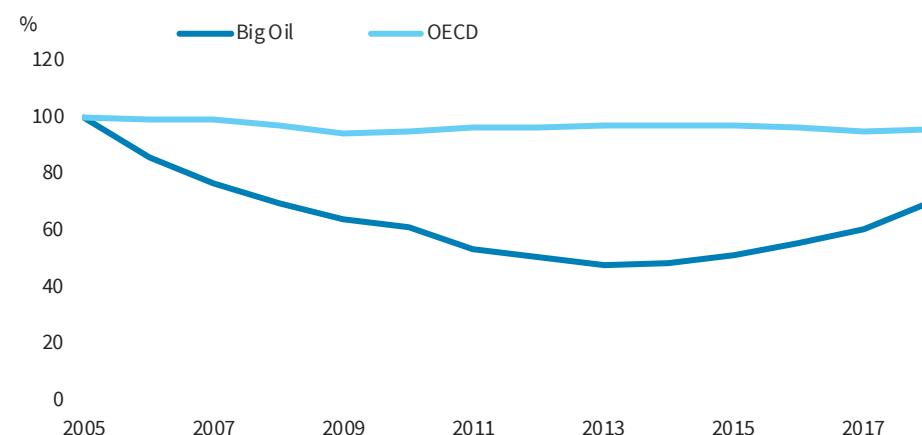
Occidental Petroleum: OXY has continued to invest in resources to take advantage of the large number of data points that it has available to process, helping it develop some of the most productive wells in the industry. OXY Drilling Dynamics is a physics-based approach to reduce inefficient use of rig energy, which improves drilling rates and lowers well costs. It helps OXY to reduce drilling days, extend the life of its tools, and improve well placement. OXY relies on data to make formation-by-formation improvements. The company also uses advanced data analytics to reduce artificial lift costs as well as optimized completion designs that have helped reduce the amount of sand pumped.

The IOCs: Looking to close the productivity gap with a hybrid approach

Since 2013, the IOCs have seen capex per barrel of production fall 50% on our estimates and opex per barrel has fallen by 30%. In some ways this was to be expected – history shows that costs typically follow the oil price and vice versa, but it is also a reflection of efforts made by the industry to standardise and simplify its cost base. But more work is to be done.

If we compare the productivity of the energy industry to the wider OECD, it is clear the sector still needs to address a significant productivity shortfall. Our European energy analysts Lydia Rainforth, Mick Pickup, and James Hosie undertook this exercise ([European Energy: The \\$60bn productivity gap, 12/11/17](#)). We calculate that, for Big Oil vs. the OECD average, a 30% gap across labour and capital productivity still exists.

FIGURE 28
Big Oil estimated productivity vs OECD



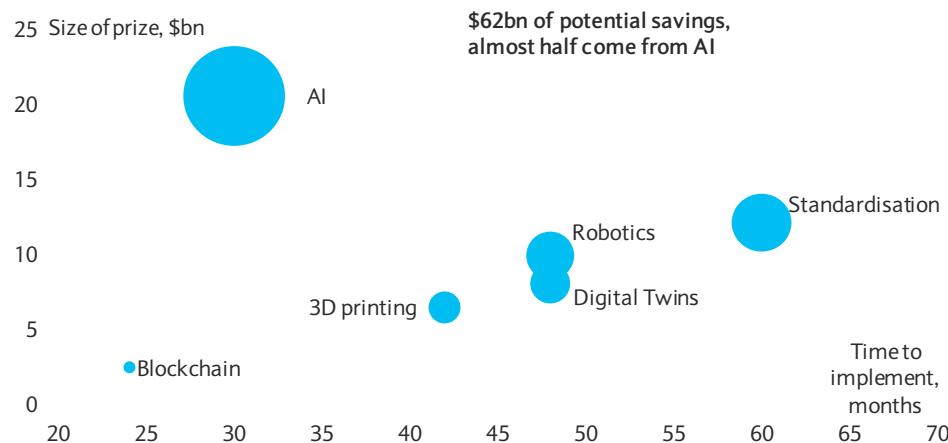
Source: Barclays Research. Labour and capital productivity are equally weighted.

We believe digital solutions, including artificial intelligence, 3D printing, robotics, digital twins and blockchain, will be critical in closing this gap. Assessing the exact impact of each technology on each individual company is extremely difficult given the lack of cost disclosure across the industry. The bubble chart below is designed to give an indication of the scale of the opportunity we see on average for the companies in our coverage universe, along with the time we anticipate to widespread deployment, although some companies are likely to be quicker to adopt new technologies than others.

Overall, we see the deployment of artificial intelligence as likely to have the biggest impact on productivity, and to take effect relatively quickly. The companies that we have spoken to are currently adopting a wide range of techniques and we expect many to be in common usage by the end of 2020.

We see the deployment of artificial intelligence as likely to have the biggest impact on productivity, and to take effect relatively quickly.

FIGURE 29
Potential sources of productivity gains



Source: Barclays Research estimates. Please note AI refers to connected devices, predictive and condition-based maintenance.

Across the energy industry, the breadth of IOC operations suggests Digital will have a material impact on the business. Our belief is that up until now the digital focus for majors digitally has been on existing production and identifying inefficiencies. While they have the capability to internally develop parts of their digital solution, they will likely also continue to leverage OFS/third-party providers where it makes sense.

As shown below, we estimate the European IOCs could reap more than \$60bn in savings from three primary areas: 1) the benefit of returning opex per barrel to 2005 levels, 2) the benefit of further cost reductions per barrel on the capex side, and 3) operational efficiency, with the aim of digital technology enhancing productivity and output as well as saving costs. We see Eni, BP and Equinor as being most advanced in terms of digital and technical deployment.

FIGURE 30
Potential efficiency gain vs numbers implied from presentations

\$bn	Opex savings potential	Capex savings potential	Operational benefit	Total available	Indicative potential benefit from company presentations
BP	1.7	2.8	6.8	11.3	5.7
RDS	6.5	4.3	13.5	24.4	10.0
TOT	3.3	2.5	5.2	11.1	2.3
ENI	1.1	1.2	3.3	5.5	0.9
OMV	0.0	0.6	0.2	0.8	0.1
REP	1.0	0.5	0.9	2.5	0.4
EQNR	2.0	1.7	2.3	6.1	2.0
Sector	15.6	13.6	32.3	61.5	21.4

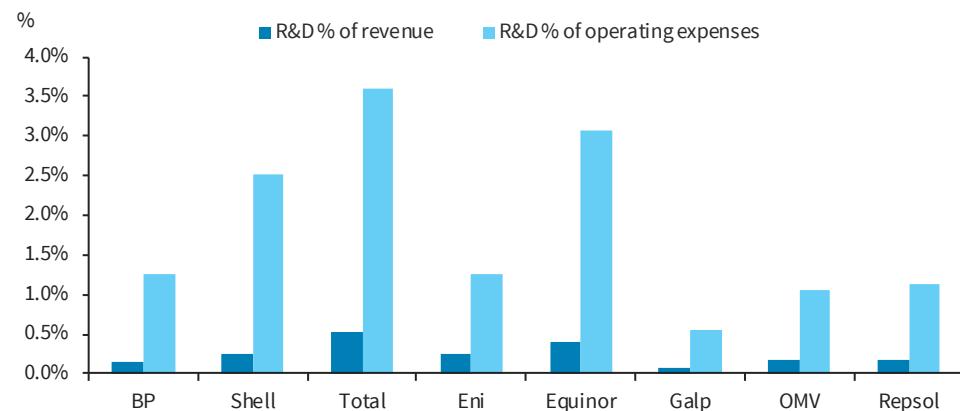
Source: Barclays Research estimates. Note savings numbers are based on 2017 production data and do not account for growth but are designed to give an idea of where 2017 could have been with new technologies applied. These numbers should thus decline over time as the companies see the benefit from new technologies being implemented.

Technology investment, like any other investment, takes time to see tangible results and R&D expenditure can be a good indicator. For 2018, sector R&D spend accounted for just under 1% of revenue and 2% of corporate opex, which is relatively low versus other sectors. We see significant potential for this to increase as the emphasis on digitalization increases.

It appears that the industry leaders are also the first movers: Shell, Total and Equinor have the highest R&D spend as a percent of opex. BP's R&D expenditure, disclosed in its annual report, does not include its investment in ventures and thus the actual number should be higher than indicated below.

FIGURE 31
R&D spend as % of revenue and operating expense, 2018

For 2018, the sector's R&D spend accounted for just under 1% of revenue and 2% of corporate opex, which is relatively low versus other sectors, but unsurprising given the capital-intensive nature of operations.



Source: Company reports, Barclays Research estimates.

Shell: Believe Digital is a \$1-2bn opportunity annually in the coming years

Shell: Currently spends ~\$1bn per year on R&D and another ~\$1bn for technical deployments on assets/projects, including advanced technical services. Real-time production optimization on LNG assets resulted in 1-2% production increase, with potential for >\$100mm in revenue on replication opportunities for its Integrated Gas portfolio. Shell has more than 800 developers working on AI solutions, including optimal well locations and pre-emptive failure. Digital has already enabled more than \$1bn in value across businesses in 2018.

Total: ~\$1bn/yr impact on Upstream, ~\$500mm/yr impact on Upstream

Total: Creation of its Digital Factory in 2020. Includes 200-300 dedicated engineers, Google as a partner on AI in Geoscience, the Refinery 4.0. Artificial intelligence to improve efficiency in geosciences – plan to shift employee work load from 50% high value, 50% routine to 80% high value and 20% routine. Impact on Upstream of ~\$1bn/year, impact on Midstream/Downstream of ~\$500mm/year through revenue, availability, and costs coming out. Spending \$1bn/yr on total digital R&D. ~\$400mm/yr budget for seismic acquisition and interpretation/studies.

Chevron: Won't speculate into numbers, but the opportunity is "big" and has "real potential"

Chevron: When asked how big the grand prize could be for Digital at CVX's security analyst meeting on March 12, 2019 James William Johnson, Executive Vice President for Upstream, said: "You're asking me to speculate, and I don't like to do that. I rarely do it. This one is big. I won't put a number on it, but I think it's got real potential. In terms of operating cost and lowering cost is one thing. In terms of lowering our unit operating costs because it works on both the numerator and the denominator. We get more production and we get fewer cost at the same time with many of these applications and that's what makes it so powerful."

Exxon: 50,000 bpd added by 2025

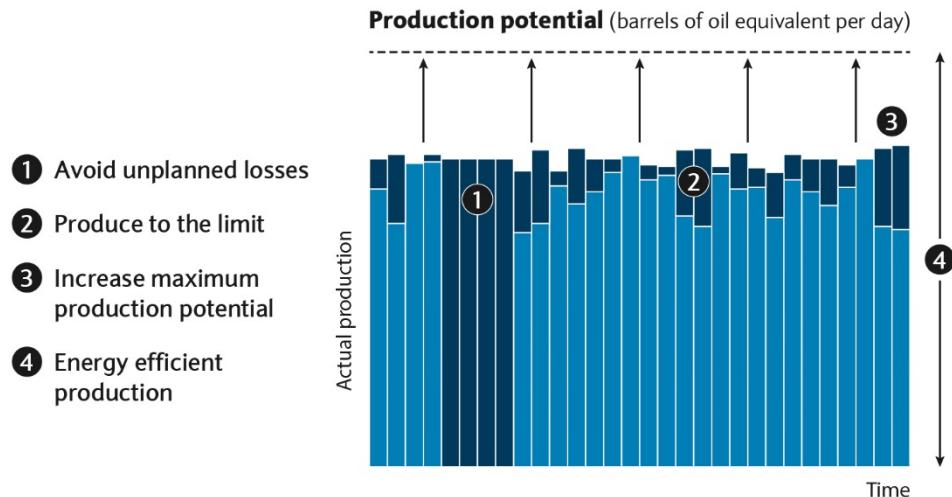
Exxon: Announced a partnership with Microsoft which is expected to expand production by as much as 50,000 oil equivalent barrels per day by 2025. In a 22 February 2019 press release XOM said the use of cloud technology is expected to generate "billions" in net cash flow over the next decade through improvements in analyses and enhancements to

Equinor: We believe that Digital can halve operating costs and reduce investments by at least 30% (facility capex)

operational efficiencies. Investment in Digital won't just impact Permian and Upstream, but its entire business (Midstream, Downstream, etc.) Says 5% of volume will be impacted by the digital program.

Equinor: Investing in Digital to reduce costs considerably, increase efficiency in production and drilling, improve discovery and production rates, contribute to reducing greenhouse gas emissions and improving safety. Believes that Digital can halve operating costs and reduce investments by at least 30% (facility capex). Krafla is Equinor's unmanned production platform, built at 30% lower facility capex. Automated drilling control reduced drilling costs on several rigs in 2019 (offshore, want to reduce drilling costs by 15%; see pilot with Songa Enabler where they have already been able to reduce costs by 10%). At its Autumn seminar on 23 November 2018 Equinor's CIO Ashild Hanne Larsen said: "The amount of data itself is really increasing exponentially, so at least doubling every year so far". Equinor has a 7-year partnership with MSFT worth hundreds of millions of dollars for Microsoft. Equinor utilizes a full digital twin of Johan Sverdrup. The biggest value lies within subsurface and production, where there is an incredible capacity/efficiency gain to be seen. Digital can be used to achieve better analysis, more analysis, more well targets, better well targets, and higher hit rates. The production side is the biggest prize, where a small amount of capex/opex could be linked to debottlenecking existing fields as well. Omnia is Equinor's cloud-based data platform. It also leverages external partner API (applications). Through its integrated operations centre, it now has 16 assets supported by new production optimization tools.

FIGURE 32
Equinor has already realized an impact from its Integrated Operations Center



Source: Company Presentation

BP: Right now spending ~\$200mm per year on Digital

BP: We continue to believe that use of digital technology and enhanced efficiency could deliver about \$10bn of FCF longer term relative to 2016 for BP through a combination of further opex savings, unit capex savings and critically enhanced operating efficiencies. BP said that the costs of oil and gas production have the potential to fall by 30% with the use of new technologies. CEO of Upstream, Bernard Looney, said during BP's 4Q18 Earnings Presentation on February 5, 2019 that Digital would be as important to the industry as knowing how to drill a well.¹¹ Right now we think the company is allocating c.\$200mn/year to Digital, although the total spend on technology improvements is likely to be much more. Earlier this year, BP used Full Waveform Inversion with its Wolfspur machine to uncover an extra billion barrels of oil in the GoM.

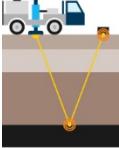
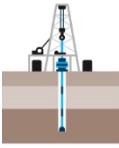
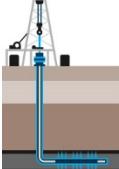
¹¹ BP Earnings Conference Call February 5, 2019

PART V

The Digital Well of the Future and the Competitive Landscape

We look at Digital through the lens of production and asset optimization, but we do understand that there is some overlap between the two. The goal is common: lower cost per barrel of production and increase the ultimate recovery of hydrocarbons. **Production optimization** focuses on optimization across the lifecycle of the reservoir, while **asset optimization** is increasing equipment efficiency. Using that framework, we present the Digital opportunity set matrix:

FIGURE 33
Digital Opportunity Matrix

	Production optimization	Asset Optimization
 G&G / Seismic	<ul style="list-style-type: none"> • Better, faster reservoir interpretation • Increase rate of success in discovery • Decrease exploration wells, dry holes • Integrate development and capital planning across the lifecycle of the well 	
 Drilling	<ul style="list-style-type: none"> • Collect real time data on reservoir characteristics 	<ul style="list-style-type: none"> • Surface Equipment Optimization • Predictive maintenance • Downhole equipment optimization
 Completion	<ul style="list-style-type: none"> • Real-time frac data and analytics can reduce pump time, optimize material use • Enhance completion design stage-by-stage or on future wells • Reduce frac hits 	<ul style="list-style-type: none"> • Automate the frac job so that performance is 100% tied with planning
 Production	<ul style="list-style-type: none"> • Automate and optimize artificial lift systems using real time data (edge-enabled) to maximize production and minimize opex 	<ul style="list-style-type: none"> • Failure detection, decrease workover costs, reduce NPT • Remote monitoring
 Midstream / Downstream	<ul style="list-style-type: none"> • Optimization of flowthrough • Look at refineries on asset-specific and entire system level to enhance operations 	<ul style="list-style-type: none"> • Monitor rotating equipment for failure detection • Use digital twin to predict failure, optimize performance

Source: Barclays Research

Data Structuring, Normalization

As noted earlier, the need for data to be shared data and accessed by various applications has created an opportunity. Companies including Cognite and Sfile have focused on cleaning and structuring often disparate and non-congruent data sets into comprehensive sets that can be used to add value. We also believe that this is a space where the Big Tech companies see an opportunity and are already operating to some degree. Still, as evidenced by the lack of an industry-wide data standard, there is a long way to go.

Cognite (Norway; Private, Not Covered): Cognite enables the development of applications and machine learning.

- Cognite helps to extract data from various sources and contextualize it. It can break down silos and present data in an operational context, in real time. This enables applications and machine learning to generate insights on the data that can then be used in operations. Cognite is able to model the entire operation in oil and gas, eliminating silos so that data can be integrated and used properly. Essentially, what Cognite does is data liberation and contextualization as a service, and that data is usable in milliseconds. This process can help larger oil companies to work with start-ups and other application providers.

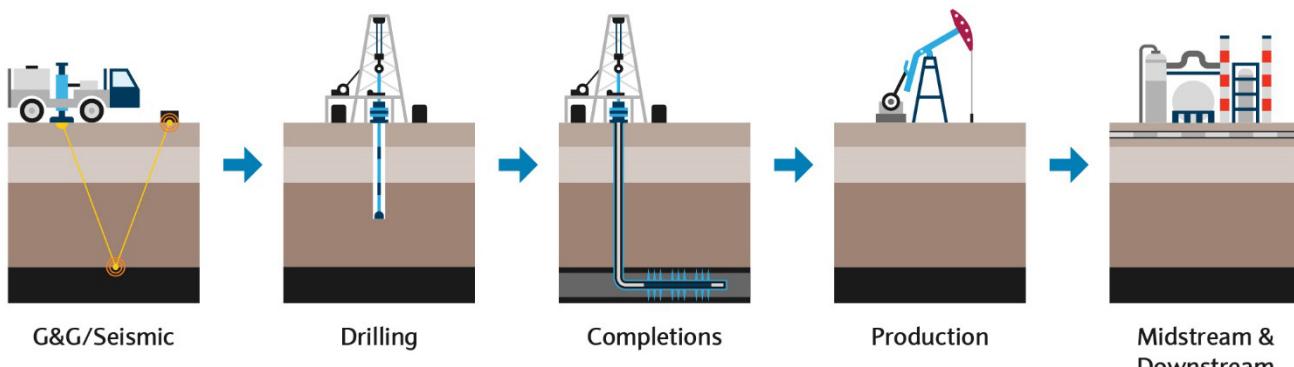
Sfile (Houston TX; Private, Not Covered): Structuring data to deliver actionable insights. Sfile normalizes reports so that they can be implemented into models, creating wider access to data and improving the quality of models.

- Frank Perez, CEO of Sfile, explained that until recently producers were managing their reports very subjectively, using short hand notes and acronyms, similar to how a doctor manages a patient chart. Sfile uses AI algorithms to normalize and structure the data that was previously unusable, helping companies “work across” silos. Sfile algorithms apply specific industry knowledge to normalize the data so that it can be implemented into models. This creates better access to data and improves the quality of models. Sfile was able to bring their model error rates down to 5% from the accepted oil and gas industry standard of 35%.

Across the Lifecycle of the Well

The digital well of the future will have lower costs, increased productivity, and faster time to first oil than current wells. We believe that costs can be reduced by ~10% and production can be increased by ~9%.

FIGURE 34
O&G Well Lifecycle



Source: Barclays Production



G&G/Seismic

Understanding the subsurface and identifying a potential hydrocarbon reservoir is the first step in the lifecycle of the well. 80% of the value of the well is created by making the correct choice about where you drill and how you drill (research, making decisions, test wells, well planning).

The first task is to locate and identify hydrocarbons and the characteristics of the reservoir. To create a geophysical model, seismic surveying techniques are employed using sound waves transmitted into the subsoil, which then undergo reflection and refraction based on geologic properties. Though techniques vary, both land and offshore rely on a source of the sound wave along with an accompanied receiver to probe the rock structure of the Earth's crust by timing the reflections from the rock layers – known as seismic surveying. The data received is then processed and interpreted, resulting in a subsurface map that is used to identify potential hydrocarbon locations. However, it does not tell an oil company if there are hydrocarbons in place.

Seismic companies like CGG have been early adopters of Digital (and thus likely further along in terms of adoption), having embraced “Big Data” for over 20 years, with a reliance on supercomputers and capacity measure in terms of petaflops of processing power. Indeed, the product of the seismic industry is often pure digital data and adoption of new technology has been continuous, being more of an iterative process of improvement than something fuelled by a step change in technological advancement over the last few years. Throughout, there has been continued demand for ever increasing volumes of data, with the next potential phase being the uplift from nodal surveys as baselines for 4D seismic. These will greatly increase the volume of data and hence are driving advancements in processing.

The second purpose of seismic is to help map/plan the optimal well and completion design after the data has been collected, which can be updated throughout the drilling/completions process as additional well data comes in. When trying to determine where and what type of well to drill, reservoir-specific and historical data from wells drilled in the past (public and private) can be used to create forecasting models using advanced analytics. In US land, for example, AI is only just being used, by companies such as TGS, to link seismic data and well logs and to predict the initial production rates of future wells.

Oilfield Services

CGG: Primarily functions as a provider of geological/geophysical data, which is then fed into clients' systems for interpretation. The company collects and processes its own proprietary data with its state-of-the-art processing algorithms and also processes third-party data for its clients

- **CGG (GEPH.PA)**, known for having the highest-quality seismic imaging, has been an early adopter of Digital as one of the first companies to embrace big data and supercomputing. The rest of the industry has gone through a step change more recently that, at least in part, enables the improvements we are seeing or will see in the future. For CGG, however, the step change happened a few years ago (they describe it as like going from an X-ray to an MRI), and going forward improvements will be more iterative, with big step changes less likely.

CGG is focusing on a few key areas within Digital, including optimization (getting the best out of the petabytes of data they are running every day), quality control (the better the data quality, the more it can be used), and advanced interpretation (using advanced analytics for interpretation, where a lot of interest lies today).

CGG does compete with the WesternGeco unit of Schlumberger, which is a multi-client seismic provider, and it supplies key data to the digital systems run by the Oil Service companies (HAL/SLB/IHS Kingdom, etc.). It also competes with some of the OFS firms

Potential opportunities

Increased rate of success in finding oil and gas, finding additional reserves, better and faster reservoir interpretation and well planning, fewer “dry holes,” increased accuracy of production forecasting (capital budgeting)

with its HampsonRussell and Jason plug-ins (which can be integrated into OFS ecosystems/platforms). HampsonRussell provides a fully integrated suite of geophysical interpretation tools for reservoir characterization, and the JasonWorkbench is similar in supporting geoscientists and engineers to optimize well productivity, field development, and reservoir management.

Schlumberger (SLB): Historically the leader in reservoir characterization, SLB's legacy solutions are being integrated with DELFI.

- The Petrotechnical Suite, also known as "Petrel" has long set the standard in the industry, integrating geo-science disciplines into a user friendly environment. Petrel helps with seismic interpretation, providing "a common canvas for a shared earth model in the reservoir," according to the company.¹² In essence, it integrates the subsurface domains of geology, geophysics, petrophysics, reservoir/production engineering, and drilling into a single shared workspace, SLB says. Petrel and its associated applications are being put onto on DELFI.

The GAIA digital subsurface platform (through WesternGeco) is powered by DELFI and was developed to help accelerate hydrocarbon discovery by providing access to cross-domain data, documents and reports including seismic data, well/production logs, subsurface measurements and basin history. SLB's ECLIPSE reservoir simulator is the industry benchmark for reservoir simulation. DrillPlan is a well construction planning tool that can help customers build better drilling programs quicker.

Halliburton (HAL): Has products targeting characterization of the subsurface to reduce uncertainty, improve exploration success and boost recovery.

- HAL has a number of tools and software offerings in this area. Several of its cloud-native DecisionSpace365 applications target exploration and reservoir development, including its assisted lithology interpretation, full-scale asset simulation, seismic engine, and scalable earth monitoring. It also has Well Construction applications on DS365, including holistic field development planning and well feasibility & detailed design.

On top of the DecisionSpace365 tools, Halliburton in 2014 acquired Neftex, which provides regional geological interpretations and uses tectonostratigraphic modelling to offer insights into resource potential. It is now integrated with DS365. Another important part of HAL's offering is the EarthStar ultra-deep resistivity service, which is a logging-while-drilling (LWD) technology that now has the ability to map the reservoir up to 225 feet from the wellbore.

Digital Innovators

OAG Analytics (Houston TX; Private, Not Covered): Provides cloud-enabled data science software for oil & gas exploration and planning. OAG Analytics focuses on reducing costs and increasing production through applying machine learning to more rapidly connect insights with decision makers.

- OAG Analytics says that its extensible SaaS targets critical functions like subsurface mapping, predicting well interference (frac hits) and estimating cash flow (decline curves). OAG uses machine learning technology to automate data management, feature engineering, simulations and visualizations with the aim of accelerating planning cycles and increasing collaboration between subsurface and data science teams. OAG believes that its proprietary techniques for combining physics-based algorithms with machine learning are highly effective and extensible for customer specific use cases. For example, according to OAG Analytics one customer used them to operationalize their in-house

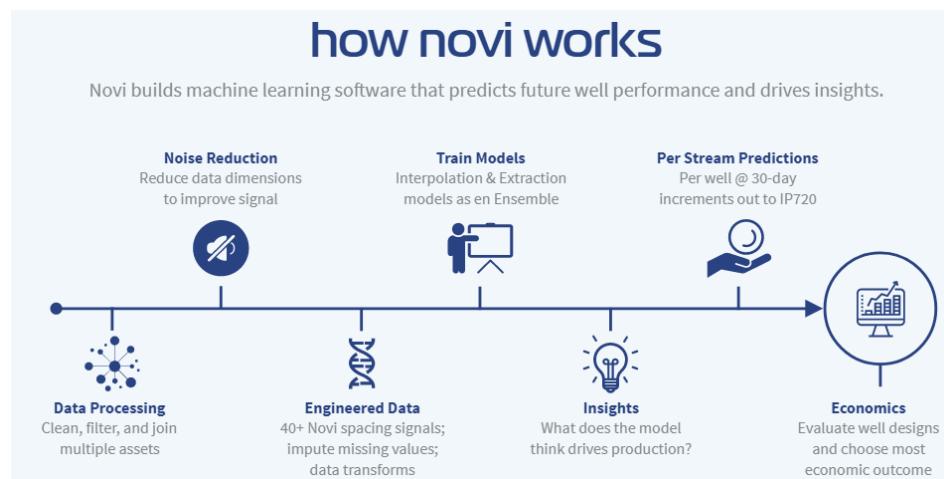
¹² <https://www.software.slb.com/products/petrel/petrel-drilling>

well spacing algorithms “3 times faster than we could have done on our own”, resulting in improved pre-drill production estimates.

Novi Labs (Austin TX; Private, Not Covered): Automating and optimizing well planning decisions through cloud-based software that ingests and transforms data, trains predictive models, and enables business leverage out of predictive models. According to the company, Novi increases efficiency and improves return on capital for oil & gas investments.

- Novi claims to answer the “where”, “how?” and “when?” of well-planning questions, where it believes 80% of value creation lies. The company’s software uses predictive analytics to drive dynamic per-well type curves for oil, gas, condensate and water that scale automatically for completion designs and spacing considerations. It supplements asset teams, petroleum engineers and financial analysts with machine learning algorithms, cloud scale computing power and intuitive web applications. Novi can build and compare many possible full field development plans in minutes, versus weeks to months for a team of engineers. The scale and speed of Novi’s platform allows asset teams and acquisition teams to focus on improving economic outcomes on capital drilling programs.

FIGURE 35
Novi Labs Explained



Petro.ai (Houston TX; Private, Not Covered): Activating data from across the well lifecycle to drive better engineering decisions and economic outcomes. Petro.ai provides an extensible platform with premade applications that apply advanced analytics and machine learning to workflows ranging from G&G to D&C, and Production.

- Petro.ai breaks the current dogma that data should be organized according to which service line collected it. These disparate data types are blended inside Petro.ai and served up to end users in a well-centric digital workspace where all the data related to an area of interest is available for analysis. Private data can be augmented with public data sources to expand analysis. Producers can then run number of premade workflows with embedded analytics and machine learning. Alternatively, producers can deploy their own models or feed their own workflows on the platform. Petro.ai has been deployed in conventional and unconventional reservoirs, both onshore and offshore. Petro.ai integrates with existing IT architecture and can be hosted in a private cloud, deployed on premises, or deployed as a managed service.

Beyond Limits (Glendale CA; Private, Not Covered): Coupling conventional AI and symbolic logic in well planning. Beyond Limits allows operators to incorporate hypothetical scenarios and build models quicker to supplement engineers.

- Beyond Limits uses its cognitive AI technology in field management, which allows operators to accelerate data integration, run hypotheticals, and speed up time to decisions. Beyond Limits' software can run build models in minutes that would take engineers weeks or months. The differentiation is that Beyond Limits also layers in symbolic logic. The models can factor in human expertise as well as the data that they ingest and have the ability to show teams the risks, knowns/unknowns, and whether the best course of action is being taken. Solutions can also make recommendations on what human operators should do, and according to management, the recommendation is not a "black box", but fully documented and transparent.

Case Study: Recommendations from two different models based on high or low permeability reduced the NPV of a development by 30%

ResFrac Corporation (Palo Alto CA; Private, Not Covered): Physics-based model that integrates reservoir simulation and completion design. ResFrac's software for hydraulic fracturing and production allows customers to run different scenarios and see how that changes the simulation.

- ResFrac sells software licenses and consulting services that help customers integrate reservoir simulation and hydraulic fracturing planning, which runs all the way through production. Its orientation is to help frac design. It is differentiated from other solutions because it is an integrated offering and it is physics-based, whereas some competitors use data-driven models. ResFrac's software helps to supplement companies' internal engineers in decision-making about completion design, which will inherently impact well spacing and other pre-drilling decisions. ResFrac is locally installed but uses Azure to perform the computation. It is not currently integrated with any other platform. Competitors on the reservoir simulation side include SLB's Eclipse/Intersect and Computer Modelling Group (CMG.CN, Not Covered). On the completion design side, competitors include SLB's Kinetix and HAL's GOHFER.



Potential opportunities

Decreases number of drilling days, number of workers on the rig. Reduces error in drilling results, especially important in pad drilling (parent/child and frac hits). Hazard avoidance

Drilling

Once a drilling location has been identified, a rig is brought in to bore the well. Directional drilling capabilities will be used to "land the drill bit" at a specific depth and location in the targeted formation. In the case of an unconventional onshore well, this will also include a "dogleg" turn to place the well horizontally within shale.

Automation, which can also be used in offshore wells, is able to increase rate of penetration by as much as 30%. Sensors can deliver real-time data through intelligent drill pipe, while machine learning can be used to optimize the drill speed and weight on bit. Most drilling-focused companies have introduced systems that allow some degree of automation.

Geosteering software and other technologies help to place the bit in the optimal location, reducing the "ellipse of uncertainty" by keeping the path of the well closely aligned to the drilling plan and avoiding hazards. Autonomous drilling is likely the future and can reduce onshore/offshore drilling times while improving performance and safety. The ideal rig of the future would have a closed-loop automation system performing the drilling using real time data and analytics to drill a better, safer well in less time.

Oilfield Service

Case Study: Using NOVOS and real-time drilling data from wired drill pipe, drilling time in a particular section was reduced by 25%. Combined with cost reductions from less trips and tool damage, overall cost per foot was reduced by 33%.

National Oilwell Varco (NOV): Delivering a higher level of consistency with NOVOS. NOVOS is a platform that helps automate the oil rig, and can house internally or externally built applications.

- The NOVOS reflexive drilling system aims to fully automate the oil rig. NOVOS is an automation layer that sits on top of existing control systems and is scalable and designed to be relatively easy to implement. The system has been installed on at least 50 rigs, the company says, while more than 100 systems have been sold (including double-digits offshore). One of the first value creations is from drilling more consistently. NOVOS has a collection of 30+ apps developed both internally and externally. NOVOS is open sourced and allows for external development or customization of applications (NOV also provides a software development kit to aid app development). The apps have different levels of automation: while some are meant to guide the driver of the drill, others aim to completely automate the system.

NOV also has the IntelliServ wired drill pipe, which collects data in real time that can benefit NOVOS or even be used for fully-automated closed-loop drilling in conjunction with NOVOS. In a five-part trial with Equinor, where drilling decisions were based off insights from the wired drill pipe, BHAs used were reduced by 33% and FPD (feet per day) was increased by 25%. Furthermore, insights from the trials enhanced understanding of subsurface data so much that adjacent rigs without wired drill pipe increased at a faster rate than the original trials. Thus far, NOVOS has been used to drill over 2 million feet, with over 6,000 days of operation. Precision Drilling (PDS, Not Covered) is a big NOVOS customer and expressed to us that they have been extremely happy with the product from NOV.

Schlumberger (SLB): Rig of the future can enable autonomous drilling more in line with plans.

- Schlumberger has been talking about its “rig of the future” for a few years now. At our conference in September, management said that more than 30 customers had come to see the rig in person in recent months. The goal is for the rig of the future to help enable autonomous drilling. DrillOps is not widely deployed yet but it is software that implements plans built in SLB’s DrillPlan to enable automatic drilling, which can be done by the land rig of the future (similar to other automation platforms mentioned in this section).

Halliburton (HAL): Halliburton has a number of different digitally-enabled parts of its drilling offering.

- Important components include the Digital Well Program, iCruise, LOGIX, Baralogix, and Cerebro. The Digital Well Program on DS365 combines the digitalized well design process with engineering models on the same platform, which can cut well design times by up to 80%. Well Construction 4.0 (also on DS365) uses digital twin technology to reduce time and uncertainty and also keeps the well program up to date in real time as drilling is conducted, integrating real time data. iCruise is the intelligent Rotary Steerable System that uses electronics, algorithms, sensors, and high speed processors to maximize ROP. It allows for drilling automation that can decrease NPT and improve well placement. LOGIX is HAL’s Automated Drilling Director that uses physics-based models and machine learning. Baralogix provides real-time analysis of fluids data that can help keep operations on track. Cerebro is an electronic data capture system that allows Operators to get a high-speed look at data captured from the bit.

Helmerich & Payne (HP): “Driving the development of advanced technologies and directional drilling automation solutions.” Offering includes FlexApps, AutoSlide, Motive, MagVar, and DrillScan.

- HP offers FlexApps through its operating platform that offer different capabilities (similar to NOV’s NOVOS), which are for the most part exclusive to HP rigs. In our view the more differentiated, value add part of the offering comes from acquisitions it has made, which include MOTIVE, MagVAR, AutoSlide (developed after MOTIVE acquisition) and most recently DrillScan. The company likens MOTIVE (currently on 25 rigs) to Google Maps. It is an automated bit guidance system that does the calculations to drill the well according to the plan, providing an output for the directional driller while eliminating the human in the decision making process (but not the execution). Autoslide was born out of MOTIVE and is the next evolutionary step, where it will actually be “pulling the knobs and the joystick” and directing the rig without human interaction. MagVar is a downhole tool corrective software that reduces the ellipse of uncertainty for the actual drill location by 50-60% vs. competing products. DrillScan can help select the optimal equipment to use based on well design and the type of well operators want to drill.

Patterson-UTI (PTEN): Automating surface and downhole equipment to improve drilling performance. Offering includes its Cortex operating platform and Superior QC.

- **Cortex** is PTEN’s internally developed operating platform, which is the user interface that sits on top of the rig’s operating system and allows the driller to interact with and control the rig. Cortex is operating system-agnostic (can run on Antheon, OMRON, Current Power). Because Cortex was internally developed, it can be added to Patterson’s rigs at a low cost. The company has also developed applications internally, and it will have the ability to run third-party software (i.e. applications) soon. **Superior QC** helps increase the accuracy of wellbore placement by reducing the ellipse of uncertainty to reduce frac hits and lessen parent-child communication between wells. Superior QC’s Bit Guidance provides real-time corrections and accurate well placement, essentially giving the directional driller a recommendation on how they can make adjustments to get back to the drilling plan. The next iteration is the Cortex Automated Toolface Drilling Control, a closed loop technology that will actually automatically implement the recommendations from Superior QC.

Case Study: An operator using Precision’s automation system realized total well savings of ~5-8% (0.75 to 1.2 days on a 15 day well).¹³

Precision Drilling (PDS, Not Covered): Rig automation to reduce customer drilling costs. PDS leverages NOVOS process automation and couples it with in-house and externally built applications for on-bottom and cost-control functions.

- Precision Drilling’s AlphaAutomation technology can help enhance the efficiency and value of its drilling rigs. Currently there are more than 30 systems deployed across the US and Canada, contracted at commercial rates (\$1,500 per rig per day in EBITDA) with add-ons through applications that can add an additional \$250-\$1,000 per rig per day to EBITDA. Precision Drilling decided to partner with a company that it viewed as a leader (NOV), which has given them a field-hardened technology over the past ~three years. The AlphaAutomation platform is an open platform that can host both internally and externally developed applications that focus on both bottom application (drilling efficiency) and cost savings (surface efficiency).

¹³ Precision Drilling Investor Presentation November 2019

Digital Innovators

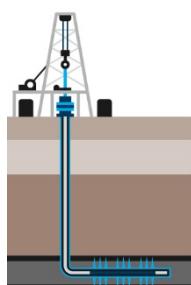
Rogii (Houston TX; Private, Not Covered): Geosteering software provider that is used on 65-70% of the wells drilled in NAM (according to the company). Rogii helps customers (Producers and OFS companies) drill more accurate horizontal wells with software that can be installed in 10 minutes.

- Rogii's StarSteer is an easy to use geosteering software solution that the company said is used on 65-70% of wells drilled in NAM. Geosteering is the key technology for unconventional development, but the goal in developing it was for it to be as mobile, flexible, fast and easy to use as applications on a phone. StarSteer is differentiated in that it feels simple, looks simple (visually), and has superior functionality. It only takes 10 minutes to install and users typically take 2-3 days to learn and familiarize themselves with using it. Unlike previous/other software offerings for geosteering, there are no limits to the number of offset wells or petrophysical logs being used. Rogii is agnostic as to which cloud provider a producer is using, but does have a prior relationship with Amazon. Rogii can be used on any horizontal well, and the company is in the midst of expanding internationally. The company also helps in integrating from geology to drilling to completions in its SOLO Platform.

Corva (Houston TX; Private, Not Covered): Platform and applications to help optimize drilling and completions. Corva is an all-in-one solution that helps customers bring in and analyze real-time data with more than 70 mobile and web applications to help improve drilling and completions.

- Corva has built a software platform that houses more than 70 internally developed mobile and web apps to monitor drilling & completions, identify hazardous conditions and give users recommendations based on current/historical data. Taking advantage of data that comes from 30-50 sensors every second on top of static historical variables, Corva seeks to help producers drill faster while avoiding or preventing potential problems. One of the company's focuses is cleaning the data, because having high quality data is a differentiator. The drilling aspect of the offering is more built out and can deliver performance optimization, hazard avoidance, and operational analytics/KPIs. When we spoke with the company the plan was to ramp up to ~350 rigs by the end of 2019. Corva also recently announced that it was partnering with Drill2Frac in order to create an integrated frac design and execution solution, which can help optimize each lateral and stage, prevent frac hits, and keep pump trucks running longer.

Completion



Potential opportunities

Increase in initial production, less material used (sand/chemicals), avoid frac hits, reduce pump time

After the well has been drilled, it then goes through a completion process in which producing zones are isolated, downhole hardware is installed, and chemicals and sand are injected. Using non-intrusive means for fracture interpretation, the completion process can be optimized (in some cases in real time) to increase initial production rates and reduce the required amount of materials. In unconventional resources, digital applications can check the effectiveness of perforations and help optimize the number of stages required to complete a well while also controlling the length of the propagated frac to prevent well-to-well interference (i.e. frac hits). Other technologies impacting completions include automated fracking, which helps to ensure that fracturing results (pump rates) align directly with plans.

Oilfield Service

Halliburton (HAL): Improving completions with better fracturing.

Halliburton's Prodigy Intelligent Fracturing Service utilizes automated fracturing to optimize the execution parameters. In essence, it automates the frac job so that performance is directly aligned with plans. Right now it is automating the first break, or frac, but the goal is to automate more in the future. The company anticipates that eventually all fleets will use Prodigy. The other part of HAL's offering is intelligent completion through its SmartWell systems that collect, transmit, and analyze downhole data.

Digital Innovators

Case Study: A Mid-Con operator was able to save nearly 400 gallons of friction reducer per stage and roughly \$400,000 because of an issue identified through Well Data Labs analysis tools and high-frequency data¹⁴

Well Data Labs (Denver CO; Private, Not Covered): Collecting & analyzing frac data in real time on ~40% of completions. Well Data Labs cleans and structures frac data from the field quickly to deliver time-series that can be used in further analysis by operational engineers/data scientists.

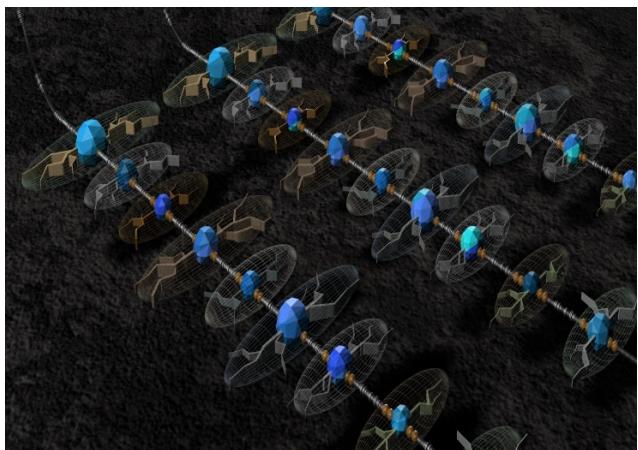
- A modern web application that gives producers a fast, simple way to manage, analyze and report internal frac data. Well Data Labs sits between the E&P and the service provider and provides a platform that standardizes the delivery of time-series and field-generated frac data to operational engineers and data science teams. Its primary function is to clean and structure the data, and they are less focused on analyzing the data. Data can be streamed in real time, and WDL has over done over a quarter million stages to date (40% of completions are managed using WDL's platform, according to the company). The platform can deliver significant time savings by streamlining data acquisition and management. Companies can bring their own model or use one of WDL's existing models for analysis. Data can be real time or post stage and the breakeven for the product is approximately 15 completions per year.

Seismos (Austin TX; Private, Not Covered): A "plug and play", modular subsurface intelligence platform. Seismos delivers real-time measurements of the fracture network during fracking, helping to enable intelligent completions.

- Seismos delivers real-time measurements of the fracture network during hydraulic fracturing operations, which in turn enables intelligent completions. The sensor connects to the wellhead in minutes and does not impact operations. Deliverables include geometry (length, width, height), accurate measurements of network complexity, conductivity, and proppant distribution. It displaces conventional microseismic techniques that require equipment to be put down the well to estimate fracture activity, which is more costly, more time-consuming and invasive to field logistics. Seismos-FRAC measures accurately all fracture-network properties, while Seismos-CONNECT evaluates the effectiveness of perforations before pumping commences for any given stage. Both Seismos-FRAC and CONNECT can be used for new field development, for optimal well spacing for the optimization of completion designs and are particularly effective as the transition to pad development continues (enabling optimal depletion of the reservoir eliminating unstimulated volumes/areas). Data is collected and analyzed in minutes and customer E&P operators have access to all subsurface information/measurements before transitioning to the next stage. Based on the data, customer E&P operators make real time adjustments at the completions operations boosting well production numbers, eliminate undepleted reservoir areas thanks to optimal well spacing, and mitigate operational risks. Seismos-FRAC has been applied to more than 15,000 stages over the past years in 11 different basins.

¹⁴ https://assets.cdnma.com/20825/assets/CS_Midcontinent_Operator_190624.pdf

FIGURE 36
Example of Seismos Output



Source: Seismos

FIGURE 37
Example of Seismos Instrument



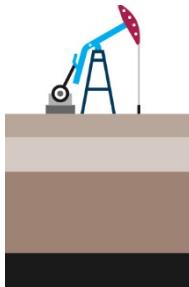
Source: Seismos

Deep Imaging (Houston TX; Private, Not Covered): Real-time fluid tracking technology to detect subsurface problems. Deep Imaging offers diagnostic tools that help identify the cause of subsurface problems, which can help avoid frac hits.

- Deep Imaging's diagnostic tool provides a tracking technology that helps to identify the cause of subsurface problems that often lead to poor economic returns (i.e. frac hits). The technology can help operators detect frac hits, bad cement, plug failures, and open zippers among other problems that can cause underperformance. Currently it takes a few hours for them to collect and provide usable data, but the goal is to come out with a real time product in January of 2020 so that data can be used to optimize completions. While Deep Imaging does not itself do AI/ML on the data, it provides some of the data points that can be used within analysis. Instead, Deep Imaging has taken a partnership approach, including with Well Data Labs (Well Data Labs will help deliver data in real time). A couple of key differentiating points for Deep Imaging are that they are not on the pad during operations (less crowding) and they do not put anything downhole (less costly and less risky).

Reveal Energy Services (Houston TX; Private, Not Covered): Mapping fracs at a fraction of the cost. Reveal Energy Services has an asset-light offering that can help companies understand frac hits by using wellbore pressure from an offset well, which can be done on a stage-by-stage basis.

- In a nutshell, Reveal uses pressure-based technology to make better completions. The core concept, called ImageFrac, was developed by Statoil (Equinor) and is designed to quantify the geometry of the fracture. FracEye, a concept the company created after spinning off from Equinor, is designed to understand frac hits. Reveal has no field assets and no field personnel. Data is collected using wellhead pressure from an offset well and analysis can be provided in very close to real time (depending on the size of the job), which allows producers to take action on a stage by stage basis. Reveal Energy Services Solutions are asset light, especially compared to traditional microseismic/fiber-related offerings that actually need to put equipment down the well and are associated with higher costs in general. Per the company, it has monitored more than 10,000 stages, and the technology is something like 20% of the cost of traditional microseismic. Production increases can range from a few percent to a 20% in cases where the company is able to prevent or mitigate frac hits. Reveal also has a cloud-based database that can store and analyze data sets.



Potential opportunities

Increase in production,
decrease in workover costs,
decrease in operating costs,
decrease in capex, reduce
unplanned downtime

Production

Once a well begins producing, the rate of production slows over time as the pressure in the reservoir declines (the decline curve). To offset the decline rates and increase production, energy is added to the reservoir with various forms of artificial lift. Digital applications can be used to optimize the amount of energy being placed into the reservoir, which continually fluctuates to match the dynamic requirements of the reservoir. It can also be used to help optimize the chemical injection and predict failures, helping to reduce operating costs and reduce failures. Surface production facilities tie together multiple producing wells (both onshore and offshore), which can be viewed as oil and gas manufacturing facilities. Through remote monitoring, performance measurement and artificial intelligence significant efficiencies can be reaped from these facilities increasing production and reducing opex. Remote monitoring can also be applied to offshore platforms, reducing the necessary size of the platform (30% reduction in capex) and opex associated with it (50% reduction).

Oilfield Service

Apergy (APY): Digital solutions across the artificial lift suite. Apergy focuses on production optimization and predictive failure. Note: Apergy also operates on midstream/downstream

- Apergy focuses on production optimization and maintenance optimization, the two top priorities of customers that can have a tangible impact on bottom line. Apergy has its own ENTERPRISE platform that ties together all of the hardware and software into a single platform for customers. ENTERPRISE can be integrated with other customer offerings to enable collaboration and bring data together. SMARTEN is Apergy's edge controller for continuous monitoring and control for all types of artificial lift. The XSPOC solution provides production optimization at the edge device level in the field as well as in the cloud, helping customers improve yield by as much as 10-15% in the field. Bloodhound software optimizes gas injection in gas lift operations, also helping to optimize production and reduce operating costs. LOOKOUT services use AI solutions for predictive maintenance on equipment and processes in the field. For maintenance optimization, APY's SPOTLIGHT sensors transmits information from compressors and engines back to ENTERPRISE and has helped customers reduce planned downtime by as much as 20%.

Sensia: Joint venture between Schlumberger and Rockwell Automation, focused on improving connectivity of various assets at the wellsite, both onshore and offshore.

- In February of 2019 Schlumberger and Rockwell Automation announced an agreement to create Sensia, a joint venture focused on providing fully integrated automation solutions. The deal closed in early October of 2019. With a focus on upstream (primarily production), Sensia is expected to generate ~\$400mm of sales in 2019 (closed 10/2/19), 15% of which is recurring. Sensia will offer cloud and edge-enabled process automation. 80% of revenue is expected to come from upstream (we assume primarily production), with 15%/5% coming from Midstream/Downstream. Sensia essentially automates the manufacturing on production and can be used on any production facility, including well heads, artificial lift, gathering and processing, separation & surface process automation, pipelines, offshore production, and more. It will operate as an independent entity, with ROK the majority owner (53%) and SLB the minority owner (47%). The TAM is ~\$5-6bn and growing at a double-digit rate, according to Rockwell management. Schlumberger brings the measurement and production optimization capabilities, while Rockwell helps more with the actual implementation and predictive maintenance.

Halliburton (HAL): ESP monitoring and production optimization capabilities.

- HAL offers real time monitoring and well surveillance of its Summit ESP product line, which can eliminate the need for manual interventions. Its web-based system gives HAL's monitoring group a full view of each well's equipment and operations. On

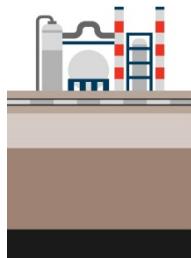
DecisionSpace365, HAL now offers its Digital Field Solver application, which help detect and solve production problems in real time with increased precision and speed.

Digital Innovators

Case Study: In a trial of 450 wells on rod lift, Ambyint was able to increase Equinor's overall production by 6%, (equates to \$80mm per year across its full field), 48% reduction in workover + maintenance costs, 10% reduction in electric/utility costs, and 5% reduction in labor efficiency savings.¹⁵

Ambyint (Calgary / Houston; Private, Not Covered): Software that enhances artificial lift operations using a combination of physics-based modelling, subject matter expertise and artificial intelligence to automate processes, diagnose anomalies and optimize production operations across all lift types. Proprietary physics models learn rapidly from increased data and use cases, engage with subject matter experts to be retrained and redeployed, and output results which can be applied at scale across all wells for production and artificial lift optimization

- Ambyint's optimization platform can be integrated seamlessly with other platforms (front-end and back-end APIs) and is cloud-agnostic. Each Ambyint application delivers one or more of four functional capabilities: Production Surveillance, Asset Optimization, Setpoint Management and Predictive Maintenance. Production surveillance becomes a more powerful tool when combined with lift optimization in one screen. Users can identify anomalies affecting the well, view setpoint changes generated by an advanced physics engine, and visualize the impact on production.



Potential opportunities

Decrease in unplanned downtime, reduction in opex, increase in production, optimize production.

Midstream/Downstream/LNG

To maximize utilization rates in the downstream and midstream parts of the business, the key is to reduce non-productive time (NPT) of rotating equipment, including turbines, compression, and motors. Using advanced sensors and creating a digital twin, artificial intelligence can predict failure of equipment and increase the uptime of facilities through preventative maintenance. The opportunity on Midstream, Downstream, and LNG facilities is also substantial, but it is more difficult to attribute a value. Scaling solutions across entire facilities represents a challenge, but also is demonstrative of the substantial opportunity.

There is additional opportunity on Midstream, Downstream, and LNG facilities, but it is difficult to attribute a value. For pipelines, opportunities include sensors to detect leaks and corrosion of assets, output can be maximized through real-time monitoring of compressors and other equipment, and drones can even be used to inspect pipelines. For refineries sensors can be used to not only monitor rotating and other equipment for predictive maintenance, but also to automate and optimize entire plants. Scaling across entire facilities provides a major challenge, but is also a massive opportunity.

Oilfield Service

Baker Hughes: Partnership with C3.ai is still in its early stages, but our sense is that the primary focus will be on the Midstream and Downstream markets, in particular, with its core customer Shell.

- In 2018 Shell selected C3 as its artificial intelligence platform and is now the first oil and gas company introduced into the Baker Hughes/C3.ai joint venture. The initial scope of the agreement covers midstream and downstream operations with the aim of expanding into upstream, unconventional and retail operations in the future. Shell has already adopted digitally over the last few years, and has operationalized a number of AI applications in predictive asset maintenance. The challenge was calling its internal digital platform up and out, which is where BHC3 comes in. The JV is rolling out a series of applications over the next few years to Shell (see details in Part VI), which we think is a good example of the potential this JV can have with other companies. Notably, BKR

¹⁵ <https://ambyint.com/bakken-formation-case-study/>

also has upstream offerings throughout the lifecycle of the well; however, we think in the near-term, the focus will remain on Midstream and Downstream.

Apergy: Monitoring and conducting predictive maintenance on pipeline compression and gathering lines.

- APY's asset integrity management of reciprocating compressor engines in pipelines and gathering lines has seen increased adoption over the past few quarters. Done through its SPOTLIGHT product line, APY typically completes proof of concept on a few compressors before seeing further adoption across product portfolios. Management highlighted that a compressor shutdown on a gas supply shutdown could cost between \$300,000-\$400,000 per week (vs. cost of ~\$30,000-25,000), and SPOTLIGHT is a cost-effective, easy-to-install data acquisition/analysis system that can perform critical analysis on the equipment. APY has seen as much as 20% decrease in planned downtime through SPOTLIGHT continuous monitoring. One large pipeline company already has ~200 APY sensors on it and today asset integrity is ~\$20-25 annually with an opportunity to grow.

Schlumberger/Rockwell Automation: We expect this JV to focus on Upstream (~80%), but the end markets of the JV extend beyond Production and will have additional opportunities in the Midstream/Downstream.

Case Study: The use of Digital allowed DCP to increase capacity from 365,000 bpd to 400,000 bpd, representing “tens of millions of potential margin opportunity¹⁶

DCP Midstream (DCP): Leveraging the capabilities of Digital, DCP monitors major field assets with its Integrated Collaboration Center.

- DCP Midstream has made Digital a priority. The company said that it is increasingly reliant on digital technology to run its business and operate assets. The DCP 2.0 digital transformation is a focus on increasing the use of Digital across all aspects of its business where it uses digital technology to conduct plant operations, to monitor pipelines, compressors, and pump meters, and to maintain various information databases. The strategy helped increase capacity from 365,000 to 400,000 barrels per day, which represents “tens of millions of potential margin opportunity” because the company is able to maximize volume capabilities since it knows real-time conditions. As part of the strategy, DCC opened an Integrated Collaboration Center that monitors major field assets 24/7, which it believes immediately improves operations and can also help with predictive analytics. As far as digital development goes, it is still likely in the early innings, despite the improvement in margin DCP has already been able to realize from it. So far the increase in capacity is largely attributable to optimization across the system increasing flowthrough, and it seems like opportunities on the horizon are cost optimization and the use of predictive maintenance.

¹⁶ DCP Midstream LP Earnings Conference Call May 8, 2018

Digital Innovators

Case Study: Major offshore O&G platform operator was able to reduce opportunity cost from production up to \$8mm per unexpected failure event through predictive maintenance monitoring in real time¹⁷

SparkCognition (Austin TX; Private, Not Covered): Using AI and ML for predictive and prescriptive analytics. Not only does it predict asset failures, but also gives details of the how and the why.

- SparkCognition delivers artificial intelligence systems “to advance the most important interests of our society”. SparkCognition has data science in its DNA, but also has SMEs on staff to help build out capabilities. Its **SparkPredict** application targets predictive maintenance, working on production platforms, refineries, turbines and generators, reciprocating compressors, and ESPs among other pieces of equipment. There is a massive potential for savings from predictive maintenance and production optimization, and in some cases SparkCognition has been able to help increase production on offshore platforms by as much as 4%. **Darwin** is automated machine learning technology which gives customers the ability to analyze data and build models without having a data science background (i.e. it can supplement engineers). Darwin use cases include helping predict which oil wells will require a workover and what the production will be like thereafter, allowing producers to focus maintenance crews on the wells that actually matter. While SparkCognition’s applications have use cases across the lifecycle of the well (drilling optimization, production, midstream/downstream), its midstream/downstream capabilities appear to be the most developed part of the offering.

Beyond Limits (Glendale CA; Private, Not Covered): Looking at the entire refinery on the device level and system level. Beyond Limits software understands the relationship that different units have, and can identify problems and make recommendations accordingly.

- Refineries are complex systems effected by a lot of different factors. Beyond Limits developed a system that looks at all of the refinery operations in conjunction. Starting at the device level and going all the way up to the system level, the systems have contextual awareness, i.e. they understand the relationship between different devices and can identify if a problem in unit 4 was caused by something that happened in unit 2, for example. In essence, it gives the operator a bird’s eye view of the operation and can diagnose problems and give recommended solutions.

¹⁷ https://learn.sparkcognition.com/white-papers/improving-offshore-production-with-ai-based-predictive-analytics?utm_medium=direct&utm_source=direct

PART VI

Enabling Technologies

The following analysis on p.66-71 is provided by Dave Anderson and Raimo Lenschow. Raimo Lenschow¹⁸, who is Barclays' U.S. Software analyst, provides his views on the software industry's intersection with Digital in the Oil & Gas sector.

The hype around digitalisation in Oil & Gas has until very recently been a classic case of over-promising and under-delivering. Over the last several years, not only has the technology caught up, but C-suite executives have embraced it as well, with many coming to realize that third parties can offer both expertise and cost effectiveness.

At the 2017 Barclays CEO Energy-Power Conference in New York, virtually every E&P in attendance spoke about a digital solution, talking up algorithms and the potential for big data to change operations. A totally different story emerged in 2019, with very few companies even mentioning internal digital efforts. That reflected a realization that building the aforementioned complete Digital offering was extremely difficult, costly, and time-consuming, especially in light of pressure to reduce SG&A and increase capital discipline. The digital market is just now starting to open up, fuelled by new technological innovations, advancements in programming and software architecture (open architecture & AI/ML algorithms), emerging business models, and increasing subject-matter expertise to move beyond proof of concept and scale up digital technologies to impact workflow and entire organizations.

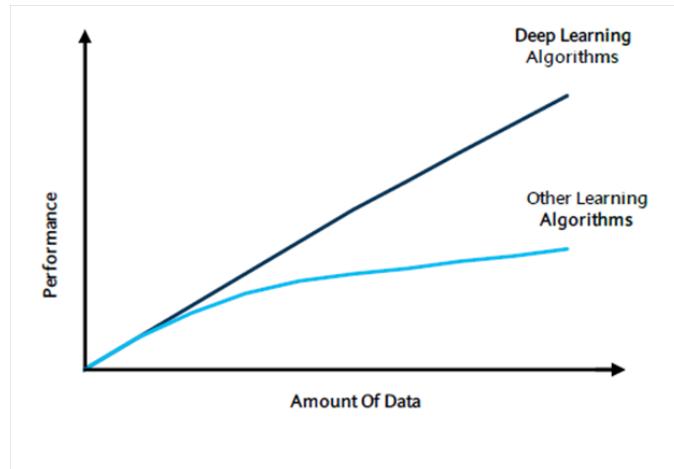
Cloud Vendors Biggest Enabler to Date

Cloud adoption (IaaS, PaaS) is not a new theme, but the market is substantial at \$50bn, with a high growth rate (+40%). The first wave of spending in public cloud was driven mainly by companies that are cloud-native (Netflix, Pinterest, etc.) and by test and development (non-production) workloads from enterprises. Now, established enterprises are starting to increasingly embrace the public cloud due to digitization, AI/ML technology maturing, compliance/regulatory concerns, regional data center footprints expanding, and advancements in hybrid computing.

Data is the starting point for developing AI or any sort of advanced analytical technology. The greater the amount of data that is fed through a machine learning module, the more accurate the predictions will become. Hence, large amounts of data are necessary to drive the success of the AI solution. An increase in data corresponds to an increase in machine learning capabilities and, ultimately, more intelligent applications.

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FIGURE 38
Deep Learning Algorithms Can Deliver Better Performance with More Data



Source: Baidu, Google

Cloud vendors have provided scale and driven down the costs of infrastructure and support around data analytics. In particular, we believe that the following are major catalysts for enterprises to store/use more data:

1. Scalable Infrastructure

Machine learning not only needs a tremendous amount of data, but also requires significant computing and networking capacity to run models. Pre-existing infrastructure in most sectors, including the Oil & Gas segment, is limited in its ability to process all of this data. Planning capacity for ML/AI (typically peak computing and storage needs) in-house makes little sense from a fiscal standpoint. Instead, companies such as Microsoft have developed cloud computing platforms to provide scale. At the same time, we have seen several catalysts on the infrastructure side:

Cost of compute is down 60% since 2012

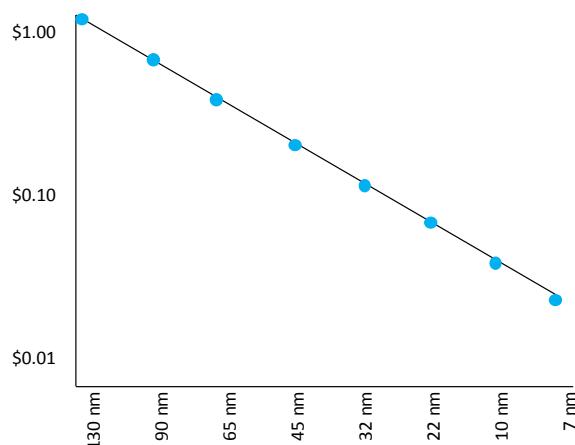
Processing costs have historically shown a reliable cadence of annual cost decreases and performance enhancements. The cost per transistor (proxy for computing cost) is down nearly 60% since 2012 but, more importantly, improvements to parallel processing and cloud computing have been significant in enabling machine learning and artificial intelligence. The greater the amount of data that is fed through a machine learning module, the more accurate the predictions will become. Hence, large amounts of data are necessary to drive the success of AI solutions.

Cost of storage down more than 80% since 2012

The cost of storing all of this unstructured data is also down significantly since 2012. Cloud vendors in particular tend to discount storage costs for customers in the hopes of eventually recouping money via value-added services. For example, Amazon's S3 storage costs are down nearly 90% since 2012, while overall storage costs are down ~80%.

FIGURE 39

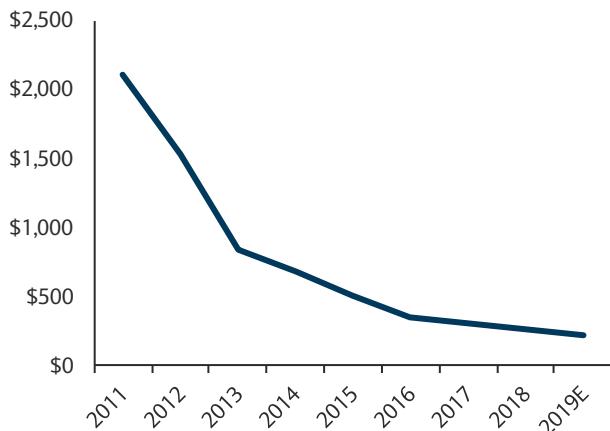
The Cost Per Transistor is Down Over 60% Since 2012



Source: Intel

FIGURE 40

Overall Cost of Storing Data Keeps Decreasing (\$ / terabyte)



Source: Barclays Research

Server network speeds no longer a bottleneck

Network speeds have increased 4x on average over the last few years and, more importantly, the market has recently introduced ports that are 100GBPs (ideal for large data transfer). With network speeds no longer a bottleneck to move data from server to server, enterprises don't need to have processing collocated with storage any longer. This has significant implications for how data can be stored and retrieved.

2. Algorithm Competency

Historically, the field of artificial intelligence has been experimental at best. AI has been in an experimental stage over the last few decades, but there has been a step change over the last few years with a correlation to the cloud providers scaling up. Cloud platform companies have been hiring industry experts from various industries to help develop machine learning algorithms that are specific to each sector. These algorithms are significantly reducing the time it takes to develop machine learning models that have practical application. This helps to reduce barriers to entry, as traditional industrial companies lack data scientists to create all this work from scratch.

Cloud companies have also been investing time and resources into developing ancillary functionalities such as computer vision, voice recognition, and natural language processing. These products are offered as APIs, where the functionalities can be tailored into the application they are developing without having to “reinvent the wheel.”

3. Development of Hybrid Products

Most public cloud vendors have introduced or announced an on-prem version of their cloud offerings. Having this product means that enterprises don't need to move their existing applications or all of their data to the cloud, but can instead extend on-prem applications to the cloud with minimal disruption. This essentially removes the largest barrier to entry for enterprises that have a large/complicated on-prem footprints.

However, these products have only been announced over the past 18 months and functionality/regional availability has been limited so far. As these solutions mature, we should see actual use cases where hybrid computing is able to lessen the burden for enterprises by allowing full use of existing infrastructure to harness the advantages of cloud-native applications.

Microsoft has an advantage here due to its legacy on-prem server business and was early to introduce a hybrid product, Azure Stack, which is essentially an extension of Azure that will consistently run hybrid applications on-prem. We have already seen this turn into positive results for Microsoft over the past year. Amazon announced a similar hybrid offering during its AWS re:Invent event (2018) that should soon start to see traction.

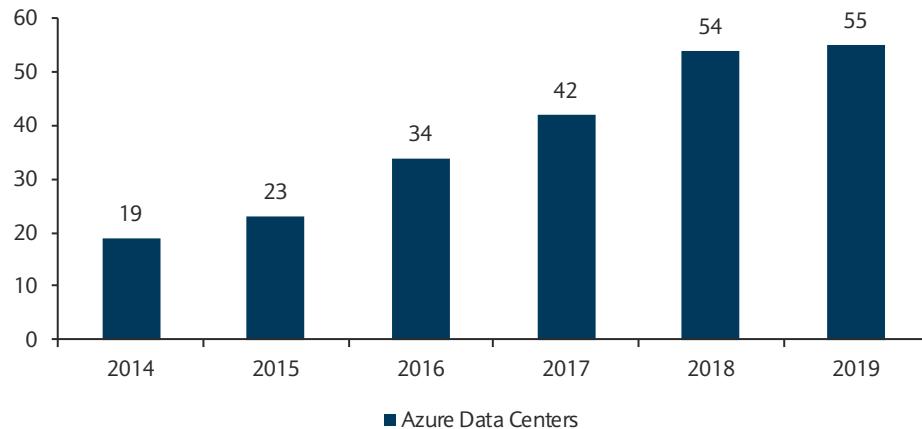
4. Regional Data Center Build-Out

Public cloud data centers have historically been concentrated in North America and Western Europe, which is a limiting factor for enterprises that have a global presence, or for companies looking to scale out to different geographies. However, the global market has seen a significant uptick in regional data centers over the past two years.

Microsoft increased its footprint from 34 to 55 data centers and AWS is expected to add a few data centers (currently has 22) this year, all of which are expected to be outside of North America. Having a sizeable regional footprint will be an important factor for many industries that are looking to move workloads to the cloud.

For example, gaming companies will have similar volumes of traffic coming from Asia and North America and need a global data center footprint. Also, companies looking to expand their presence outside of the US would be able to leverage public regional data centers instead of building out their own infrastructure or relying on an unfamiliar, potentially untrustworthy regional player.

FIGURE 41
Azure Data Center Footprint More Than Doubled Since 2015



Source: Company data.

Other Enabling Technologies and Trends

Edge Computing: Edge computing is the computation of data near the edge of your network, where the data is being generated, rather than in a centralized data-processing warehouse. This is particularly useful for remote operations. The diminishing cost of computing and sensors, increased data (internal and external), and smaller footprint of devices has helped the maturation of edge computation, according to Jane Ren of Atomiton.¹⁹

Rockwell Automation estimates that 75% of processing will be done on the edge in the next five years (not specific to Oil & Gas).²⁰ While the cost of computing and storage has been coming down dramatically, the cost to move data around from node to node is still

¹⁹ Forbes, “Moving To The Edge is Crucial For Oil and Gas Companies To Make Better Use Of Data”, May 5, 2019

²⁰ Rockwell Automation Annual Investor Slide Presentation November 20, 2019

an issue. Edge computing takes away this issue by not forwarding all data to a central location for processing.

Open-source systems. These are solutions where the source code can be modified so that the application can be tailored to specific use cases. They often have a wide community of developers.

Taking this concept a step further, the **Open Subsurface Data Universe (OSDU)** was created as an open-source standard data platform for the oil and gas industry. Data ownership has been an impediment to digital advancement and now major oil producers recognize the need to create a standards-based data set to reduce data silos, enable workflows, accelerate deployment of digital solutions and create a standards-based ecosystem.²¹ In essence, the goal is to enable applications created by different companies the access to a full suite of subsurface and well data that can run on the same data platform. The Open Subsurface Data Universe was established in 2018 and has nearly 100 members, according to its [website](#). In August, Schlumberger announced it was open sourcing DELFI and contributing it to the OSDU in order to accelerate the delivery of the data platform.

Cleaning, structuring, integrating data: Data comes a multitude of formats, depending on the application, the operating system etc. For the data to be useful, it first must be gathered, cleaned, and stored before it can be analyzed. One of the biggest challenges is integrating older, unstructured data into a comprehensive data set that can be used to build algorithms. Merging and processing this data has become a critical industry, where cloud providers, OFS companies, industrial companies and digital innovators have seen an opportunity over the last few years.

There are a few companies that primarily focus on cleaning and structuring data, including Cognite and Sfile, and we believe that the Big Tech companies are working on this as well. While progress has been made, there is still a long way to go.

Software as a Service (SaaS). Traditionally, software in the oil and gas industry has been sold through perpetual licenses that are installed and run on the premises of the customer with its native computing resources. The new model is to sell the software as a subscription model, whereby the customer accesses a suite of software that is centrally stored and accessed over the internet through a public cloud vendor (Azure, AWS). Customers will typically pay a monthly subscription price or on-demand usage fee for applications which may be on the basis of compute hours, the number of wells, or for a specific task. *The SaaS model allows for more rapid innovation (continual updates), increases customer penetration (easy access), decreases upfront costs (no infrastructure to host the application) and creates a more reliable revenue stream for the platform developer.*

Digital acceptance needs to move beyond the C-Suite. Part of the over-promise, under-deliver paradigm for digital transformation in oil and gas over the past several years has been that while the technology has found broad acceptance within the C-suite, it has met resistance at the operating level. The oil and gas industry is almost 150 years old and is notoriously averse to technological change, instead relying heavily on experience and institutional memory. While new advances in equipment and techniques have improved drilling and completion operations, the next step change in efficiencies will only come from Digital being applied across all facets of the well lifecycle, which needs buy-in at all levels of the operation.

Combining oil and gas industry domain knowledge with data analytics capabilities. One of the crucial parts of developing a competent digital product is marrying data science

²¹ <https://www.opengroup.org/osdu/forum-homepage>

know-how with domain expertise in O&G (subject matter experts). We believe that in the long run, the most successful companies will be those that have invested resources and hired experts in both camps.

One of the lessons of the past several years has been that you can't do it alone in Digital - you need to bring in third parties who can provide unique expertise. US E&Ps have difficulty in building out software teams and analytical tools on their own, while technology companies don't have sufficient knowledge of the oil and gas industry to gain customer acceptance. The key is to combine the two, marrying analytical capabilities with industry domain expertise.

PART VII

Appendix: Additional Company Details on Digital Offerings

Apergy: An early adopter of Digital, Apergy believes that its SME and digital knowledge give it an advantage in creating solutions for customers. Apergy focuses on production and maintenance optimization; the two top priorities of customers that can have a tangible impact on the bottom line. APY's ENTERPRISE platform ties together the hardware/software into a single platform for customers and can be coupled with integrated with partner platforms to integrate data and increase the value added for customers. ENTERPRISE can be run both on prem and off prem. Apergy's digital solutions for artificial lift can be used throughout its suite of artificial lift offerings. Importantly, Apergy hardware and software can be used on artificial lift equipment that is not its own. SMARTEN is the edge controller for continuous monitoring and control, XSPOC is the software that utilizes information on the edge and in the cloud, LOOKOUT provides predictive failure analytics and Bloodhound can be used to optimize gas injection in gas lift. APY customers have seen as much as a 10-15% increase in production, 25% reduction in operating expenses (chemical costs, compressor utilization), and a 20% reduction in unplanned downtime.²² SPOTLIGHT is Apergy's maintenance optimization IIoT device, which is easy to install and use. Information is transmitted directly to ENTERPRISE which can help predict failures and reduce unplanned downtime while increasing asset efficiency. SPOTLIGHT is typically used on engines in compressors in upstream/midstream/downstream. As a point of reference, a compressor shutdown in a gas pipeline could cost between \$300-400k per week.

Baker Hughes: Of the Big 3, it is hardest to project the impact over the coming years for BKR. Baker Hughes does have a legacy Digital Solutions segment that consists of a hardware (90%+) and software component to it. Digital Solutions is comprised of Bently Nevada (~25%), Pipeline inspection & commissioning (~25%), Inspection Technologies (~20%), Measurement & Sensing (~15%), and Control Solutions (~15%). The Predix component within the software has begun to roll off as BKR made the decision to transition away from it in late 2018. There will still be a small software component within Digital Products, but the main digital impact as we define it in our report for Baker will be through its C3.ai joint venture. Management identified that if Baker Hughes continued trying to build a full-scale digital solution internally (Predix), it would 'miss the market' (their words, not ours) because it would have taken an additional ~2 years to develop, which led to the joint venture agreement with C3.ai. In June of 2019, BKR entered into a joint venture with C3.ai, the world's leading provider of enterprise-scale artificial intelligence applications. For an undisclosed fee Baker took an undisclosed minority interest in C3.ai, and received one board seat. The deal marries BKR's SME with C3.ai's AI domain expertise, and we are of the belief that it can have a profound impact on the industry over the longer term. Tom Siebel, the founder and CEO of C3.ai, is a visionary Silicon Valley entrepreneur that previously pioneered customer relationship management (CRM) software. According to Mr. Siebel many companies have tried to build an AI platform on an industrial scale, but C3.ai is the first to succeed after spending over \$600mm on the infrastructure. The interconnection of software programs necessary to build a successful suite is immensely complicated, and C3.ai has built one of the only commercially deployed AI systems. Several large customers have already adopted the C3.ai suite, including Enel, ENGIE, 3M, and the US Air Force. Shell has also been an early adopter, and could be the industry model for Oil & Gas. Pricing for the services is based on an annual subscription license for the software based on number of

²² Apergy Investor Day March 8, 2019

developers and a run-time fee based on the number of CPU hours each application is used. Baker Hughes will realize benefits in four different ways. First, the sales model with C3 where Baker Hughes will get commissions and services work associated with software that is sold by C3.ai, which will flow through its Digital Solutions segment (likely 10-20% of the value of the software contract). Second, there will be hardware and equipment sales pull through. In the short term it will be primarily sensors and lift products, but as the model evolves there should be an opportunity on compressors and RSS among other equipment types as well. Third is the internal productivity benefit. BKR will pay C3 a licensing fee that is materially less than the \$60-70mm that they were spending annually internally on digital capabilities. Last but certainly not least is the value of the investment in C3.ai. BKR's minority stake should increase as C3.ai continues its growth. Although it is nearly impossible to quantify now, Baker Hughes' opportunity is substantial over the long-term.

Halliburton: Halliburton groups Digital into three different buckets, which is aligned with how they are addressing their customers' objectives. First is Reservoir, which improves understanding of the sub surface to reduce uncertainty and improve exploration success/recovery. Second is Drilling and wells engineering & operations. Third is Reservoir-centered Completions and Production which aims to lower cost/bore while simultaneously maximizing recovery. Its digital solutions are sold through its Landmark product service line. Landmark was purchased by HAL in 1996 for more than \$550mm and while it likely looks very different than the company that was bought in the 1990s, this is where its digital DNA came from. Landmark is in HAL's D&E segment, though some parts of its broader digital offering are likely also in C&P. For the sake of quantification in this report, we are focused on its Landmark Solutions portfolio. HAL made the decision to pivot to the cloud more than 3 years ago and hybrid Cloud, HAL's solutions include DecisionSpace365, which is a suite of E&P SaaS applications. Applications address Exploration & Reservoir Development (Assisted Lithology Interpretation, Full-Scale Asset Simulation, Seismic Engine, Scalable Earth Modeling), Well Construction (Holistic Field Development Planning, Well Feasibility & Detailed Design), and Production (Digital Field Solver). Other important software in HAL's offering includes the Neftex Insights geological interpretation software and ARIES economic planning software. HAL's digital offering extends beyond software and into the redesign of equipment for both surface and subsurface applications. Management emphasized that the digital technologies, software and services go through the same investment returns and other customer requirements as other decisions HAL makes. With that being said, there are a number of important technologies worth highlighting across the lifecycle of the well. For Reservoir Characterization, the EarthStar ultra-deep resistivity service, which is a LWD technology that can map the reservoir and fluid boundaries up to 225 feet from the wellbore. For Drilling there is iCruise, Logix, Baralogix, and Cerebro. iCruise is the intelligent Rotary Steerable System that uses electronics, algorithms, sensors, and high speed processors to maximize ROP. It allows for drilling automation that can decrease NPT and improve well placement. LOGIX is HAL's Automated Drilling Director that uses physics-based models and machine learning. Baralogix provides real-time analysis of fluids data that can help keep operations on track. Cerebro is an electronic data capture system that allows Operators to get a high-speed look at data captured from the bit. For Completions HAL has Prodigy Intelligent Fracturing Services, which automates fracturing to optimize execution parameters as well as SmartWell systems that collect, transmit and analyze downhole data. For Production HAL offers real time monitoring and well surveillance of its Summit ESP product line.

Helmerich & Payne: HP offers FlexApps through its operating platform that offer different capabilities (similar to NOV's NOVOS), which are for the most part exclusive to H&P rigs. Examples of application functionalities include lower vibration, optimize slip-to-slip connection time, and automate drill string rotation. In our view the more differentiated, value add part of the offering comes from the acquisitions it has made which include MOTIVE, MagVar,

AutoSlide and most recently DrillScan. The company likens MOTIVE (currently on 25 rigs) to Google Maps. It is an automated bit guidance system that does the calculations to drill the well according to the plan, providing an output for the directional driller while eliminating the human in the decision making process (but not the execution). Autoslide was born out of MOTIVE and is the next evolutionary step, where it will actually be “pulling the knobs and the joystick” and directing the rig without human interaction. MagVar is a downhole tool corrective software that reduces the ellipse of uncertainty for where you are actually drilling by 50-60% vs. competing products. DrillScan can help select the optimal equipment to use based on well design and the type of well operators want to drill.

National Oilwell Varco: NOV has developed the NOVOS system, which aims to fully automate the oil rig. The system has been installed on at least 20 rigs. NOVOS has a collection of 32 apps that operate based on downhole data collected by wired drill pipe. Those apps have different levels of automation. Some are meant to guide the driver of the drill while others aim to completely automate the system. In a 5-part trial with Equinor where drilling decisions were based off of insights from wired drill pipe, BHAs used were reduced by 33%, FPD (feet per day) was increased by 25%. Furthermore, insights discovered in the trials enhanced understanding of surface data so much so that adjacent rigs without wired drill pipe increased at a faster rate than the original trials.

Schlumberger: Schlumberger has made Digital a priority, investing over the last few years internally to build out its offering. Management said that it has more than 1,000 software engineers, and has devoted ~50% of R&D spend to Digital (no time frame given, but total R&D for '18 was ~\$700mm). DELFI, a cloud-based E&P environment that has the ability to connect people, data, and applications across the lifecycle of the well, is the focal point of Schlumberger's offering. One of the advantages of using a product like DELFI is that it can connect planning and operations through all of the domains involved (subsurface, drilling, production) and put together a holistic workflow incorporating all of the data that can be accessed by people in different places at the same time, increasing collaboration. DELFI has three “suites” (subsurface, drilling, and production), and data can be shared and integrated across different phases of the well to extract more value. Legacy solutions (platforms and applications) have been deployed on DELFI including DRILLPLAN (well planning), DRILLOPS (drilling performance optimization), DRILLING INTERPRETATION (real-time drilling monitoring and analysis), and PETROTECHNICAL SUITE (also known as “Petrel”, reservoir software). At its 2019 SIS Global Forum, SLB introduced four new native applications in the DELFI environment: ExplorePlan (exploration planning solution), DrillOps (on-target well delivery ensuring rig performance), FDPlan (agile field development), and ProdOps (risks/insights for production operations) Other important parts of the Digital offering for Schlumberger include the Sensia joint venture with Rockwell Automation (closed on 10/2/19, focused on Production/Midstream/Downstream), edge opportunities (includes rig of the future), the reservoir product line portfolio (new intelligent wireline formation testing platformed, “Ora”, announced 9/18/19), and WesternGeco. The closing of Sensia was announced on 10/2/19 by SLB and ROK. SLB contributed ~500 employees, measurement instrumentation software and analytics, and artificial lift technologies, which account for more than half of the estimated run rate revenue of ~\$400mm and are higher margin than the expected ~22% EBITDA of the JV (based on ROK commentary). SLB did get \$250mm from ROK at the time of the deal close, but only has 47% ownership of the JV. While DELFI has more of a focus on production optimization, Sensia is more focused on asset optimization (competes with BKR), and will use automation and software capabilities to control and optimize equipment on production, midstream, and downstream. We do note that Sensia will still leverage and be integrated within DELFI. At our CEO Conference in September Schlumberger said that they had more than 30 producers on site to look at the rig of the future in the prior 3 months, with some committing to using it and others committing to use pieces of it. Reservoir characterization is embedded in SLB's roots, and

the company has been thought of as the industry leader. At the SIS forum it announced the ORA intelligent wireline formation testing platform. The digitally enabled hardware can automate complex workflows and reduce operating time by more than 50%. Since the platform is built on digital cloud-based infrastructure it can enable real-time decisions. Schlumberger also introduced its GAIA Digital Exploration Platform, which will leverage the power of DELFI to provide a personalized experience that enables the discovery, visualization and interaction of all available data in a region or basin, which helps with the transition of WesternGeco to a more asset-light model.

ANALYST(S) CERTIFICATION(S):

In relation to our respective sections we, J. David Anderson, CFA, Raimo Lenschow, CFA, Lydia Rainforth, CFA, Mick Pickup, William Thompson, Jeanine Wai, Christopher Tillett, CFA and Julian Mitchell, hereby certify (1) that the views expressed in this research report accurately reflect our personal views about any or all of the subject securities or issuers referred to in this research report and (2) no part of our compensation was, is or will be directly or indirectly related to the specific recommendations or views expressed in this research report.

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Materially Mentioned Stocks (Ticker, Date, Price)

Apergy Corporation (APY, 13-Jan-2020, USD 31.52), Overweight/Neutral, CD/CE/J

Baker Hughes Company (BKR, 13-Jan-2020, USD 24.41), Overweight/Neutral, A/CE/D/J/K/L/M/N

BP (BP.L, 13-Jan-2020, GBP 4.97), Overweight/Positive, A/CD/CE/D/E/GE/J/K/L/M/N

CGG (GEPH.PA, 13-Jan-2020, EUR 2.91), Equal Weight/Positive, CD/J/K/N

Eni (ENI.MI, 13-Jan-2020, EUR 14.04), Underweight/Positive, A/CD/CE/D/E/J/K/L/M/N

EOG Resources, Inc. (EOC, 13-Jan-2020, USD 85.52), Overweight/Positive, CD/CE/E/J/K/L/M/N

Equinor (EQNR.OL, 13-Jan-2020, NOK 180.90), Overweight/Positive, CD/CE/J/K/M/N

Halliburton Co. (HAL, 13-Jan-2020, USD 23.75), Equal Weight/Neutral, CD/CE/J/K/M/N

Schlumberger Ltd. (SLB, 13-Jan-2020, USD 39.23), Overweight/Neutral, CE/J

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European Integrated Oil & Refining

BP (BP.L)	Eni (ENI.MI)	Equinor (EQNR.OL)
Galp Energia (GALP.LS)	Neoen (NEOEN.PA)	Neste (NESTE.HE)
OMV (OMVV.VI)	Repsol (REP.MC)	Royal Dutch Shell A (RDSa.L)
Royal Dutch Shell B (RDSb.L)	Saras (SRS.MI)	Total (TOTF.PA)

European Oil Services & Drilling

Aker Solutions (AKSOL.OL)	CGG (GEPH.PA)	Hunting (HTG.L)
Maire Tecnimont (MTCM.MI)	Petrofac (PFC.L)	Petroleum Geo-Services (PGS.OL)
Saipem (SPMI.MI)	SBM Offshore (SBMO.AS)	Subsea 7 SA (SUBC.OL)
TechnipFMC Plc (FTI.PA)	Tecnicas Reunidas (TRE.MC)	Tenaris (TENR.MI)
TGS (TCS.OL)	Vallourec (VLLP.PA)	Wood (WG.L)

North America Oilfield Services & Equipment

Apergy Corporation (APY)	Baker Hughes Company (BKR)	Cactus, Inc. (WHD)
Covia (CVIA)	Diamond Offshore Drilling (DO)	Dril-Quip Inc. (DRQ)
Forum Energy Technologies Inc. (FET)	Frank's International NV (FI)	FTS International (FTSI)
Halliburton Co. (HAL)	Helmerich & Payne Inc. (HP)	Liberty Oilfield Services (LBRT)
Mammoth Energy Services, Inc. (TUSK)	Nabors Industries (NBR)	National Energy Services Reunited Corp (NESR)
National Oilwell Varco (NOV)	NexTier Oilfield Solutions (NEX)	Noble Corp. (NE)
Oceaneering International (OII)	Patterson-UTI Energy (PTEN)	ProPetro Services (PUMP)
Quintana Energy Services Inc. (QES)	Ranger Energy Services (RNGR)	RPC, Inc. (RES)
Schlumberger Ltd. (SLB)	TechnipFMC Plc (FTI)	Tenaris S.A. (TS)
Transocean Ltd. (RIG)	U.S. Silica Holdings, Inc. (SLCA)	Valaris plc (VAL)

U.S. Integrated Oil & E&P

Apache Corporation (APA)	Brigham Minerals, Inc. (MNRL)	Callon Petroleum (CPE)
Centennial Resource Development (CDEV)	Chevron Corporation (CVX)	Cimarex Energy (XEC)
Concho Resources Inc. (CXO)	ConocoPhillips (COP)	Continental Resources, Inc. (CLR)
Devon Energy Corporation (DVN)	Diamondback Energy (FANG)	Encana Corporation (ECA)
EOG Resources, Inc. (EOG)	Extraction Oil & Gas (XOG)	Exxon Mobil Corporation (XOM)
Hess Corporation (HES)	Magnolia Oil & Gas (MGY)	Marathon Oil Corporation (MRO)
Noble Energy, Inc. (NBL)	Oasis Petroleum Inc. (OAS)	Occidental Petroleum Corporation (OXY)
Parsley Energy (PE)	PDC Energy Inc. (PDCE)	Pioneer Natural Resources Company (PXD)
SM Energy (SM)	Viper Energy Partners LP (VNOM)	Whiting Petroleum (WLL)

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IMPORTANT DISCLOSURES CONTINUED

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