"Valuable advice on how progressive energy leaders can turn disruptive challenges into a generational opportunity." PETER TERTZAKIAN, EXECUTIVE DIRECTOR, ARC ENERGY RESEARCH INSTITUTE

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BITS, BYTES, AND BARRELS

The Digital Transformation of Oil and Gas

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WHAT IS "DIGITAL"?

Data, Analytics, and Connectivity

DESPITE THE NEAR-UNIVERSAL use of the term "digital" to represent features of our modern economy, there is no shared definition of what digital actually is. To an engineer, digital could be the opposite of analog. To a millennial, digital is an integral part of everyday life. To a lawyer, digital could be a new kind of asset that has different intellectual property rights. To a banker, digital is the way of business in the future.

I am constantly asked to define digital, and frankly, it's devilishly hard. But my best examples include three key building blocks that together create something that most people generally concede is a digital device, solution, or service.

- Data—data is the lifeblood of digital. A digital device, solution, or service produces and uses data.
- Analytics—a digital device, solution, or service has the ability to carry out calculations and computations on the data.
- Connectivity—a digital device, solution, or service uses a telecommunications network that allow digital devices to connect with one another to exchange or share data, or computations.

Something that is digital (and that something could be a physical thing, a process, or a business model) has these three basic elements operating together in some configuration.

A smartphone is an excellent example of a digital thing: it has data, such as address books, music files, and maps; analytics, which are apps that carry out calculations, such as the distance between two points; and connectivity, since a phone, by definition, can use the cell phone network and likely has multiple network connection technologies embedded within, including Wi-Fi and Bluetooth.

Other examples of digital things in the oil and gas world include:

- Tank gauges—Fuel tank gauges have shrunk in size, cost, and power demand while expanding in capability. Australia's unmanned outback airports have gauges on their tanks that give fuel providers real-time visibility to tank contents, so that the tanks can be replenished when needed.
- Cars—Next-generation vehicles are packed with digital smarts to allow them to communicate with each other and with smart transportation environments. Porsche is embedding blockchain technology in its sports cars.
- Valves—With sensors and actuators falling in cost, even traditionally dumb devices like valves can be brought online, generate their own data feed, and tie into supervisory systems. The same for drill bits, flow-measurement devices, motors, and filters (the basic building blocks of process manufacturing).

JUST ABOUT ANYTHING can become digital and participate in the digital world. Here's a perhaps silly example, but one that's instructive: a fish tank, albeit a high-tech one with lots of sensors to monitor temperature, salinity, lighting, and pH balance, included a network connection that sent the data the sensors collected to a remote monitoring system. A digital fish feeder was recently exploited by criminals to steal log-in IDs and passwords from a casino.

These three building blocks (data, analytics, and connectivity) share a common foundational technology, which is the lowly computer chip. As chip technology advances, the cost of earlier generations of chips falls to zero (manufacturers basically give them away) and it becomes economically feasible to incorporate chips into almost everything. They become smaller, thinner, lighter, and, most critically, they need very little power to operate. It is the chips that store the data, provide the computations, and enable the telecommunications computers that drive the network connections.

We've all read about the exponential growth curve of transistors and now computer chips and about this growth's impact on the electronics industry (see sidebar). It turns out that the three components that make something digital (data, analytics, and communications) are each experiencing massive expansion because they are themselves based on computer chips.

GORDON MOORE, THE co-founder of leading computer-chip maker Intel, noted with curiosity in 1965 that the density of transistors on a computer chip appeared to double every year. This rate, a consistent doubling per unit time, is called Moore's law. Things that demonstrate this kind of exponential growth rate early in their life cycle bear watching as they appear to suddenly become very large without notice. Many things in the digital world share this phenomenon.

Occurring in parallel with the exponential growth rate in capability is an exponential fall in cost. At some point, the capability of a digital thing is effectively infinite in terms of data storage and processing—and practically free as the cost approaches zero. Where the oil and gas industry has always worked in a world of constraint, digital is creating a world of abundance.

I first began to notice the impact of digital on my own life when I was traveling on business. Fifteen years ago, the sole electronics that I might have packed for travel included a laptop and portable phone. Today I travel with a jumble of electronics, including a smartphone, a smart watch, digital pens, a tablet, the company-issued work laptop, mouse, wireless headphones, wireless earbuds, spare rechargeable batteries, plus all the cabling and outlet jacks. Rarely do hotels offer anything close to the number of outlets I need to recharge everything. Soon, articles of clothing and luggage will be electronic and the hunt for hotel room electrical outlets will become even more pressing.

THE DATA TORRENT

The volume of data our societies create, represented as zeros and ones in a storage device, have been growing by truly staggering amounts. According to the International Energy Agency (IEA), IBM estimates that between 2015 and 2016, the world generated almost as much data (90 percent) as already existed in all of the world's storage systems. Our devices and our increasingly digital lives contribute to this growth rate in many ways.

- A high-quality photo comprises eight to ten megabytes of data. Most of us do not even discard photos anymore. They simply pile up on our phones and home computers.
- A high-quality ten-minute video taken on our smartphone takes up 1.5 gigabytes. Four hundred hours of video are uploaded every minute to YouTube.
- A typical flight produces a terabyte of data, and autonomous vehicles and trucks will generate similar data volumes.

Industrial data volumes are not growing at quite the same pace as consumer data, but that's because industry has not yet equipped all its various assets, tools, and people with sensors. But as industrial assets become data generators, they will match the prolific data generation of humans. An Airbus or Boeing aircraft is festooned with hundreds of sensors that produce discrete data measurements every tenth, hundredth, or thousandth of a second throughout a flight.

A NEW REFINERY, Canada's first in a generation, rises from the industrial land northeast of Edmonton and will incorporate 25,000 sensors, an order of magnitude more than its predecessors. Each sensor will generate a steady flow of measurement data every second. The future of digital plants has arrived in oil and gas.

Beyond the growth in volume, data is also changing shape. Early generations of computer systems could only process highly structured data, such as rows and columns on a spreadsheet, in the form of numbers and letters. But modern data can take almost any shape, including unstructured data like photographs, waves, sounds, video, and sensations like vibrations and smells.

The DNA of living things can be represented as data, a very important development. Industry will soon be able to tell the provenance of a thing or substance by investigating its DNA and comparing it to a registry of DNA samples. The oil and gas industry is not far from a future where it will be able to take a sample of a barrel of oil and identify which oil basin it came from by testing microbes found in oil samples (although perhaps not after crude oils are blended in pipelines and tanks). Ethical producers of oil, those nations that invest more to protect the environment, will be able to command a premium for their product.

An emerging challenge is how to analyze this flood of data. Tools and techniques for data analysis, interpretation, visualization, and monitoring need to keep pace with the growth in data volumes, the flow of that data from one location to another, and the analytic demands of data users. The spreadsheets of the past are simply not up to the task.

CHEAP MATH

Analytics, a term for computer horsepower, is also demonstrating the same rapid development and growth as data, which isn't surprising because analytics are carried out on computer chips, too (though not the same chips that store data). Think of "analytics" as consisting of these math computer chips mounted on circuit boards and the software that carries out the math. Both data and math chips have been advancing with vigor, and along important lines:

- Chips can be both highly specialized (for such intense tasks as video gaming or robot controlling) and generalized (for laptop and desktop computers). Car makers now use video-gaming chips' ability to process visual data as the basis for autonomous car navigation systems.
- Sensors are basically chips. Inexpensive sensors for GPS, orientation, cameras, light, sound, and speech-processing are all just math chips with embedded software.
- Chips need power to operate—to keep them running longer and more continuously. To prevent them from overheating and depleting their batteries, engineers have been designing them to be power-stingy, and power consumption has been falling with each generation of chip.
- Along with their power profile, physical size, and capabilities, their costs have fallen dramatically, allowing chips to be installed in many unexpected devices including pumps, valves, and gauges.

We can see the impacts of these developments on a personal level. My Apple Watch, which retails for a few hundred dollars, has the equivalent analytic capability to a multi-million-dollar Cray supercomputer from the 1980s. A smartphone has much the same capability of the mainframe systems that enabled NASA's moon-shot programs in the 1960s, and, in just ten years, smartphones advanced from a novelty to a must-have for modern life.

Industries have varied in their drive to put sensors onto things, but the pace of adoption is accelerating. Roland Berger estimates that 15 billion smart sensors were installed globally in 2015, but by 2020, the number of sensors is expected to be greater than 30 billion. This phenomenon is giving rise to the Industrial Internet of Things (IIoT)—pumps and motors, valves and gauges, pipes and tanks, wires and switches are being fitted and retrofitted with sets of sensors. Once in place and live, the sensor adds to the flood of data, draws on the power grid, and creates demand for connectivity to send that data elsewhere.

The prize for industry is enormous. Greater visibility through sensors means that health and safety issues, like leaks and spills, can be detected faster, even before they occur. Better understanding of equipment performance means equipment can run longer and at higher rates without failure. Faster collection and processing of more accurate field data means faster payment by oil companies for the services they purchase.

Chips that can perform calculations need software code to execute the math. Similar to the chips, software development shows the same exponential growth characteristics.

- Programming languages are becoming easier to learn. They feature drag-and-drop interfaces, high reusability, and standardization so that coders are more productive. Compute needs like sorting, analysis, and mapping are simple and built-in.
- Programming languages are becoming more ubiquitous and common to multiple uses, rather than specialized by asset or application. Recruiting coders is much easier.
- The use of common chip sets means the development of industrial software for a piece of equipment is not dramatically different from coding for a commercial system or a web application.
- It is now acceptable for companies to rely on open-source code—software that is developed freely and shared openly—which both accelerates the delivery of new solutions to business and lowers the cost.

BIG PIPES

The final building block in a digital world is connectivity. Without connectivity, a device that has data and analytics is just a calculator and, these days, not a very useful calculator.

Low-cost chips, analytics, and software development have helped transform the telecommunications sector in just one human lifetime to enable extraordinary connectivity. From 1991, with the launch of 2G, the telecom industry has progressed to 3G, 4G, LTE, NFC, Bluetooth, and now 5G.

As a result, the world is becoming highly interconnected. According to the IEA, at the dawn of 2016:

- the number of households globally with Internet service was around 54 percent, compared to 80 percent that had access to electricity, concentrated among developed nations, but accelerating in the developing world;
- the number of individual Internet users was about 3.5 billion;
- the number of mobile phone subscriptions, a measure of the number of users able to tap into digital services, reached 7.7 billion; and
- the number of inanimate objects or things that are connected to the Internet is estimated to be about 8 billion and will grow to 30 billion by 2030.

The volume of data that networks move provides a good indication of the penetration of and demand for connectivity. In 1974, the total amount of data that was transmitted on worldwide networks in a month was one terabyte. By 2016, worldwide networks move one terabyte every second, an increase of 2.5 million times.

There are no signs that this volume of data is flattening out. If anything, the growth in the number of sensors and the greater capability of analytics suggests that data volumes are likely to continue to grow. Indeed, certain technical innovations in our digital world are still very early in their own adoption life cycle (such as autonomous vehicles), suggesting that the demand for data connectivity has serious propulsion.

CANADIAN NATURAL RESOURCES, a leading oil producer, had entered into an auction for telecommunications spectrum in competition with the nation's wireless providers. Effective telecommunications have become a priority for large industrial concerns who need better networking capabilities for the future.

One clear issue for the oil and gas industry, even in very developed nations like Canada, and still very pressing in developing nations, is the lack of robust and ubiquitous telecommunications infrastructure. Oil and gas is often found far from concentrated areas of civilization, and telecom companies have been slow to roll out network connectivity. This continues to plague both Australia and Canada, as well as the offshore industry in general. Telecom technology still suffers from intermittency during weather events, a serious challenge for dangerous infrastructure that needs constant supervision.

LESSONS FROM THE FRONT

While the digital wave of change has had only a modest effect on oil and gas to date, early adopters in other industries have been much more profoundly impacted. Several lessons about digital warrant consideration for later adopters, such as oil and gas, in order to avoid the same pitfalls and to take full advantage of digital's might.

New Business Models

The most important insight is that digital solutions unlock new and different business models, where value is exchanged in exciting new ways. For example, PlantMiner aggregates spare capacity of earth-moving equipment and makes that capacity available to a global market; it's one of several similar services. Cars2Go can turn virtually any parking spot into a rental car kiosk, eliminating the tediousness of rental-car contracting. Whim, a startup in Finland, is pioneering the idea of mobility as a service where its customers have unlimited access to rental cars, shared cars, taxis, buses, ferries, Uber, and rental bikes for a low monthly subscription fee. GasNinjas is an app that allows car owners to purchase fuel and have it delivered to their vehicle; without owning fuel stations, GasNinjas is in the fuel retail business and can even outsource the fuel delivery truck.

What's fascinating about many of these business models is how they tend to be asset-light and information-intense, placing more value on data than on infrastructure. Many in the world of commodities and heavy industry still believe pretty profoundly that asset ownership and ownership of all asset-related data is the key to economic success. At some stage, the risk is that a new entrant will figure out how to run a heavy industry company without owning the assets.

AN EMERGING SERVICE in the oil and gas industry is called Digital Oil Recovery: an oil company provides some of its underperforming assets to a more digitally savvy operator who then applies the latest in digital thinking to the assets. Both win by sharing the improved production, but the digital service company gains more from the experience. It is not a stretch to see how such a digitally advanced company may become the Uber for the production industry—all the software, but none of the assets.

The Importance of Ecosystems

With the digital world evolving in so many dimensions at the same time and at a pace vastly faster than most organizations can absorb, players quickly conclude that they cannot do it all, and certainly not at a level of excellence. Digital entrants tend to specialize in some niche area to achieve early cash flow and some market position and dominance. Ecosystems of connected organizations tend to emerge, with a few large anchor companies and a halo of smaller specialist outfits.

Ecosystems are everywhere in the digital world. For example, much of this book was written using an Apple iPad Pro, and at one time I thought almost the entirety of the iPad's capabilities were the product of the talented team in Cupertino. But a quick look at the legal notices on the iPad reveals dozens and dozens of companies whose intellectual properties have contributed to Apple products. Apple clearly recognizes that it does not have a monopoly on good ideas and innovation, and so nurtures an ecosystem of companies whose technologies can play a role in the Apple product line.

Successful companies that pursue digital seem to do so in the context of a successful ecosystem, either as large anchor players, like Apple, or as technology specialists. Companies that choose to go it alone are at a disadvantage.

The Network Effect

The telephone introduced us to the network effect, a phenomenon whereby the bigger the network, in terms of nodes or nodal points, the greater the value of being on a network. Having a phone is of little value if you have no one to call, but once everyone has a phone, being on the network becomes indispensable. Further, the cost to add one more node becomes practically zero.

Digital innovators design solutions in anticipation of the network effect, to achieve maximum participation as quickly as possible by all those connected phones, users, and devices. Designers use existing cloud services to avoid creating their own compute infrastructure. Software gets distributed using app stores, not in-house CD burners. The user interface is so simple to use and intuitive that training is not offered and not required. Software is often open source so that it is freely available to anyone to incorporate into their own digital innovation and it replicates quickly across solutions.

The network effect has other benefits. Large networks deliver scale, reduce costs, and improve the productivity of its users. Innovative enhancements can be quickly and cheaply delivered. Value-added services (yesterday, the Yellow Pages; today, search, trending, and analytics) become revenue generators. The bigger the network, the greater the value of these attributes.

Speed to Market

Digital solutions demonstrate an entirely different pace of adoption than their non-digital counterparts. At the time of Edison, the rollout of the phone system took years. Few companies had the scale of operations or the balance sheets to build out national or global systems quickly. Even hiring enough workers to build a physical network system required an enormous effort.

These constraints have been largely removed for digital innovations that leverage ubiquitous networks, billions of smartphones, and cloud computing. Now, almost anyone with a good idea can build a global solution at breathtaking speed. For example, recent new rideshare services launched in eighty-four countries within twenty-four months. Tesla, reacting to a complaint from a customer that cars were using plug-in stations for all-day parking, coded a feature that limited time on a plug to just the duration it took to recharge the battery. This feature was implemented in a week to all Tesla charge points.

Today, a specific goal for digital innovation and innovators is to anticipate the benefits and impact of the network effect, as well as to design their solutions to encourage hyper growth and rapid take-up.

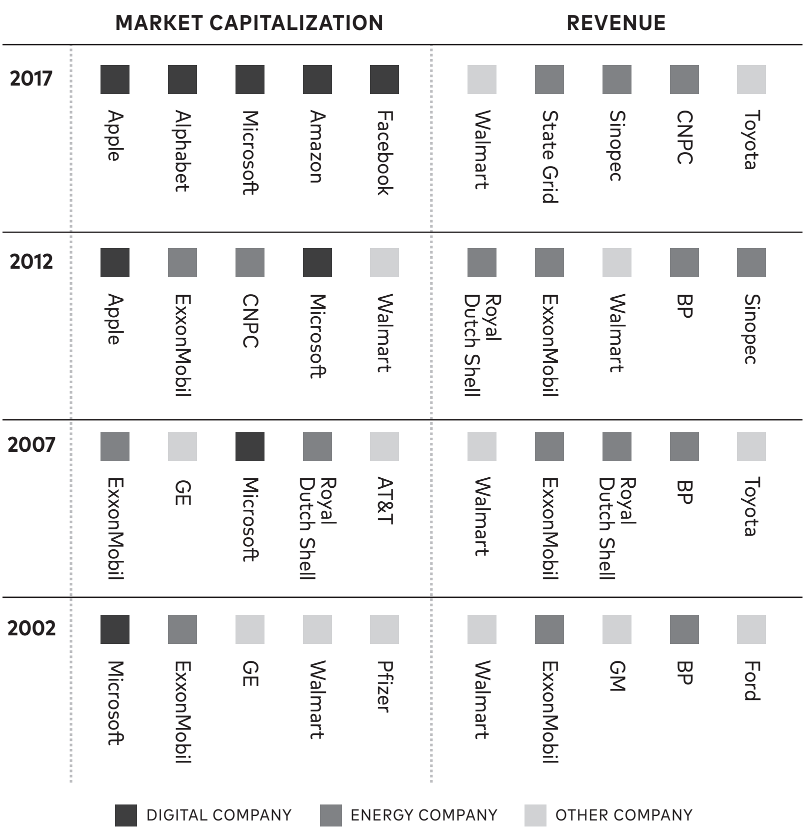
Cyber Worries

Not a week goes by without a media story about the latest cybercrime. From ransomware to denial of service to data theft, it's clear that these digital technologies both create a greater attack surface for bad actors to exploit and are being deployed themselves as bots to disrupt industry. Companies that sell industrial equipment may be eager to embellish their valves, pumps, and motors with digital smarts, but their equipment must allow for patches to repel the latest virus. They need to allow for remote control so that they can be switched off at the first sign of attack. They need to withstand being highjacked for Bitcoin mining or other schemes for theft of energy and processing cycles. Take a lesson from the early digital adopters who have underestimated how the nefarious will promulgate fake news, disrupt elections, and create needless social discord and dissent. Cyber disruption is such a critical issue for the industry that I will devote a portion of Chapter 4 just to this topic.

Follow the Money

Digital industry leaders excel at piecing together its components (data, analytics, and connectivity), exploiting the lessons from early adopters (the network effect, speed to market, falling costs, and new business models), and using these tools to cut across business silos and achieve outsized growth rates. At the time of writing, the largest companies in the world, as measured by market capitalization, are the digital brands that have grown over the past fifteen years into colossal global companies. They have handily displaced the largest global companies of the past, many of which were oil and gas companies, in market value.

Valuing Asset-Heavy vs. Digital Companies



- Amazon, a pioneer in developing online shopping, is now a leading player in e-books, video and music services, reseller and logistics, advertising, cloud computing, and entertainment, and has big investments in artificial intelligence and machine learning.
- Apple, the famous designer, manufacturer, and marketer of mobile phones, computers, and music players, also offers digital services including iTunes, the App Store, Apple Pay, and Apple TV.
- Alphabet, the market leader in online search and advertising, offers services in fast fiber, the Internet of Things, and medical devices, as well as possesses a huge range of online assets like YouTube, Maps, and Gmail. Google is fast becoming a leader in cloud computing and artificial intelligence.
- Facebook began as the world's largest social media site and is now a major news, advertising, and shopping site, with additional services in mobile messaging (replacing telephone calls) and photo-sharing services.
- Microsoft, developer of the original personal computer software and operating system, is today a leader in cloud computing, database, enterprise resource planning (ERP), collaboration and productivity tools, gaming platforms, search engines, and social media.
- Tencent is the market leader in Chinese social networks and gaming, online music distribution, videos, and entertainment. Its WeChat app has almost a billion users.

Any industry targeted by these leaders, either directly (like retail through online shopping) or indirectly (like phone services through chat), can find itself under siege. The business press is full of stories of industries, suppliers, and corporate incumbents that did not grasp the significance of these and other digital innovators and struggled to adapt fast enough. Sectors particularly hard hit include retail, from online shopping; real estate for shopping malls, which house the retailers; the music and TV industries, from streaming services; publishing, where books, magazines, and newspapers have struggled; photography, particularly the film industry; the game industry, where video games double the sales of board games; and the taxi industry, from rideshare platforms like Uber.

Entrepreneurs now seek out investment opportunities where digital creates the potential for exponential growth rates, rapidly declining costs, and network effects: once something starts growing that quickly, it becomes very difficult to displace.

A quick scan of published reports hints at where large digital companies are investing for the future:

- autonomous cars and transportation services;
- artificial intelligence, machine learning, and robots;
- voice, interpretation, and translation;
- electrical power generation;
- residential automation;
- wearable technology, such as Google Glass or smart watches;
- business-to-business sales;
- medical information;
- financial services and banking;
- healthcare technology; and
- games, entertainment, and experiences.

My survey suggests that digital companies are not targeting the oil and gas industry directly but focusing on key sectors vitally important to the industry—notably transportation. Connected, shared, and autonomous cars could alter the demand for gasoline and diesel permanently, but more important, they create new disruptive business models. Many of these same innovations (artificial intelligence, wearables, financial services) could be put to work in oil and gas to lower costs, raise productivity, and enhance sustainability, possibly unlocking disruptive value. In fact, many companies are already experimenting with digital to do exactly that, which is the topic I will turn to next.

KEY MESSAGES

Here are a few key takeaways from this survey of the rapidly developing world of digital innovation:

1. Digital is made up of data, analytics, and connectivity.
2. Virtually anything (services, products, and assets) can and will be digitally enabled because of the falling cost of chip technology.
3. The building blocks of digital are also in hyper-growth mode.
4. Early successes in industries that adopted digital focused on building ecosystems, concentrating on speed to market, and enabling new disruptive business models.
5. Capital markets value digital companies with more optimism than asset-heavy and revenue-rich companies.
6. The market leaders have perfected their skills at bringing digital innovation to industry sectors and are investing to bring their know-how to other industries, including energy and transportation.