Digital Transformation in the Oil and Gas Industry: Challenges and Potential Solutions

by

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MASTER OF SCIENCE IN ENGINEERING AND MANAGEMENT

AT THE

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FEBRUARY 2022

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Science in Engineering and Management

ABSTRACT

The digital transformation is proving to be a significant force for change globally and is especially true in the oil and gas industry. Many in the oil and gas industry struggle to understand what a digitally transformed future will look like. This thesis aims to explore the oil and gas digital transformation, its challenges, and potential solutions. By using this approach, organizations will be able to establish their organizations' current state (or baseline state), allowing them the opportunity to benchmark against what their future state will look like in the digital transformation environment. As oil and gas operators begin to contemplate the implications of their digital transformation and the coming changes to the upstream sector, all the key stakeholders must be engaged closely with the ecosystem to adapt to the disruptive trends. In the age of digital, oil and gas operators will also need to focus more on establishing partnerships that help promote technology innovation not only within their organizations but also within their business partners' organizations. Digital transformation will push the oil and gas industry out of its comfort zone. Oil and gas operators must prepare to embrace the discomfort to compete in the future.

Thesis Supervisor: Michael Cusumano
Title: Sloan Management Review Distinguished Professor of Management
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This one is for you, Daddy-o. I love and miss you every single day. I pray I make you proud.
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<tr>
<td>3D</td>
<td>Three-Dimensional</td>
</tr>
<tr>
<td>ADNOC</td>
<td>Abu Dhabi National Oil Company</td>
</tr>
<tr>
<td>AI</td>
<td>Artificial Intelligence</td>
</tr>
<tr>
<td>API</td>
<td>Application Programming Interface</td>
</tr>
<tr>
<td>AsiaPac</td>
<td>Asia Pacific</td>
</tr>
<tr>
<td>AS-IS</td>
<td>As it is</td>
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<tr>
<td>B2B</td>
<td>Business to Business</td>
</tr>
<tr>
<td>B2B2C</td>
<td>Business to Business to Consumer</td>
</tr>
<tr>
<td>B2C</td>
<td>Business to Consumer</td>
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<tr>
<td>BHA</td>
<td>Bottom Hole Assembly</td>
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<tr>
<td>BOE</td>
<td>Barrel of Oil Equivalent</td>
</tr>
<tr>
<td>BP1</td>
<td>Business Partner 1</td>
</tr>
<tr>
<td>BPMN</td>
<td>Business Process Model &amp; Notation</td>
</tr>
<tr>
<td>CAGR</td>
<td>Compound Annual Growth Rate</td>
</tr>
<tr>
<td>CCE</td>
<td>Circular Collaborative Ecosystem</td>
</tr>
<tr>
<td>CDO</td>
<td>Chief Digital Officer</td>
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<tr>
<td>CEO</td>
<td>Chief Executive Officer</td>
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<td>CFO</td>
<td>Chief Financial Officer</td>
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<td>CIO</td>
<td>Chief Innovation Officer</td>
</tr>
<tr>
<td>CIO</td>
<td>Chief Information Officer</td>
</tr>
<tr>
<td>CISR</td>
<td>Center for Information Systems Research</td>
</tr>
<tr>
<td>COO</td>
<td>Chief Operating Officer</td>
</tr>
<tr>
<td>COP21</td>
<td>21st Conference of the Parties</td>
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<tr>
<td>COVID-19</td>
<td>Coronavirus Disease - 19</td>
</tr>
<tr>
<td>CRM</td>
<td>Customer Relationship Management</td>
</tr>
<tr>
<td>CTO</td>
<td>Chief Technology Officer</td>
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<tr>
<td>DCoE</td>
<td>Digital Center of Excellence</td>
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<td>DD</td>
<td>Directional Drilling</td>
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<td>DSC</td>
<td>Decision Support Center</td>
</tr>
<tr>
<td>DSM</td>
<td>Design Structure Matrix</td>
</tr>
<tr>
<td>E&amp;P</td>
<td>Exploration and Production</td>
</tr>
<tr>
<td>EBIT</td>
<td>Earnings Before Interest and Taxes</td>
</tr>
<tr>
<td>EMEA</td>
<td>Europe, the Middle East, Africa</td>
</tr>
<tr>
<td>ERP</td>
<td>Enterprise Resource Planning</td>
</tr>
<tr>
<td>G&amp;A</td>
<td>General &amp; Administrative</td>
</tr>
<tr>
<td>GIS</td>
<td>Geographic Information System</td>
</tr>
<tr>
<td>H&amp;P</td>
<td>Helmerich and Payne</td>
</tr>
<tr>
<td>HSE</td>
<td>Health, Safety, and Environment</td>
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<tr>
<td>IEEE</td>
<td>Institute of Electrical and Electronics Engineers</td>
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<tr>
<td>IoT</td>
<td>Internet of Things</td>
</tr>
<tr>
<td>IPv6</td>
<td>Internet Protocol Version 6</td>
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</tbody>
</table>
IR  Inputs in Rows, Outputs in Columns
IT  Information Technology
Kbps Kilobit per second
LatAm Latin America
LTO Light Tight Oil
LWD Logging While Drilling
Mbps Megabits per second
mD Millidarcy
MENA Middle East and North Africa
MIT Massachusetts Institute of Technology
MPD Managed Pressure Drilling
MWD Measurement While Drilling
NIT New Information Technology
NOC National Oil Company
NOK Norwegian Kroner
NPS Net Promoter Score
ODECO Ocean Drilling and Exploration Company
OECD Organisation for Economic Co-operation and Development
OPEC Organization of the Petroleum Exporting Countries
OPEX Operating Expenditure
PID Proportional, Integral, Derivative
PIR Post-Implementation Review
PLC Programmable Logic Controller
RDDC Remote Directional Drilling Center
ROI Return on Investment
ROIC Return on Invested Capital
RSS Rotary Steerable System
SDM Systems Design and Management
SE Systems Engineering
SOP Standard Operating Procedure
UAE United Arab Emirates
USA United States of America
USD United States Dollar
VR Virtual Reality
WEF World Economic Forum
WTI West Texas Intermediate
XML Extensible Markup Language
Introduction

Digital transformation is proving to be a significant force for change globally and is especially true in the oil and gas industry. Connectivity has demonstrated its ability to empower millions of individuals while also giving companies unrivaled opportunities to create and extract value from their current operations and practices. Since the industrial revolution, the oil and gas industry has played a crucial role in the world’s economics and politics and in supplying the world's population with heat, light, and mobility. Through digitization, digitalization, and digital transformation, the oil and gas industry now has the chance to redefine its limits and push its boundaries even further. After years of turbulence due to declining crude prices, numerous budget cuts, schedule overruns, increased expectations for climate change accountability, challenges attracting new talent, and the ongoing COVID-19 pandemic, the oil and gas industry needs practical remedies to remain relevant in today’s everchanging environment. Digitization, digitalization, and digital transformation have the potential to help solve these most critical problems and prove benefits to all of the stakeholders involved.

This thesis will explore the oil and gas digital transformation, its challenges, and potential solutions. With the digital transformation of the oil and gas industry, organizations should see more efficiency gains and streamlined interactions within their operations and business. Although there may be some initial disruptions, once the disruptions have been overcome, organizations will see more adoption leading to prioritization and further innovation within the oil and gas industry.

Research Objective and Questions

The objective of this thesis was to explore the oil and gas industry’s digital transformation focusing on its challenges and potential solutions leading to improved prioritization efforts, ultimately resulting in enhanced adoption and future innovation efforts.
Research Scope and Process

Research Scope

This thesis used a comprehensive approach to evaluate the integration of digital efforts into the oil and gas industry, emphasizing an analytical technique to the oil and gas industry. The thesis aims to assess the interdependencies of an organizational structure as it transitions from traditional to digital processes and workflows. Several tools have been used/identified through the research that can help improve the efficiencies of the previously mentioned transition. This thesis also explores the importance of digitization and digitalization of an organization leading to a digital transformation.

To further investigate the needs of the digital transformation in the oil and gas industry, data collecting was performed. Empirical and non-empirical data were gathered using the following methods:

- Oil and gas industry exploration overview
- Literature review
- Personal experience and observations
- Focus group
- Survey(s)

This thesis intends not to identify all of the digital dead-ends within the oil and gas industry as this would be difficult to achieve due to the nature of the industry and lack of available information regarding failed initiatives. However, this thesis aims to highlight the digital transformation by exploring several industry case studies focusing on the future of the oil and gas industry that have shown promising results. This thesis also aims to evaluate the dynamics, characteristics, and requirements that contributed to the success of the various case studies leading to improved adoption and further innovation. This approach guides organizational and business partnership management, leading to improved efficiency gains and better collaboration efforts across the industry.
By applying the design structure matrix (DSM), the intent is to highlight the specific elements that currently compromise the system/organization and their interactions. The DSM provided a compact, easily scalable, and intuitively accessible representation of a particular system architecture within a large oil and gas operator. This exercise aimed to improve interindustry collaboration with a critical focus on future project development and efficiency.

This thesis aims to evaluate and understand the following questions:

- What is digital transformation?
- What does digitalization look like in the oil and gas industry?
- What are the digital transformation challenges in the oil and gas industry?
- What is the current state of the digital transformation in the oil and gas industry?
- Is there a better way to assess the business value and alignment of a digital strategy in terms of its fit into an organization's culture, competency, capacity, vision, and partnerships?
- How can designing a strategic digital transformation implementation plan lead to prioritization efforts, ultimately leading to adoption and further innovation?
- What does a future-ready company look like in the oil and gas industry?
- How does digital savviness fit into the bigger picture of success in the oil and gas industry?

This thesis leveraged industry exploration and a literature review, in addition to personal and professional experience in the oil and gas industry. This thesis will also demonstrate the use of a systems engineering approach – DSM – that can be used to model the structure of complex systems and processes in the oil and gas industry. This thesis shows that using a system engineering approach can offer improved system analysis, project planning, and organizational design, leading to enhanced productivity and efficiency. The thesis will look at a specific example from the upstream oil and gas industry segment focusing on a particular component in drilling operations.
The recommendations provided in this thesis are based only on the analysis that was performed through this research. As a disclaimer, these conclusions are based on incomplete/limited knowledge due to the competitive need to keep some information confidential. Despite the uncertainties within the oil and gas industry, this thesis aims to provide some insights into some techniques and methods that will lead to operational and administrative improvements. The intent of this thesis is not to provide a roadmap for an oil and gas industry digital transformation but rather to highlight specific tools and practices that can be used to encourage better cross-functional, cross-company, and interdisciplinary collaboration processes and products, allowing key stakeholders to ask the right questions, explore the possible answers, challenge the status quo of current oil and gas industry operations and/or practices leading to an organization that is future-ready and tailored to meet the organization’s needs – both current and future.

Chapter 2 - Literature Review

A literature review was conducted to establish an understanding of the current research in the Fourth Industrial Revolution, oil and gas digital transformation and its challenges, and the history of digital in the oil and gas industry. The literature review helped provide a foundation of knowledge for the topics discussed and helped identify areas of inconsistencies and the need for additional research. The literature review also covers the current business environment, industry pain points, and root causes of some of the difficulties in the digital transformation of the oil and gas industry.

2.1 - What is digital transformation? – general summary

In January 2016, Klaus Schwab, the Founder and Executive Chairman of the World Economic Forum, published the book, “The Fourth Industrial Revolution” [1]. Philbeck and Davis's article published in Columbia’s Journal of International Affairs noted that technology progress is a transformative force that affects all industries and areas of society, and an industrial revolution, by definition, is a transition
in a system that surrounds us, resulting in new ways of seeing, behaving, and being [2]. Following the
publication of Schwab’s book, the term “Fourth Industrial Revolution,” also known as Industry 4.0, was
used to describe and analyze the impact of emerging technologies on nearly every aspect of human
development in the early twenty-first century, from changing social norms and “national political
attitudes to economic development and international relations” [3]. The Fourth Industrial Revolution
also emphasizes the concept that at particular points in history, a combination of technologies emerges
and combines in ways that have far-reaching consequences beyond incremental efficiency gains [2]. The
concept of Industry 4.0 was primarily targeted to the digital transformation of industries related to
manufacturing or production and their value-creating processes.

According to Schwertner, digital transformation is “the application of technology to build new
business models, processes, software and systems that results in more profitable revenue, greater
competitive advantage, and higher efficiency” [4]. To reap these benefits, businesses must modify or
transform their strategy, processes, organizational structures, culture, and business models, leading to
empowered workforce efficiency, innovation, and personalized customer experiences [3, 4]. However,
these technologies, implemented with the intent of increasing productivity, value creation, and social
welfare, are disruptive to the organization [5]. Yet, companies that have emphasized big data, cloud,
mobile, and social technologies as part of their strategic infrastructure have seen higher revenues and
bigger market valuations than their competitors, who do not have a robust strategic vision [4]. Forecasts
have predicted that the digital transformation will result in high annual growth and fast penetration
within the companies and organizations that embrace these disruptive technologies [5].

Since the first industrial revolution, the oil and gas industry has propelled global economic
development [6]. Oil corporations were able to generate huge profits without needing to be particularly
smart, efficient, or inventive during the years when crude oil prices soared above $100 per barrel [7].
With the Fourth Industrial Revolution currently underway, the oil and gas industry is presented with new
challenges. Between 2014 and 2016, a worldwide supply glut and concern of losing market share pushed oil futures into rapid decline, slashing the price per barrel in half [7]. Today, the oil and gas industry is suffering from fluctuating petroleum prices, increased public demand for sustainable climate change accountability, in addition to a shift from being digital technology leaders to an entire industry that is lagging in terms of digital transformation [6]. According to a late 2014 study from MIT (Massachusetts Institute of Technology) Sloan Management Review and Deloitte, the oil and gas industry’s digital maturity ranking had fallen, and, along with education, insurance, and health care, oil and gas ranked at the bottom in terms of how far the industry has adopted digital technology [8]. However, with lower technological costs and a new environment of reduced oil prices, this seems to be changing. Persistent lower oil prices have prompted oilfield service providers to discover innovative methods to enhance their bottom lines and exploration and production (E&P) corporations to develop cheaper, faster ways to produce oil and gas [8]. Although oil prices are projected to rise, oil firms can no longer count on the long-term luxury of operating in an environment of higher pricing. Instead, the industry must embrace new forms of technology to create a new normal focused on improved efficiencies, increased organizational transparency, cost savings, better customer experience, flexibility, a better operating model and supply chain management, and enhanced competitive advantage.

Artificial intelligence (AI), machine learning, the Internet of Things (IoT), predictive analytics, and digital platforming will all play a role in the Fourth Industrial Revolution in the oil and gas industry. These digital solutions will assist oil and gas operators in discovering new methods to implement their plans to boost productivity, enable predictive maintenance, and extend operational insights, resulting in consistent, repeatable, and quicker decision-making. The Fourth Industrial Revolution could create value based on knowledge through:

- Asset optimization via predictive analytics
• Technological advancements that improve environmental and human monitoring, as well as operational logistics

• Optimization of downstream, midstream, and upstream operations

Oil and gas is not the only industry to look to digital business transformation to increase competitive advantage and performance. Over the last decade or so, there has been a surge in the number of corporations promoting the notion of digital transformation to their businesses.

According to a study by MIT, digitally transformed businesses are 26% more profitable than organizations that still manage their operations in a traditional business manner [4]. Industries are seeking to adopt “holistic business models, completely redesign products and services, and establish closer interactions with suppliers and long-term partnerships with customers” [5]. Still, if organizational structures, management principles, and company strategies are not considered part of a digital transformation, the transformation will not be truly successful [5].

The digital transformation opens the doors for technology innovation, new business models, and cross-industry collaboration [5]. Even though digital transformation has become an everyday business concept, some organizations and industries lag in strategic implementation due to prevailing mental models, legacy systems, and existing organizational structures. Duarte refers to this phenomenon as “some [organizations] are just running in their hamster wheel,” not truly understanding the implications of digital transformation from both a positive and negative perspective [5]. But organizations should be cautious. Technology strategist Herman Kahn stated that: “Everybody can learn from the past. Today it’s important to learn from the future” [5]. However, too many companies are focused on technology rather than the customer without the necessary strategy. To achieve a successful digital transformation of business, it is essential to address organizational change, technology, and data integration all at the same time [4].
In addition, the key to a successful digital transformation is understanding how and when to apply technologies [9]. To succeed, businesses must develop a digital transformation plan that integrates with existing company goals and objectives and allows for the coordination, prioritization, implementation, and control of technological transitions. In a study of large corporations in North America and Europe, Andal-Ancion et al. identified ten different drivers determining the competitive advantages of deploying new information technology (NIT) [9]. Each driver is not simply a general factor but is very specific to how NIT can be applied in a particular industry [9]. These drivers are different from the critical success factors that affect the implementation of information technology and are mainly specific to a company instead of being characteristic of an entire industry [9].

The ten drivers of NIT and their categories are [9]:

| Table 1 The Ten Drivers of New Information Technologies (NIT) (Source: [9]) |
|-----------------|-----------------|
| Type of Driver  | Driver          |
| Inherent        | 1) Information  |
| characteristics  | intensity       |
| of product or   | 2) Customizability |
| service         | 3) Electronic  |
|                 | deliverability  |
|                 | 4) Aggregation  |
|                 | effects         |
| Interactions    | 5) Search costs |
| between the     | 6) Real-time    |
| company and its | interface       |
| customers       | 7) Contracting  |
|                 | risk            |
| Interactions    | 8) Network      |
| between the     | effects         |
| company and its | 9) Standardization |
| partners and    | benefits        |
| competitors     | 10) Missing     |
|                 | competencies    |

<p>| Table 2 Description of Drivers (Table is an adaptation from Source: [9]) |
|-----------------|-----------------|
| Driver          | Description of Driver |
| 1 Electronic deliverability | Some products have a significant component that can be delivered electronically. |
|                 | • <strong>Effective example</strong>: Airline companies enabling customers to book reservations online, after which confirmations and tickets can be delivered efficiently through e-mail |
|                 | • <strong>Not as effective example</strong>: Electronic car shopping – consumers can get information on different models and compare prices online, but still need to test-drive vehicles and physically inspect them before taking delivery. |</p>
<table>
<thead>
<tr>
<th></th>
<th><strong>Information intensity</strong></th>
<th>Almost all products and services contain some type of information, but the amount varies greatly. Customers used to bear the responsibility of getting the data they required by sifting through manuals and other documents or phoning for assistance because the information was scarce and difficult to come by. Companies may now take advantage of the information content built into their products and services thanks to the introduction of new technologies. Undeniably, products and services with a higher information density have a more significant potential of impacting and benefitting an organization.</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td><strong>Customizability</strong></td>
<td>Many businesses can use NIT to adjust their overall product to their client's specific requirements and preferences. Newspapers, for example, were once a one-size-fits-all offering. Today, online publications can be personalized to feature only the news and information that a specific subscriber is likely to find interesting.</td>
</tr>
<tr>
<td>4</td>
<td><strong>Aggregation effects</strong></td>
<td>How products and services can be aggregated or blended differs. The banking business is an excellent example of this. In the past, customers had to interact with a bank for savings and day-to-day transactions, an insurance agent for life insurance policies, and an independent financial counselor for personal investments. On the other hand, institutions can now offer customers bundled services that address all their financial demands through a single account, thanks to NIT. Aggregation provides clients with more assurance in addition to convenience. Amazon is an excellent illustration of this. Because they are familiar with the website and trust the quality of its product and service, many consumers have begun to purchase items other than books from Amazon.</td>
</tr>
<tr>
<td>5</td>
<td><strong>Search costs</strong></td>
<td>People may access large volumes of information on the internet regardless of their location or time zone, which reduces the cost of searching for the particular product or service they desire. Additionally, NIT increased transaction transparency. However, NIT has revolutionized markets with significant search requirements, like the travel sector. It has not done so for other products, such as a pair of socks with restricted and consistent qualities. This distinction explains why most people still purchase socks through the conventional channels of traveling to the shop or ordering from a catalog.</td>
</tr>
<tr>
<td>6</td>
<td><strong>Real-time interface</strong></td>
<td>Companies and customers are dealing with crucial information that changes abruptly and unpredictably need a real-time interface. Active drilling operations are an excellent example of this because sudden changes in drilling parameters can be deadly to individuals who do not have instant access to this information. On the other hand, real-time updates are of limited use when the relevant data is infrequently updated.</td>
</tr>
<tr>
<td>7</td>
<td><strong>Contracting risk</strong></td>
<td>Leveraging the book-buying example previously discussed, customers have little contractual risk when purchasing new books.</td>
</tr>
</tbody>
</table>
online because costs are meager, identifying precise titles is simple, the physical quality of the book varies little, and merchants are encouraged to fulfill each order quickly to entice customers to return. Buying a car, on the other hand, is an entirely different story. Prices are significantly higher; it is difficult to define the specific product; the actual condition of the automobiles may differ from the description on the internet; vendors are unlikely to receive repeat business, so they may be less driven to provide premium services.

| 8 | Network effects | In many sectors, the utility of a product or service grows in proportion to the number of people who use it or are compatible with it. The Microsoft Office suite of products is one example of this. The Microsoft Office suite of products has become widely used in the corporate world, allowing users to quickly share Word, PowerPoint, and Excel documents. When it comes to other items and services, however, the connection is flipped. People who buy status goods, for example, are drawn to them because of their exclusivity. |
| 9 | Standardization benefits | NIT has enabled companies to synchronize and standardize specific processes, resulting in greater efficiency in business-to-business transactions and increased customer convenience. NIT can be seen in the banking industry by using standardized, automated teller machines through shared networks. These shared networks have allowed people to withdraw cash from their accounts and check their balances even when traveling internationally. This means that they are not limited to the proprietary ATMs of their own specific banks. The extensible markup language (XML) family of standards will significantly increase a company’s ability to broadcast a message to a broad audience most efficiently and powerfully on the Web. However, businesses that do not rely heavily on NIT, such as the restaurant industry, will see fewer direct benefits from standardization. |
| 10 | Missing competencies | NIT can facilitate company alliances in which partners use each other to fill in missing competencies. Missing competencies can be defined as activities that an organization lacks internally but are critical to an overall product or service offering. In contrast, NIT provides fewer opportunities for industries (usually low-tech ones) to be more self-sufficient. |

Despite the many advantages a digital transformation can offer an organization, it also presents challenges because it demands a new set of competencies that require the combination of embedded systems development with IT (Information Technology) and cybersecurity [5]. Software and data are the cornerstones of digital transformation. Digital transformation, according to Duarte, will radically change
the landscape of software technologies and processes as conventional IT and embedded systems engineering collide [5].

In a recent MIT Sloan Management Review webinar, Capgemini Consulting senior vice president, Didier Bonnet, discussed why some companies are able to adapt to digital transformation while others get left behind. During the webinar, Bonnet stated that “only about one-third of organizations seem to be adapting their organization to a more digital culture in terms of decision-making based on data, promoting exploration and experimentation, and so on”[10]. Based on Bonnet’s research, there are five key reasons why companies struggle with digital transformation. These reasons are:

1. Unrealistic expectations
   - According to Bonnet, some businesses were likely overconfident in the early days of digital transformation, dazzled by technology but ill-equipped to adapt. Today, decision-makers are starting to realize how daunting the digital transformation challenge is.

2. Underdeveloped talent
   - Companies have talent and competency gaps, and it is challenging for firms to reskill current personnel.

3. Poor communication
   - Organizational silos exist between business and technology teams, and the gap must be bridged.

4. Lack of digital culture
   - Employees aren't actively participating in digital efforts. According to Bonnet, “employee-wide engagement is still the exception to some extent, the minority.
People are finding it hard to translate what they’re doing in digital transformation to something meaningful to front-end products”.

5. Constant competition

- In the meantime, customers’ digital expectations continue to increase with the bar being raised in real-time.

Duarte identified similar internal and external barriers that hinder the propagation of a digital transformation within an organization [5]. These internal and external barriers were, but not limited to:

- Internal barriers
  - business structures or cultures that are insufficient or excessively diverse;
  - the absence of digital transformation strategies;
  - Return on Investment (ROI) visibility; and
  - the perception of cannibalization of existing businesses (the “innovator’s dilemma”).

- External barriers
  - the lack of recognition of how digital transformation will benefit all of society
  - a scarcity of skilled workers and a competent workforce;
  - infrastructure that isn’t there or isn’t enough;
  - a lack of or insufficient regulation and consumer protection; and
  - limited access to funds.

In recent years, researchers, academics, and business professionals have seen a surge in interest in finding ways to implement digital transformations within their organizations and industries successfully. However, companies often lack structures and procedures for navigating such significant
shifts. In addition, the introduction of new business models and the creation of digitized product offerings and services are causing industrial disruption due to the digital transformation.

2.2 - Digital Transformation versus Digital Disruption

To truly discuss digital transformation, one must first define and explore the difference between these three terms – digitization, digitalization, and digital transformation. These terms are often interchanged within the literature, and many often disregard the importance of each. However, this interchanging has resulted in some confusion among scholars as the words have very different meanings and nuances pertaining to a digital transformation. The following section aims to provide insights into the differences between digitization, digitalization, and digital transformation. In addition to this, this section will also explore the difference between digital transformation and digital disruption and discuss the relationship digital disruption has to digital transformation, digitization, and digitalization.

2.2.1 - Digital Transformation

Digital technologies are having an influence on not only businesses but almost every aspect of human life. To compete and succeed in the digital era, businesses must integrate digital technologies and their capabilities to alter processes, engage people, and create new business models [4]. Simply put, a digital transformation is a business transformation that the process of digitization and digitalization has enabled. A digital transformation does not lead to radically new software technologies but instead gives rise to new software technology applications [5]. Because the heart of the digital transformation is the changing of business processes facilitated or driven by digitalization technologies, the term "digital" is a little bit of a misnomer [11]. The goal of digital transformation is to do things differently – to create new business and operational models augmented by digital technologies to help drive efficiency and improvements within an organization [12]. A digital transformation is more than just automating or incorporating technologies into an existing process to optimize the current value chain; it is also about changing the current business model and changing the value chain, resulting in the creation
of a new supply of products and services caused by the application and/or incorporation of digital technologies [12]. By changing the way in which business is done, organizations will be able to provide a new and better way of delivering customer value and competitive advantage [12].

The ability to adapt rapidly and efficiently to changes is one of the most critical success elements in today's global corporate climate [4]. An example of this can be seen in the most recent oil and gas downturn. Through digital business transformation and strategy, oil and gas companies could leverage technology during the upswings in economic cycles that will also assist their operations during the downturns. One such technology is drilling rig automation. Oil and gas companies could potentially limit a downturn's impact on an organization by using rig automation. Rig automation would help with dropping and picking up new rigs in specific areas as area-specific information could be stored, leading to more resilient operations resulting in stable efficiencies and minimizing the need to relearn the drilling learning curves in the future in addition to improving the bottom line and enhancing profitability during the “good times.” With the growth of cloud computing, big data and analytics, mobile and broadband connection, e-commerce, social media, and the usage of smart sensors and the IoT, the global economy is changing into a digital economy [4]. The objective should be to provide a seamless customer experience across all corporate intersections [4].

Digital transformation has been a source of continuous entrepreneurship and business dynamism, particularly in technology-intensive oil and gas industries [5]. To successfully transform, companies need to reorganize themselves to operate simultaneously in two distinct modes – the standard and disruptive modes [5]. The standard mode keeps traditional businesses and operations running, while the disruptive mode seeks “additional opportunities to exploit new markets and innovate in technologies, processes, products, or services” [5].
To thrive in the digital age, companies must undergo two distinct digital transformations – digitization and digitalization. To truly discuss digital transformation, one must first define and explore the difference between these two terms. These terms are often interchanged within the literature, and many often disregard the importance of each. However, this interchanging has confused scholars as the words have very different meanings and nuances pertaining to a digital transformation. According to a recent research briefing from the MIT Center for Information Systems Research (CISR), although both digitization and digitalization rely on embracing new technologies such as analytics, artificial intelligence, and the cloud, becoming digitized and becoming digital are two different transformations and require very different rules and strategies to deploy ([14], [15]).

2.2.2 - Digitization

According to the Oxford Language dictionary, digitization is “the process of changing data into a digital form that can be easily read and processed by a computer” [16]. In other words, digitization is about converting something non-digital into a digital representation or artifact [11]. Process digitization is the conversion of a process to a digital format that can either reproduce the process exactly as it is (AS-IS) or improve it to include some process optimization [12]. Companies frequently claim to have been digitized (also known as "digitalization"), noting that they have reduced or eliminated nearly all paper (by digitally storing information) and that, instead of manual processes, they have created digital models of processes using the BPMN (Business Process Model and Notation) [12].

Once the digitization process has been completed, computerized systems can ingest the information leading to insights [11]. The digitization process is essentially the underpinning for a digital transformation. However, this step is often overlooked or not given the significance and/or resources it deserves to help drive a digital transformation. One cannot have digitalization without going through the process of digitization first. Because of the necessity for consumable data, digitalization activities enable all processes that produce corporate value [11].
Transforming the company’s operational backbone, which supports basic activities like providing goods and services, keeping books, and performing back-office tasks, is critical to becoming digitized [14]. While customer relationship managers and core banking engines have traditionally served as the operational backbone’s basic technology, software-as-a-service may now be able to help in digitization [14]. Companies create an operational backbone by defining a desired process goal state [14]. If companies can define and implement their desired process goal state for their operational backbone, it can lead to stability and scalability for the firm [14].

2.2.3 - Digitalization

On the other hand, digitalization is emerging as a driver for sweeping transformation across organizations and industries. Connectivity and technology have proved their potential to empower millions of people and provide unparalleled value-creating opportunities for many businesses and industries [6]. The use of digital technology to transform company models and create new income streams and value-producing possibilities is known as digitalization ([11], [6]). As a result, digitalization builds on digitization. Some simple examples of processes that leverage digital technologies and digitized data are but are not limited to [11]:

- Programmable logic controller (PLC) logic or
- Proportional, Integral, Derivative (PID) control in a microprocessor-based system;
- Sequenced logic for a batch operation;
- Automated shutdown logic; and,
- A transmitter fault that generates a work order for a maintenance tech in an enterprise resource planning (ERP) maintenance system.

Digitalization enables the use of digital data to improve business performance and efficiencies, generate additional revenue, save expenses, and provide a better customer experience, among other benefits ([11],[12]). It is important to note that digitalization enhances but does not transform or change

Digitization and digitalization require creating a digital platform. However, they are typically different platforms. Digitization is the operational backbone, while digitalization works on a digital platform [17]. According to MIT CISR, a digital platform is defined as the “foundation for a company’s digital offerings and their rapid innovation” [14]. This platform, which consists of a collection of software components that can communicate with partners and consumers, allows a firm to swiftly create and add new digital products while still aiming for revenue growth [14]. It’s crucial to distinguish between a digital platform and the more widely mentioned multi-sided digital platforms used by Amazon and Facebook to promote user interactions [14]. The digital services adapt and evolve as the organization learns what technology is capable of and what consumers value, and a successful digital platform will enable speed and innovation [14]. In today’s market environment, oil and gas operators are seeking out digital offerings from their business partners that can be integrated into their current systems in such a way that would be beneficial to their business. For the sake of this thesis, the term “business partners” refers to the standard business relationships that exist between oil and gas operators and their specific oilfield service companies and drilling contractors.

2.2.4 - Digital Disruption

As many may have experienced, the corporate world is rapidly digitizing. Digitization is dismantling industry barriers, disrupting businesses, and opening up new opportunities while adapting long-standing business models to the current times and consumer preferences, a process often called digital disruption [18]. These innovations are taking place in companies of all sizes and across all industries [4]. According to a 2018 McKinsey survey, more than half of the respondents stated that their organizations’ most recent significant transformations involved implementing some digital solution [19]. However,
they share a common theme: the ability to transform processes and business models, empower workforce efficiency and innovation, and personalize customer experiences [4].

Skog et al. suggest three fundamental characteristics for digital disruption. These three characteristics are [20]:

1. Digital disruption processes arise as a result of digital innovations, and they rapidly erode competitive positions.
2. They impact value-creating actor systems by disrupting and recombining resource linkages, allowing for more direct interactions and transactions.
3. One or more enterprises coordinate the initial digital innovation activities, but value generation and capture implications are systemic.

Based on these three fundamental characteristics, Skog et al. has proposed the following definition of digital disruption [20]:

“The rapidly unfolding processes through which digital innovation comes to fundamentally alter historically sustainable logics for value creation and capture by unbundling and recombining linkages among resources or generating new ones.”

Given the level of instability caused by digital disruption, now is the time for organizations to assess these dangers and opportunities and begin developing new business strategies for the future. It can be argued that the oil and gas industry would be looking at margin enhancements and leaner operations due to the digital disruption leading to potential revenue growth.

However, despite the disruption that digitization and digitalization may present, these two offer vast opportunities for many industries, especially the oil and gas industry. Through the MIT CISR research, an important insight was found: “that in [the] period of digital disruption, businesses focused
narrowly on value chains were at a disadvantage; they needed to think more broadly about their business ecosystems” [18]. Today, most businesses are focused on strengthening their client connections and delivering a better product. Weill & Woerner have found that organizations are shifting their focus by employing several different models [18]. When determining the suitable business model to use, business leaders have four distinct model options. These different models can be used alone or in combination with another distinct model [18]. It is important to note that each of these business models have their own specific capabilities and relationships [18]. As defined by Weill and Woerner, the four business models for a digital era are modular products, omnichannel, suppliers, and eco-system driven (see Figure 1 for more in-depth information related to the definitions of these four digital era business models) [18]. To be successful, organizational leaders must be focused on determining the following [18]:

1. The amount to which they wish to manage the value chain, or drive or be a part of an ecosystem that meets the entire demands of the end customer; and,

2. The level to which they understand the goals of their end consumer
Digital disruption is typically viewed through the eyes of businesses that are substantially invested in legacy systems and whose typical or planned development path has been disrupted due to digital implementation [20]. This opinion was confirmed through a recent study conducted by MIT CISR [18]. Based on the research, smaller businesses (those with less than $1 billion in revenue) are now capitalizing on digital disruption prospects, while larger corporations are struggling to adapt [18]. Larger, more mature companies tend to have more legacy systems, be more spread out globally, and are often more risk-averse with their business strategies when compared to their smaller counterparts [18]. According to the data, smaller firms are beginning to improve their awareness of their customers and are aiming to become more networked (31 percent of smaller companies were ecosystem drivers; 36 percent were multichannel) (refer to Figure 2 for larger company results from the CISR study) [18]. Smaller businesses are also often better prepared to gather, evaluate, and act on the data needed to truly understand their end customers [18]. Larger companies have an abundance of data [18]. However,
they are typically unable (or find it difficult) to use this data as efficiently as smaller companies due to multiple silos, geographies, and systems (as well as occasionally corporate politics) that make it tough to connect the pieces [18]. Based on Weill and Woerner’s research, it should come as no surprise that businesses that earn more revenue through ecosystem management and have a deeper grasp of their customers tend to outperform their counterparts/competitors [18].

![Chart](image)

Figure 2 Current trends of digital era business models for larger companies. NOTE: larger companies are defined as those with more than $1 billion in revenue (Source: [18]).

Existing firms are under extreme pressure to adjust as the development of specific digital processes or artifacts leads to changes in established industrial structures [20]. As a result of such adjustments, operations, the technologies that support traditional business models, and even the identities of the companies and people within them may undergo significant changes [20]. Due to the pace and systematic nature of environmental change and deteriorating financial returns, when businesses are threatened by digital disruption, there is often an urgent need to react [20]. To be
successful, strategic plans need to be established that are proactive rather than reactive to preserve organizational continuity, reduce redundancy, and prevent over expenditure.

Embracing a new way of thinking, as well as adopting and integrating emerging digital technology into an organization, is a challenging endeavor [21]. Organizations will tackle challenges from a comprehensive life-cycle perspective by adopting a "systems thinking" methodology—viewing the entire system as a hierarchy of interrelated subsystems—into their digital transformation efforts [21]. The systems method analyzes the whole system with its interactions and controls, allowing for deeper exploration and understanding, instead of a more traditional approach, which focuses on the problem and tries to determine a solution [21]. According to the systems way of thinking, everything is interrelated in some manner [21]. However, understanding the control and feedback linkages between the interconnections is the key to finding solutions to the complex problems organizations face during their digital transformation journeys [21]. Uncovering the resulting emergent properties of a system and how alternative designs and respective relationships affect the resulting system function is the most important finding from systems engineering [21].

Organizations should see new digital innovations and technologies as tools that may be embraced and incorporated into their systems to increase performance and drive efficiency. To help ease some of the digital transformation tensions, Duarte argues that mutual influences between digital transformation and systems engineering must co-exist [5]. However, it is crucial to understand that digital transformation disruptions due to systems engineering innovations may emerge at any time as well [5]. These disruptions are almost impossible to predict and require an organization to be flexible [5]. At this time, one can only speculate the implications that systems engineering will have on a digital transformation, and more research should be conducted to further understand these implications.
To validate and verify the arguments established by Ebert & Duarte, 2018, a debate panel was organized during the 2016 IEEE (Institute of Electrical and Electronics Engineers) Requirements and Engineering Conference [5]. The goal of this debate panel was to gain a better understanding of the impact and relationship of systems engineering and digital transformation in industry and research institutions. From this debate panel, it was concluded that “software technologies at the core of [digital transformation] disruption have been around for some time” [5]. Based on the debate panel, Ebert & Duarte, 2018 were able to conclude that the following technologies have caused disruptions because of [5]:

- Early or timely value delivery (Agile methods)
- Usage at larger scales (APIs (Application Programming Interface), microservices, and IPv6 (Internet Protocol Version 6))
- Applications in new domains (3D modeling and printing, control software, and blockchains)
- Unpredicted technology combinations (cognitive computing, which combines computer vision, voice recognition, natural language processing, and machine learning)

The human component is crucial in tackling these challenges, yet critical competencies for problem-solving, managing complexity, and coping with high abstraction levels are frequently absent or insufficient, resulting in digital disruption [5]. Through the research conducted by Ebert and Duarte, a systematic classification of the digital transformation technology offerings was created [5]. Table 3 presents some details associated with disruptive technologies adoption in the digital transformation implementation [5].
Table 3 Disruptive Technologies Adopted in Digital Transformation Implementation (Source: [5])

<table>
<thead>
<tr>
<th>Technology type</th>
<th>Inherent nature and attributes</th>
<th>Disruption and significance</th>
<th>Early-adopter experience</th>
<th>Adopted technology</th>
<th>Ease of adoption</th>
<th>No. of alternatives</th>
</tr>
</thead>
<tbody>
<tr>
<td>Collaborative equipment (drones and</td>
<td>Hardware capable of limited</td>
<td>Adoption of cognitive computing expanded the technology’s applicability from routine tasks to those requiring adaptability or autonomy, enabling its commercial use in precision agriculture, logistics, consumable-product industries, and services.</td>
<td>Alibaba manages retail warehouses in China using teams of unmanned shelf-carrying robots, which load and unload at multifunctional workstations.</td>
<td>Cuiktron self-charging robots with QR code readers, laser or LIDAR anti-collision sensors, adaptive routing, and Wi-Fi connectivity with back-end software.</td>
<td>Hard</td>
<td>Few</td>
</tr>
<tr>
<td>3D printing and additive manufacturing</td>
<td>3D object creation from digital</td>
<td>Advances in image processing, precision mechanics, and new materials decreased the price of printers and printed objects, making them accessible to businesses and consumers for rapid prototyping and small- to- medium-scale customization.</td>
<td>BioArchitects supplies FDA-certified 3D prostheses to customers in Brazil and the US, for training doctors and planning surgery procedures.</td>
<td>GE Arcam machines, which support additive high-power Electron Beam Melting production of titanium prostheses from CAD models generated using diagnostic-imaging exams.</td>
<td>Hard</td>
<td>Very few</td>
</tr>
<tr>
<td>IoT connected devices</td>
<td>Hardware with embedded digital</td>
<td>Implementation of IPv6 and reduced device costs enabled the massive dissemination of connected devices in machine-to-machine transactions and the IoT.</td>
<td>Volkswagen uses an IoT solution based on RFID tags to manage supply chain traceability in factories worldwide.</td>
<td>A Kathrein IoT distributed antenna system with customized software and standardized UHF RFID tags and transponders to ensure end-to-end order traceability.</td>
<td>Hard</td>
<td>Some</td>
</tr>
<tr>
<td>Agile development</td>
<td>integration of cross-functional</td>
<td>Rapid-prototyping development allowed to widespread agile development owing to user involvement and rapid compliance with requirements, time-to-market reduction, and early value delivery.</td>
<td>Lloyds Bank adopted design thinking, agile methods, and a cloud-based microservice architecture to break down the transformation of 10 customer journeys, which paid back in three years.</td>
<td>IBM Bluemix, a hybrid cloud platform-as-a-service architecture, used to support Scrum and a minimum-viable-product development methodology.</td>
<td>Medium</td>
<td>Very many</td>
</tr>
<tr>
<td>Blockchain or Hyperledger</td>
<td>Continuously growing lists of</td>
<td>This technology has been disseminated to many other application domains that require secure fault-tolerant event record management, such as the arts, law, accounting, commerce, and healthcare.</td>
<td>A blockchain open source platform has been used to manage things ranging from World Food Program vouchers for Syrian refugees to a collaborative decentralized news network.</td>
<td>The Ethereum blockchain app platform, a decentralized framework with programmable virtual-machine and peer-to-peer protocols for defining and running distributed transactions.</td>
<td>Medium</td>
<td>Some</td>
</tr>
<tr>
<td>Open APIs and microservices</td>
<td>APIs and distributed services</td>
<td>This technology’s use in developing enterprise application ecosystems is out of business functionalities, with decoupled deployment and operation, maximizes value for money.</td>
<td>Equinix Cloud Exchange provides cross-cloud application integration and scalable services by using an open-API platform.</td>
<td>Google Apigee, a Java-based service platform to develop, deliver, and analyze APIs via their proxies.</td>
<td>Easy</td>
<td>Many</td>
</tr>
<tr>
<td>AI</td>
<td>A set of algorithmic tools for</td>
<td>The coupling of AI to big data, cloud computing, natural-language processing, computer vision, and voice recognition enabled scalable resolution of real problems in many application domains.</td>
<td>Telefonica launched its AURA AI service to help customers with any bureaucratic, communication, and interactive-content demand.</td>
<td>The Microsoft Bot Framework and LUIS, the respective IDE for creating and deploying software robots and natural-language understanding integrated services.</td>
<td>Easy</td>
<td>Many</td>
</tr>
</tbody>
</table>

URLs:
- [http://www.arcam.com/products/arcam-q10](http://www.arcam.com/products/arcam-q10)
- [https://www.ethereum.org](https://www.ethereum.org)
- [http://www.apigee.com](http://www.apigee.com)
Using as many technologies as possible isn't enough for digital transformation [4]. The strategy that is in motion must have a clear vision for the company's future. It must then be backed by the limitless possibilities of these technologies connected to the selected strategy to assist, avoid, or prevent digital disruption [4]. Reengineering and optimizing business processes in the most appropriate way for the plan involves successful digital transformation [4]. The digital transformation of the business is different for different companies, and it is difficult to give a universally valid strategy [4]. As discussed, digital solutions pose new and unique challenges to the implementation of digital transformation efforts. However, the capabilities that support better outcomes still remain as critical as ever. Change management is the only way to truly change an organization’s people, processes, and technologies.

2.3 - Managing the Change

Companies are faced with different challenges today when implementing large-scale change compared to previous eras. While having a solid foundation in place might help to accelerate the digitization [and digitalization] process[es], it is not sufficient to successfully transform an organization [22]. According to a McKinsey study, transformation success still remains elusive. The study showed that fewer than one-third of all global digital transformation attempts succeed, especially in technologically aware industries [22]. Other industries, such as manufacturing and oil and gas, have even lower success rates [22]. Organizations of all types and sizes are investing heavily in the digitalization efforts of their business models. To be relevant in the so-called Fourth Industrial Revolution, organizations must focus on change management practices that allow the organization to be more customer-focused, agile, lean, and collaborative. However, regardless of the level of commitment, change management is always a difficult task to accomplish.

The research tells us that most change efforts are likely to fail. According to McKinsey, “70 percent of change programs fail to achieve their goals, largely due to employee’s resistance and lack of management support” [23]. Despite this understanding, many organizations are still using change
methodologies that are stuck in a predigital era trying to drive digital transformations in their organizations [23]. Employee reluctance to embrace new technology or practices is the most significant barrier to widespread change [22]. The firm's size is also an important consideration; the larger the company, the more difficult it may be to persuade the workers to accept the change [22]. In addition, 75 percent of the McKinsey survey respondents whose companies have undertaken a digital transformation say their change efforts span more than one business unit or function compared with 64 percent who say the same about traditional transformations [19]. In today's highly competitive climate, organizations must produce both immediate results and long-term growth [23]. Organizations are being pushed to adapt and adjust in ways they've never seen before [23]. The ability to change swiftly has become a significant competitive advantage [23].

When managing digital transformation activities, the leader's job is to instill excitement in workers about the change prospects [22]. Corporate leaders must encourage, guide, assist, and inspire their self-directed employees while growing with them [5]. They must be prepared to operate in corporate contexts characterized by hyperawareness, educated decision-making, and rapid execution [5]. In addition, systems engineering will transform completely to meet the digital transformation demands, leading to changes in how systems engineering education treats human factors [5]. Human resources will be highly valuable in this new environment, maybe even more valuable than the underlying technologies [5].

To capitalize on the promise of digital transformation, leaders must be comfortable managing distinct sets of rules for those managing the operational backbone and those working on the digital platform to carry out both digitization and digitalization transformation [14]. Successful businesses must utilize strategy, culture, and leadership to drive these transformations [4]. Based on a research brief that was co-authored by MIT principal research scientist Jeanne W. Ross, University of Texas Austin Professor
Cynthia M. Beath, and MIT research affiliate Martin Mocker, there are three effects that leaders need to keep in mind when managing these two transformations [14]. These three effects are [14]:

1. Leadership differences
   - Managing an operational backbone requires top executives to make clear choices, dictate processes and standards, and monitor their implementation. On the other hand, a successful digital platform is built on empowered teams shaping and delivering new ideas. Leaders are accountable for creating a digital vision, but top-down decision-making discourages progress.

2. Operational differences
   - Conventional techniques, like metrics and customer satisfaction, may be used to plan and assess changes to the operational backbone. Still, those in charge of digital innovation, such as building a digital platform, are irritated and restricted by traditional methods.

3. Cultural differences
   - Neither the fundamental role nor the requirements for managing the operational backbone are changing due to digital technology. However, managing a digital platform necessitates fundamental shifts in how decisions are made and work is completed. This may be a source of discomfort for people of all skill levels.

To successfully harness the potential of digital transformation, organizations must focus on developing their strategy, culture, and leadership [4]. Only a well-founded strategy and leadership can ensure the success of digital transformation [4]. According to business practice research, firms with a successful digital-based business have a clear strategy, senior management commitment to change,
motivated staff engagement in the process, and a focus on changes in consumer requirements and interests [4]. In addition to this, researchers suggest three actions to manage the transformation teams smoothly [14]. A summary of these three actions is provided below:

1. Separate the teams
   - Companies in charge of digitization and creating digital platforms should clearly delineate who is in charge of what.
   - Funding should be different as well. Operational backbones demand consistent investment from year to year, but digital innovation frequently necessitates money for short-term trials that may be quickly raised or decreased as needed.
   - Established businesses must preserve their success; therefore, instead of assigning digital innovations to the broader masses, they should start with smaller, more defined groups.

2. Let digital leaders break the rules
   - According to the study, businesses that achieve digital innovation break old norms and invent new ones. This involves disregarding long-standing product development processes, defying standard budgeting methods, and avoiding established customer relationship management strategies. Even though this appears to be disruptive, the rule-breaking is restricted to a tiny section of the company, specifically the digital team responsible for generating new income.

3. Develop new leaders
   - Some leaders who have managed traditional businesses effectively are not well-suited to lead digital organizations. This is due to a belief in outdated rules or the difficulties of functioning in a volatile environment. Companies that lack executives
that are comfortable with making new rules should strongly consider teaching individuals to improve such qualities in leaders or hiring new talent.

According to the MIT CISR article entitled “Working Smarter: The Next Change Management Challenge,” “countless organizations have made huge investments in enterprise platforms such as ERPs, CRMs (Customer Relationship Management), and homegrown core transaction processing systems” [24]. Furthermore, these organizations have also had to invest substantially in change management programs aimed at assisting employees in learning new systems and new responsibilities [24]. Of the two, new responsibilities are probably the most important and most difficult to change effectively. Although many organizations claim to have seen a favorable return on investment, few have used their digital platforms to generate significant performance improvements [24]. When it comes to corporate IT and business process investments, business and IT leaders must understand that they can't simply create something and hope for a favorable outcome [24]. Leaders must be relentless at seeking out opportunities for their employees to "work smarter" to access the competitive potential offered through the use of their platforms [24]. According to Ross & Quaadgras, the definition of working smarter is “an organization-wide mindset to continuously improve performance by using information from a digitized platform” [24].

Without establishing a digital platform, organizations rely on technology to automate discrete, repetitive tasks [24]. However, as more and more separate systems and processes are being used and developed, organizations often resort to relying on “heroes” to fill the gaps that exist between the processes and insufficient or erroneous (or often missing) information [24]. The benefit of digital platforms is that they replaced the previously used, disconnected systems with an end-to-end process support system. When digital platforms are implemented and used, it creates an entirely different work environment, which usually causes people to change their behaviors [24]. According to Ross and Quaadgras, these behavioral changes will occur through a two-part business transformation [24].
two-part business transformation will lead to an evidence-based management culture (see Figure 3) [24].

Figure 3 Working smarter: A culture of evidence-based management (Source: [24])

The first stage of the transformation entails letting go of the heroics culture and replacing it with standardized, disciplined business practices, procedures, and processes, requiring employees to adopt new methods of conducting work [24]. Most of the change management focus has been traditionally on the new systems being implemented during digital transformation initiatives, frequently overlooking the more significant shift, which is how people are impacted and think about their roles and responsibilities.
Both leadership and employees must realize that with the transition to the new system, their new roles and responsibilities are to ensure that their efforts satisfy the needs of end-to-end processes rather than just completing a narrowly defined set of tasks [24]. While these adjustments may appear overwhelming at first, the advantages, particularly in terms of operational efficiency, may be quite substantial [24].

In addition to this, the previously stated “heroes” can be leveraged in the digital transformation process by helping to mentor and/or train their colleagues by providing feedback to the organizational leaders on how the new processes are working in the practical world. Sometimes, companies will invest in a lot of new capabilities that only digitally savvy people are able to utilize to the fullest. In contrast, other employees use these systems and processes to a bare minimum. Digital savvy employees can be influencers to help highlight new efficiencies on a team level to help increase adoption in small steps. This could also help foster innovation from the employees, who are usually unlikely to partake in new technology. Incorporating this way of working into the digital transformation strategy opens up “digital” to be a two-way street inside an organization with some bottoms up information and/or feedback flow.

Although a digital platform and the adoption of a culture of standardized processes and procedures have been proven to impact an organization's bottom line positively, a digital platform's full potential extends far beyond process efficiency [24]. The implementation of digital platforms can also assist with improving an organization’s agility [24]. According to Ross and Quaadgras’ research, organizations, which have implemented digital platforms, have seen agility gains through the reuse of their process platforms [24]. However, their research goes on to discover that changing the organization’s decision-making processes and procedures results in more substantial agile benefits [24]. Thanks to the utilization of these digital platforms, employees may now depend on analytics and evidence to drive their decision-making processes rather than hierarchical decision processes or idiosyncratic interpretations of events [24]. Workflow designs, risk management, and employee
interactions are all guided by evidence-based decisions [24]. Much like the transition to standardized processes and procedures, the transition to evidence-based decision-making necessitates extensive organizational learning and continuous change management to be successful [24].

According to Ross and Quaadgras' research, four managerial imperatives enable workers to work smarter [24]. These imperatives are [24]:

1. Development of an analytics back-bone
2. Explicit management of business rules
3. Redesign of structures, roles, and accountability
4. The cultivation of talent through formal training and informal mentoring

Working smarter gives you a competitive edge since it allows you to adapt quickly to client needs and new business possibilities [24]. As the age-old adage goes, “change is the only constant.” However, the idea of constant change within an organization may create a sense of anxiety, restlessness, and, in some cases, hopelessness among the employees, which can result in burnout [24]. These feelings are often a result of leadership “pushing” changes on their employees without fully understanding the extent to which these changes impact their organization. Leaders need to involve their employees in the decision-making process, allowing them to understand the employee’s specific pain points and concerns and explain how the new changes to the organization will help them work smarter and be more efficient. While there is a risk of workforce burnout, working smarter can lead to a team being more invigorated by their roles leading to boosts in productivity, creativity, and frees up the time and space to allow for more profound thought and exploration for the areas that really matter within an organization [24]. By freeing up time and space for employees to think deeply, organizations should be able to stay a step ahead of their competition, leading to a true competitive advantage [24]. By incorporating these aspects into leadership’s narrative, the digital transformation will now be seen as a means to help the
employees execute their roles more efficiently rather than a top-down mandate, which can often make employees feel like leadership doesn’t respect their job already doing.

2.4 - What does digitalization look like in the oil and gas industry?

Contrary to popular belief, the oil and gas industry is no stranger to big data, technology, and digital innovation [25]. An example of the current technology within the oil and gas industry is TotalEnergies SE’s, the French oil major, supercomputer, Pangea [8]. Pangea is ranked the 19th most powerful supercomputer globally, clocking speeds of more than five quadrillion calculations in a second [8]. In the early 1980s, the oil and gas industry was at the forefront of digital innovation leading to boosts in production potential, improvements in health, safety, and environment, and improvements to efficiencies in operations worldwide [6]. However, the industry has missed opportunities in recent years and fallen short of leveraging and exploiting the digital frontier [6]. An industry that was once seen as one of the most innovative and high tech has been surpassed by other industries resulting in the oil and gas industry being unable to fully use data and make inefficient use of new technology [6]. As other capital-intensive industries such as aviation and automotive have revolutionized their business and operating models through a holistic application of digital technologies, the opportunity for the oil and gas industry to leverage the transformational impact of digitalization has become even more evident [25]. Despite these fundamental transformations, much of the oil and gas industry's digital initiatives to date have been cautious and have had little influence on existing operational or commercial models [25]. So far, much of the work has been evolutionary rather than revolutionary. Companies have been making incremental performance improvements through the selective use of business and digital technologies [25]. This relatively slow evolution has only been made simply because organizations didn’t need to change to survive. After all, companies were still able to maintain their profitability. However, with the new headwinds facing the oil and gas industry, the digital transformation is no longer a “nice to have” but rather a “must-have.” It is critical to the future success of the industry and the organizations
that support it. As previously mentioned, a targeted digital strategy, supported by the CEO and executive teams, along with a culture of innovation and technology adoption, will be required for such a transition [25]. Investment and commitment to rethink and overhaul procedures, infrastructure, and systems, as well as a desire to work throughout the ecosystem, will be required [25]. For the industry to fully realize the benefits of digital transformation, all of the necessary enablers must be in place [25].

With the rapid development of Industry 4.0, technologies are gradually being applied to the oil and gas industry, and traditional industrial production technologies will evolve progressively and be replaced [26]. According to Lu et al., every decade will see earth-shattering developments in the evolution of the world's oil and gas technologies [26]. For the oil and gas industry, the next decade will be a golden age of technological development. Figure 4 provides a glimpse into the development course of world oil and gas technology [26].

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Figure 4 Development course of world oil and gas technology. This figure was adapted from Source: [26].
According to Lu et al.’s paper entitled “Oil and Gas 4.0”, the main objective is to increase the industry’s value by utilizing modern digital technologies [26]. However, most businesses' digitalization processes are sluggish. Based on Lu et al.’s research, One-third of oil and gas firms consider themselves to be "new" or "exploratory" in the digital process [26]. Typically, the oil and gas business should be at the forefront of new technology, but the truth is that only specific regions or groups within the oil and gas industry can embrace new technologies [26].

As previously said, one of the most popular buzzwords in the oil and gas industry right now is “digital.” Many industry specialists believe that digitization will be as significant a transformation as improvements in hydraulic fracturing and horizontal drilling were for the shale revolution [27]. These technologies are unleashing shale resources and contributing to the glut that has resulted in consistently low petroleum prices [25]. Demand is also being influenced by other reasons, such as the continuing worldwide pandemic. The oil and gas industry is feeling the effects of these factors and the potential disruption of digitalization [25]. Figure 5 highlights the shifting trends in supply and demand and displays how they are reshaping the oil and gas industry.
Technological advancements such as cloud computing, social media, and big data analytics are fueling trends with enormous promise for the oil and gas industry [25]. Combining these technologies in novel ways might vastly increase their capabilities, far beyond their efficacy if used separately [25]. Due to this combined influence, oil and gas operations will soon benefit from a new level of linked intelligence [25]. According to a recent Accenture study, the top digital themes for oil and gas businesses are big data and analytics, IoT, and mobile devices (Figure 6) [25].
The industry is currently discussing a series of developments driven by three critical changing causes when considering digitization. The first of these causes is a significant increase in processing power [27]. Computing power has risen about 20 times in the previous decade [27]. Mobility is the second factor [27]. With the release of the iPhone in 2007, the concept of mobility was fundamentally transformed, and the way the world works has never been the same since [27]. Even though the oil and gas industry has always supported digital technologies (i.e., wireline, computers, etc.), the idea of agile development, which was the hallmark of Silicon Valley, the concept that a new product can be developed every 10 to 12 weeks, being able to apply advanced analytics and machine learning to come up with much more insightful answers much more quickly, is now being implemented [27]. It is a revolutionary technology that opens up vast new possibilities for increased production, cheaper unit costs, and improved safety [27]. The oil and gas industry is now experiencing a period of great
excitement [27]. Digitalization is a disruptive force, but the eventual end state generated from the digitalization process is fascinating [27]. Digital technologies offer enormous potential to propel oil and gas businesses past slow growth and into the realms of outstanding shareholder, stakeholder, and environmental value [25]. Successful digital transformation may increase oil and gas company profitability, enhance employee safety, and help society by lowering pollutants and water usage and saving customers money (refer to Figure 7) [25].

![Figure 7 Maximizing value in oil and gas](Source: [25])

Established oil and gas companies increasingly see data as a strategic resource in the digital transformation. Many articles have been written to assess how data and analytics will become the new currency in the oil and gas industry [28]. Data is rapidly becoming the new language of business, and organizations must speak this language. According to an article written by Sara Brown, “data literacy –
the ability of a company’s employees to understand and work with data to the appropriate degree – can be a stepping stone or a stumbling block when it comes to building a data-driven company” [29].

Currently, a single drilling rig may create over a terabyte of data each day [28]. However, less than 1% of the data collected is evaluated and used for decision-making [28]. When compared to other industrial and capital-intensive businesses such as manufacturing and automotive, the oil and gas industry falls significantly behind [28]. According to a McKinsey research study, the oil and gas industry is the only asset-intensive industry that has lost efficiency over the last 100 years compared to most other asset-intensive industries [26]. Through the comprehensive application of digital technology, these sectors have digitized various elements of their operations [28]. The potential for oil and gas businesses is to capitalize on the revolutionary impact of digitization, which is becoming increasingly apparent [28].

Based on research conducted by the World Economic Forum (WEF) in collaboration with Accenture, digitalization in the oil and gas industry is estimated to be worth between $1.6 to $2.5 trillion over the next decade [25]. Another study has indicated that the IoT alone could have the potential total economic effect ranging from $3.9 trillion to $11.1 trillion by 2025, further solidifying the potential benefits of digital transformation in the oil and gas industry [28]. According to the WEF white paper, four digital themes have been identified that are likely to play a significant role in the digital transformation of the oil and gas industry between 2016 and 2025 [25]. These four digital themes are [25]:
Within each of these themes, digital initiatives define the technologies expected to significantly impact the industry’s value chain, its workforce, adjacent industries, the environment, and broader society [25]. These initiatives (shown in Figure 8) are tangible actions businesses may take when using digital technology to alter their business and operating processes [25].

Digital Theme #1 - Digital asset life cycle management

- New digital technologies combined with data-driven insights can transform operations, boosting agility and strategic decision-making, and resulting in new operating models

Digital Theme #2 - Circular collaborative ecosystem

- Apply integrated digital platforms enhances collaboration among ecosystem participants, helping to fast-track innovation, reduce costs, and provide operational transparency

Digital Theme #3 - Beyond the barrel

- Innovative customer engagement models offer flexibility and a personalized experience, opening up new opportunities for oil and gas operators, and new services for customers

Digital Theme #4 - Energizing new energies

- The digitalization of energy systems promotes new energy sources and carriers, and supports innovative models for optimizing and marketing energy. To remain relevant to customers, the oil and gas industry must understand the full impact of these changes on the broader energy system

Figure 8 Digital Initiatives in Industry [Source: [25]]
At this point, it may seem evident that digitalization will significantly influence how the oil and gas industry shapes its future for decades to come. The value coming out of each project will continue to increase as the industry pushes forward with its digital transformation efforts leading to optimization and efficiency gains. As the industry locks down capital spending, key stakeholders must make the most of their resources to remain viable. An excellent illustration of this can be observed through the technological advancements made in the Permian basin, where the initial production of some new wells has been improving quarter after quarter [27]. The observed outcomes are not the consequence of changing geology but the industry's ability to extract greater value from the geology itself [27]. It is critical to recognize that the recovery rates of the actual oil in place in most wells are relatively low [27]. The ability to introduce digital into the folds suddenly opens the potential of simply getting more out of each well drilled, leading to better yields and substantially reduced costs [27]. However, one mustn't ignore the oil and gas industry's long history of potentially increasing costs over time [27]. With digitalization, there is a method to remove those expenses from the system and make the entire system function much more efficiently [27].

Moving forward, the oil and gas industry, governments, and civil society must work together to drive future growth and policy creation to maximize the benefits of digitalization to the industry and the environment [25]. The oil and gas industry must approach digital transformation using a multistakeholder tactic that will help ensure the potential gains are reaped in this era of massive change [25]. While digitalization has the potential to be a beneficial force not only in the oil and gas industry but also for society and the environment, there are several obstacles to overcome [25].

2.4.1 - What are the digital transformation challenges in the oil and gas industry?

The oil and gas industry is ready for digital change despite its digital roots, probably more than any other. Yet, when one looks at the companies that have tried to implement a digital transformation, one will notice that the development and adoption rates of those who have tried are slow and inconsistent.
Millions of dollars have been wasted on unsuccessful or mismanaged digital transformation efforts. This does not mean that the oil and gas industry cannot successfully digitally transform, but rather that these businesses were simply not equipped for the unique digital transformation challenges that the oil and gas industry present. However, it is essential to note that the oil and gas industry is not unique in the challenges it is currently experiencing. Many of the challenges it is faced with can translate to other industries and organizations. Even though the challenges are not exclusive to the oil and gas industry, other industries have different implications compared to the oil and gas industry; therefore, a one size fits all solution will not work, and organizations need to focus on customizable solutions that are specific to each industry. To become "digital technology businesses," oil and gas corporations should continue embracing and investing in technological transformation [30]. Currently, we are living in the era of big data and analytics, and oil and gas businesses have a chance to lead the industry in digital technology once again [30].

This section focuses on the specific digital transformation challenges that every oil and gas firm will face to remain competitive in the future. It is important to note that the intent of this section is not to provide an exhaustive list and/or discussion as it relates to the digital transformation challenges plaguing the oil and gas industry.

2.4.1 A - Top 3 Digital Transformation Challenges in the Oil and Gas Industry
In a recent study conducted by Oil and Gas IQ in partnership with OpenText, nearly 200 oil and gas professionals participated in an industry survey. The results of this survey helped to shed some light on what matters to those in the oil and gas industry when it comes to pursuing a digital transformation [31]. Based on the statistics gathered from this survey, the primary hurdles of the digital transformation in the oil and gas industry can be divided into two categories: people-centric and hardware-centric [31]. Figure 9 provides the survey results for the question: “What is the biggest challenge in implementing a
digital transformation strategy?”. As can be seen in Figure 9, the top three challenges to the oil and gas industry digital transformation are [31]:

1. Culture

2. Integration with existing infrastructure/legacy systems

3. Gaining senior management buy-in

Figure 9 Oil and Gas IQ in partnership with OpenText survey results for the question: “What is the biggest challenge in implementing a digital transformation strategy? (Source: [31])

Like many other traditional industries, the culture within the oil and gas industry is the most difficult barrier that must be overcome to digitally transform [31]. As one can see from the survey results, approximately one-third of the respondents stated that their corporate cultures significantly impeded the adoption of new technologies in their organizations [31]. In addition to this, the oil and gas industry also suffers from struggles with integrating new systems with legacy systems and support and buy-in from senior management [31]. It's no surprise that transitioning to a new technology paradigm will always be regarded with trepidation in an industry where data is frequently still paper-based,
unstructured, and compartmentalized, and where downtime equals a loss of profit [31]. This is where senior management must be on board with all aspects of the digital transformation to help support and guide the organization as needed.

In large part, the apprehension for change comes from a generational gap within the oil and gas industry. According to the work of Kuan, approximately 90% of executives acknowledge that the oil and gas industry has a talent shortage, which has created a significant issue in the industry [32]. As of 2015, approximately 50% of the industry workforce was set to retire in the next 5 to 7 years [32]. The COVID-19 epidemic worsened the deadline and created a sharp drop in oil prices due to a lack of adequate demand and storage space resulting in a reduction of production. This production reduction failed to solve the excess supply issue resulting in the supply glut. Because of this turmoil, the oil and gas industry experienced the “fastest rate of layoffs in the industry’s history,” with more than 100,000 jobs being lost in the United States alone [33]. With this mass exodus, a considerable knowledge gap has been created, which will be challenging to recover from as it is not easy to replace experienced people. The industry will have no choice but to replenish the organization with new, inexperienced people presenting the challenge of how will the industry fill the knowledge gap created by the great crew change.

2.4.1 B - Additional Digital Transformation Challenges in the Oil and Gas Industry

Data Analytics

Another challenge in the oil and gas industry is data analytics. Collecting data is not the problem. Big data has long been a part of the oil and gas industry [30]. Since the 1980s, they have been at the vanguard of industry in gathering mountains of data using sensors [30]. However, there is a distinction between gathering data and comprehending and applying it to a company’s advantage [30]. Many oil and gas businesses struggle to extract value from all of the data they collect because data analytics skills are often difficult to come by [30]. According to the Upstream Oil and Gas Digitization Survey, 66% of
respondents feel analytics provides a transformational potential for their firm, yet just 13% believe their company has fully developed analytics capabilities [30].

In the oil and gas industry, the usefulness of data analytics has the potential to be transformative [30]. Companies may now utilize data analytics to forecast crucial piece of equipment breakdowns [30]. Data analytics can enable the combination of real-time drilling data and production data to improve drilling strategy and outcomes [30]. When adequately implemented inside a firm, data analytics may be used in various ways to enhance cost certainty, forecast risk, and increase efficiency by allowing the organization to be flexible and accomplish more with fewer employees [30]. According to Bain and Company, the benefits derived through data analytics may help oil and gas firms boost output by 6% to 8% [30].

Companies should seek to employ cloud computing to exploit the potential of their data to better data analytics [30]. In the next 3-5 years, 56 percent of industry experts polled expect to leverage the cloud to facilitate analytics [30]. Internet connection on oil rigs has dramatically improved in recent years, increasing the quality of life for rig employees and enabling cloud-based solutions [30]. Cloud computing enables scalability that would not be feasible without digitalization [30]. The cloud may be a key element in data collecting, storage, analysis, and archiving, providing businesses with access to a plethora of information [30].

Cyber Security
The magnitude and frequency of cyberattacks by hackers, criminals, and governments are increasing and becoming more common, respectively [25]. Companies and their assets will be more vulnerable to cyber-attacks as the oil and gas cyber environment expands to include, but not limited to, the following [25]:

- Connected computing devices
- Personnel
- Equipment infrastructure
- Applications
- Services
- Telecommunications systems
- The totality of transmitted and/or stored information.

However, using the cloud can also benefit the company's cyber security operations [30]. Gartner estimates that cloud-based cybersecurity services would see 60% fewer security issues than traditional data centers [30]. Some may believe that cloud computing is less safe since your data is stored in a distant location. However, according to Snook, this isolation makes the data more secure [30]. The lack of physical access in cloud-based security makes it more difficult for intruders to gain access to the data [30].

Movement of Data

Another challenge in the oil and gas industry is the movement of data. In all actuality, obtaining data is not the challenge; moving the data is. The real challenge with this lies within the inherent geographical nature of the oil and gas industry. Whether a rig is located onshore or offshore, moving large amounts of data to a central data center to apply analytics is simply not practical at this time. Latency is also a concern since data utility is frequently lost if it is not used quickly, especially regarding platform efficiency and safety. Though sensors have become inexpensive and used more widely in recent years, the sheer volume of produced data has become cumbersome for many organizations. Massive quantities of data are being generated at the network's edge [34]. The average offshore oil platform generates 1-2 terabytes of data per day and transmits at a rate of 64 Kbps to 2 Mbps via satellite connection (Figure 10) [28]. This means that transmitting just one day's worth of data to a central repository might take up to 12 days [28].
According to Haaland, to progress the oil and gas industry, businesses must concentrate on obtaining “the insights they need from data, even though their equipment may be remotely managed – with an intermittent network connection or in a location where bandwidth costs may prohibit transmitting sensor data to the cloud” [34].

Who Owns the Data and Evolution of Competitive Landscape

With the discussion of data analytics, cybersecurity, and data movement, it should be no surprise that the subsequent discussion is related to who owns the data-giving right to competitive advantage in a digitally transformed oil and gas industry. The topic of who owns the data and how the competitive environment will evolve is a barrier to the oil and gas industry’s digital transformation [27]. In the oil and gas industry, the chance to gain a competitive edge is as great as it has ever been [27]. Some firms in the oil and gas industry are beginning to explore the process of taking digital, embedding it into a set of fundamental operational procedures, and scaling it up from there [27]. However, one of the significant issues in the oil and gas industry is who owns the data once the data has been generated by the various organizations/companies performing work on a well [27]. This argument becomes especially critical considering the operational environment of the oil and gas industry.

Typically, E&P companies do not own their own drilling equipment or employ a drilling rig crew. This work is mainly contracted out to drilling and/or drilling services companies to drill the wells in the
project. The contracted drilling and/or drilling services companies will then charge for their services based on the services delivered and the time they have worked for the E&P company. It is important to note that most drilling contractors do not generate revenue from the oil and gas production of the wells in which they have helped drill. Drilling contractors are typically the company that owns and operates a drilling rig. In contrast, the E&P company, sometimes referred to as an operator typically owns oil and gas production and revenue rights. However, drilling data itself is collected from a dizzying array of machines, control systems, and sensors, using multiple versions of multiple standards from multiple drilling and/or drilling service providers [35]. This is where the waters of data and digital transformation start to get cloudy, and who owns all of that data can be a significant source of disagreement.

This argument is important because data is one of the most crucial aspects of the digital transformation process [27]. In recent years, the oil and gas industry has started to experience a shift in how the upstream segment views data. Traditionally, data has been viewed as descriptive information about a physical asset rather than something valuable in and of itself (i.e., geology) [36]. However, recently, leaders of big data in the oil and gas industry have taken a hard stance. They are now regarding data as foundational and the most critical asset in and of itself that an organization can own ([27], [36]). An answer to this challenge may simply lie in the terms and conditions specifically laid out during the contracting process between the different organizations. Given the overlapping framework of contracts that cover the legal ownership of data, there appears to be a broad agreement that, while information on a well’s construction is confidential and proprietary to the operator, there is another type of machine data that the rig owner/drilling contractor and their vendors may utilize to improve operations[35]. With this being said, there is room for a consensus to share data for win-win purposes such as preventing well control events, minimizing downtime, streamlining operations, implementing condition-based maintenance, and rig automation [35]. Companies believe that to get a competitive edge, they must
seize possession of a block of data and collaborate with their business partners in fundamentally new ways regarding who and how that data is utilized [27].

This segment of the digital transformation is challenging the notion of what defines competitive advantage in the age of managing data as an asset. The concept of a firm having a business partner that collects data that will be used to gain a more profound knowledge of how a business is operated is extremely critical [27]. However, who receives the insights driving the competitive advantage will be a point of contention. The oil and gas industry currently has the potential for competitive advantage now. However, in the coming years, the oil and gas industry may see a convergence resulting in that advantage disappearing if it is all integrated into a business partner's equipment and/or software, which can be shared with others within the industry [27]. The topic of data ownership for drilling automation is an opportunity for future research.

Organizational Structural Challenges
Oil and gas companies today were developed during a time when resources were scarce [37]. Oil and gas firms created massive, often complicated organizations that supported strongly centralized, often segregated activities and structures to tap into difficult-to-find and difficult-to-develop resources [37]. This strategy enabled them to handle tremendous technological difficulties, manage enormous political and operational risks, and deploy scarce talent globally as needed [37]. While these arguments were all relevant during earlier decades of rapid expansion, this organizational journey also resulted in significant complexity for larger companies, which increased costs, hindered innovation, and delayed decision-making [37]. Figure 11 was provided to demonstrate how the corporate center has grown in both size and complexity over the last 20 years [37].
However, with the current fluctuations in oil prices and the imminent digital transformation, these legacy organizational structures are no longer sustainable for today’s business endeavors [37]. More importantly, the organizational structures of years past are no longer needed, and many organizations have commenced reorganization efforts to keep up with the changing industry.
environment [37]. Market conditions and technological advances have disrupted the old ways of conducting business and have enabled step changes in employee productivity and collaboration [37]. Across the oil and gas industry, many roles, even knowledge-based work, are being replaced by automation on a large scale. Those that remain require increased human and machine interaction and skill sets to remain competitive and sustainable [37].

Although most professionals in the oil and gas industry understand the criticality of adopting digital technology and ensuring the promotion of a workforce that is future-ready and have the necessary skill sets to drive the ongoing success of the organization, the leadership teams that want to implement digitalization inside their organizations being faced with numerous challenges and speed bumps during their digital transformation efforts [30]. Many of the challenges that oil and gas companies are faced with are related to implementing changes within the organizational structure, processes, procedures, and interactions with operational partners [38]. These difficulties are often due to the amount of support and buy-in that is needed across an organization and the need to break down existing and legacy organizational silos [38]. However, the oil and gas industry is not alone in its digital transformation journey. Organizational structure issues are one of the most common problems that traditional businesses are faced with [30]. These difficulties and challenges will only continue to exacerbate the digital transformation if leadership does not take the time and effort to fully assess their organizations and choose to address these transformation issues from a proactive rather than a reactive approach.

To combat these difficulties and challenges, some companies are managing the digital transformation with “design digital teams” at the headquarters, and newly hired data scientists and experts as well as “implementation digital teams” composed of operational employees at the asset levels [38]. However, these parallel structures could also create additional silos and barriers within the organization if either asset’s end-user engagement is late or digital applications designed at the
headquarters do not incorporate end users’ input [38]. Because of these silos and miscommunication within an organization, this often results in resistance from asset teams regarding the adoption of an application, software, process, and/or procedure. That is why oil and gas organizations must focus on digital tenacity, i.e., a strong determination to engage in and embrace digitalization [30].

Strong and focused leadership is at the heart of all successful businesses [30]. If digital trends in the oil and gas industry are to be adopted successfully, the company’s leadership must become adamantly focused on digital tenacity. Digital tenacity is defined as a strong determination to engage in and embrace digitalization [30]. To demonstrate that digital transformation is paramount for an organization, digital technology should be put at the center of the strategic business plan and frequently discussed [30]. In addition to this, employees and contractors should be adequately trained and educated on the company’s organizational culture, including any pertinent new technology and procedures [30]. Change may be disruptive, but it’s how an organization manages it that matters [30].

2.5 - Strategy and Leadership Discussion
2.5.1 - What does a future-ready company look like?
To prepare for the future, many large, established enterprises are embarking on a digital business transformation journey. Often, this journey is taken without fully understanding where it is going. Future-ready companies alter how work is done by leveraging rich data for decision-making, augmenting personnel with AI, and adopting flexible workforce models with significant variances in digital adoption and digital maturity [39]. According to the work of Peter Weill and Stephanie Woerner, there are four viable pathways for transformation, each of which has its pros and cons. The objective isn’t digital transformation, but rather business transformation employing digital capabilities to turn a traditional firm into a top performer in the ever-growing digital market [40]. The four viable paths for transformation are [40]:

1. Integrated experience
2. Silos and complexity
3. Future-ready
4. Industrialized

Future-ready businesses outperformed their industry peers, according to their research [40]. However, even within a single industry, they discovered that businesses might follow multiple pathways to become future-ready [40]. To become future-ready, the company must change in both customer experience and operational efficiency [40]. Future-ready businesses can innovate to engage and satisfy customers while lowering expenses [40]. Customers should anticipate a positive experience regardless of the service delivery channel they pick because their objective is to satisfy client needs rather than push items [40]. Through digital services and accessible APIs, the company can compete in the digital market and collaborate with a wide range of partners [40]. According to these criteria, 23% of the firms they surveyed were future-ready [40]. Future-ready companies outperformed their industry on average by 16 percentage points, suggesting that if a company's typical net profit margin in a specific industry was 8%, future-ready enterprises earned 24 percent [40]. Figure 12 provides a visual representation of the four viable paths to digital transformation.
Weill and Woerner found that 51 percent of the firms they examined were in the silos and complexity quadrant [40]. Many of the businesses in this sector were burdened by an extensive catalog of products and services created over time [40]. A sophisticated combination of corporate procedures, technology, and data underpin their goods and services [40]. As a result, customers have a fragmented, labor-intensive, and unpleasant experience, typically exacerbated by internal product silos [40]. Often, the capacity of such businesses to offer an engaging customer experience is highly reliant on employee heroics, which makes it challenging to scale throughout the organization [40]. With this, it shouldn’t be surprising that the Weill and Woerner survey showed that the profit margins of enterprises from the silos and complexity group were weak, averaging approximately five percentage points below their industry average [40].
Companies that are defined by digital industrialization use the best automation methods in their operations [40]. They take the qualities that make them a strong business and transform them into modular and standardized digital services [40]. Companies in this category discovered the optimal approach to handle each critical activity, such as standard operating procedures leading into automated systems and implemented it across the company [40]. The aggregated data generated by customer interactions and activities may often become a competitive advantage that anybody involved in the company can access [40]. Of the companies that Weill and Woerner “studied, 11% were in the industrialized group; their net profit margins averaged 4.6 percentage points higher than their industry average” [40].

Despite complicated processes, enterprises that deliver what Weill and Woerner call an “integrated experience” produce a better-than-industry average consumer experience [40]. Many companies engage in analytics to improve the customer experience [40]. However, they have discovered that these businesses frequently cannot simplify or automate the underlying and complicated business processes, technology, and data landscape [40]. As a result, companies are seeing an increase in their customer service expenditures [40]. They analyzed around 15% of the businesses and found that their net profit margins were 3.6 percentage points lower than the industry average [40].

Based on their survey, Weill and Woerner identified four different pathways that companies took to become future-ready. Each pathway begins in the bottom left quadrant (Silos and Complexity), and each involves significant organizational disruption [40]. The following list provides the assigned name of the pathway as well as a brief description for each of the pathways [40]:

- Pathway #1 – Standardize first
  - Description:
• This route transitions businesses from the Silos and Complexity quadrant to the Industrialized quadrant. This route is based on establishing a platform mindset by providing API-enabled business services that can be accessed both internally and externally. It allows a company to get rid of a lot of its outdated procedures and systems. The difficulty with this route is that changing fundamental operations in a company is a costly, multi-year endeavor. It will also necessitate the postponement of several other projects. Cloud computing, APIs, microservices, and improved solution designs accelerate, reduce risk, and reduce disruption in the industrialization process. However, starting along this road takes time. Changing the decision rights, for example, is required to highlight integrated services for consumers instead of focusing on items.

• Pathway #2 – Improved customer experience
  
o Description:
  
• Moving from the Silos and Complexity quadrant to the Integrated Experience quadrant is part of this journey. When the most important strategic aim is to improve customer experience throughout the whole business, companies use this method to address the problem across various organizational silos. Typically, they try to do multiple things at once, such as create new appealing offers, construct mobile applications and websites, improve contact centers, and empower relationship managers, all with the objective of boosting customer happiness in a measurable way. The benefit of this approach is that it prioritizes the customer and improves the customer experience, which leads to better customer satisfaction and, in some instances, increased sales. The main drawback is that customer experience enhancements often add more complexity to existing complicated systems and
procedures, raising the cost of serving a client. Employees may still be required to
go above and above to fulfill what was promised.

- Pathway #3 – Take stair steps
  o Description:
    ▪ Businesses on this route progress toward future readiness by switching their
      attention from enhancing customer experience to improving operations and back
      again, adjusting the focus as needed. A project to develop an omnichannel
      experience, for example, may be the initial step. Businesses may improve their
      operations by replacing a few outdated procedures or building an API layer. Then,
      by making better use of internal data, they may try to put together a more
      appealing collection of consumer products. The difference between success and
      failure with this strategy is having a plan that guides everyone’s efforts rather than
      taking a random approach. Asking a manager how a single project fits into the larger
      strategy is the most significant way to discern the difference. The advantage is that
      the phases are smaller, consisting of closely linked sets of projects, which reduces
      risk. The drawback is that explaining the frequent changes in direction can be
      difficult, and employees may become confused as a result. Weill and Woerner
      observed organizational whiplash as a result of changes in direction in some
      businesses, with a decrease in staff performance and an increase in burnout.

- Pathway #4 – Create a new organization
  o Description:
    ▪ Instead of fighting the uphill struggle of transforming their present organization,
      executives who choose this road establish new firms that start as future-ready
      businesses. Weill and Woerner discovered that the biggest problem for companies
following this road was figuring out how to integrate the parent company and the changed enterprise. Everything about them is distinctive — their business methods, cultures, and even the clients they serve. The benefit of this approach is that it allows a company to start fresh in terms of client base, employees, culture, procedures, and systems to be future-ready. There are no legacy systems, silos, or cultures to contend with. The problem is figuring out how to – or not to – merge the new entity with the mother ship if it is successful.

For the purpose of this thesis, an analysis of companies that had identified their organization’s primary industry as mining/oil and gas was conducted on data from a 2019 MIT Sloan CISR survey. This narrowing effort resulted in 38 oil and gas/mining companies being represented from North America (48%), Europe, the Middle East, Africa (EMEA) (35%), Asia Pacific (AsiaPac) (13%), and Latin America (LatAm) (4%). In addition to this, 74% of the enterprise’s 2019 total revenues came from Business to Business (B2B) types of customers, followed by 16% Business to Consumer (B2C) and 10% Business to Business to Consumer (B2B2C). When looking at the type of transformations, these organizations are currently undergoing, approximately half (42%) of the survey respondents stated they are undergoing an industrialization transformation, indicating that the organizations are more focused on improving the operational efficiency of their organizations rather than increasing the Net Promoter Score (NPS) leading to an improved customer experience [41]. These organizations are focused on establishing their platform(s) leading to plug-and-play products and services, understanding how shared data could be a competitive asset, and standardizing how tasks are being performed within the organization(s). In general, industries such as oil and gas tend to focus more on the industrialization pathway because they have more to gain from this initial pathway rather than focusing on the customer experience. Figure 13 displays the oil and gas/mining enterprise approaches to digital business transformation.
When asked the question, “what percentage of your enterprise effort for digital business transformation is allocated to each approach,” the survey revealed the following results (Figure 14):

The results from the figure above (Figure 14) align with the overall oil and gas/mining industry trends of focusing on operational efficiency rather than customer experience.
All transformations involve significant organizational changes. However, based on a scale from 1 to 5 (1 being not effective at all and five being extremely effective), it appears that many representatives from the oil and gas/mining industry feel that their organizations have moderately addressed the following facets:

- Changing decision rights (3.1)
- Developing new ways of working (e.g., agile test and learn) (3.1)
- Instilling a mindset around creating and reusing platforms (3.0)
- Restructuring the enterprise (3.1)
- Partnering across the ecosystem (3.0)
- Changing business models (2.9)

When asked the question, “how far along is your enterprise on its digitally-enabled business transformation and how quickly were you able to see measurable results of the transformation”, the collective surveyed that they were 40% complete, and it took approximately 23 months to see any measurable results.

According to MIT CISR, there are four options for handling technology during transformations. These four options are [42]:

1. API Layer – adding APIs that connect legacy systems to digital channels/customer offers to accelerate transformation
2. Partial replacement – replacing only selected parts of your legacy systems to accelerate transformation
3. Migrate – creating a parallel technology platform/business model to make customers offers and migrate to the new approach
4. Replace the core – replacing legacy systems with a modern, flexible core platform, taking several years and costing many millions of dollars

Companies, it turns out, employ all of these technology handling mechanisms throughout their digital business transformation, depending on where they are in the process, what they are trying to accomplish, and how competitive their environment is [40]. Based on the results of the CISR survey when asking the representatives to pick the one that best describes their overall approach, one third stated they are working on applying an API layer on top; one third stated they are looking at completely migrating and moving towards a future-ready platform; And, one third are undertaking some partial core replacement. The issues we see here are fascinating and are challenges shared across many industries, not only the oil and gas/mining industry.

One might be wondering how to decide which path a business should take to accomplish a successful digital transformation at this stage. The answer is that leadership (or, depending on the circumstances, a business unit) is responsible for determining which road to follow and how aggressively to go after that option has been chosen [40]. To do so, executives must examine their companies critically and identify where they stand in relation to the rest of the market on measures like customer experience (NPS) and net margin [40]. Based on the survey, the oil and gas/mining industry appears to be on par with its competitors. Table 4 provides the results:
Currently, how does your enterprise perform relative to other firms in its industry on the following metrics?

<table>
<thead>
<tr>
<th></th>
<th>Significantly worse than competitors</th>
<th>About the same as competitors</th>
<th>Significantly better than competitors</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0 10 20 30 40 50 60 70 80 90 100</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Revenue growth</td>
<td></td>
<td>65%</td>
<td></td>
</tr>
<tr>
<td>Cost of operations</td>
<td></td>
<td>51%</td>
<td></td>
</tr>
<tr>
<td>Time to market</td>
<td></td>
<td>56%</td>
<td></td>
</tr>
<tr>
<td>New product or</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>service offerings</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Customer experience</td>
<td></td>
<td>57%</td>
<td></td>
</tr>
<tr>
<td>New business model</td>
<td></td>
<td>52%</td>
<td></td>
</tr>
<tr>
<td>Employee experience</td>
<td></td>
<td>60%</td>
<td></td>
</tr>
<tr>
<td>Organizational agility</td>
<td></td>
<td>56%</td>
<td></td>
</tr>
</tbody>
</table>

Selecting the appropriate executive to drive the change is another crucial phase in the process. The best option will be determined by the company’s conditions, the industry climate, and management’s goals. Through the research performed by Weill and Woerner, they provided some insights as to which pathway is the right pathway to choose and who should be responsible for driving the transformation [40]. The Weill and Woerner pathways are defined by the customer experience offerings that a company provides. Table 5 provides a summary of Weill and Woerner’s findings based on their industry research [40]:

Table 5 Transformative Pathways and their descriptions as well as leadership choice (Source: [40])

<table>
<thead>
<tr>
<th>Transformative Pathway</th>
<th>Description of the Pathway</th>
<th>Who is a good choice to lead this transformation?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pathway #1</td>
<td>If the company’s customer experience is comparable to the industry norm and the risk of digital disruption is low, this pathway makes sense.</td>
<td>Chief Innovation Officers (CIOs)</td>
</tr>
<tr>
<td>Pathway #2</td>
<td>If the company’s customer experience is considerably poorer than the industry norm and cannot be improved, or if there are concerning new rivals, this pathway makes sense.</td>
<td>An executive passionate about customer experience who is technologically literate</td>
</tr>
<tr>
<td>Pathway #3</td>
<td>If the company’s customer experience is an issue, yet a few little activities can make a huge impact, this pathway makes sense. Begin with those, then go on to operations, and so on, in tiny increments.</td>
<td>A chief digital officer (CDO)</td>
</tr>
</tbody>
</table>
Once the company has settled on the desired pathway, it is time for the difficult work to begin. According to the CISR survey results of the oil and gas industry, 52% of the organizations stated that they have a single executive (such as a CDO, COO, or CIO) who oversees digital. However, when asked how the top management team spends its time, 70% stated that it works as “business as usual,” indicating that their sole focus is not on their organizations' digital business transformation(s). Figure 15 provides a visual representation of the CISR survey results for how digital is primarily managed in the oil and gas/mining industry.

![Figure 15 How is digital primarily managed in your enterprise? (Oil and gas/mining industry)](image)

The digital era is an excellent opportunity for leaders to reinvent the enterprise. There is no denying that digital is the way of the future in business. Companies ahead of the curve in adopting digital technology have seen significant improvements in operational efficiency and consumer
satisfaction [43]. More importantly, the new capabilities made possible by digital technology have allowed them to rethink their goals and business strategies [43]. The most successful enterprises will be those that are future-ready and ambidextrous, continually innovating to improve the customer experience while also reducing costs [40]. According to Weill and Woerner, “those that don’t become future-ready will likely suffer a death by a thousand cuts, with startups, players from other industries, and agile competitors slicing bits out of their businesses” [40]. Transformation is complex, and leadership needs to decide on a pathway and stick to that pathway. It is critical that all of a company’s stakeholders, including the board, employees, partners, and customers, understand where the company is heading and how it intends to get there [40].

2.5.2 - Digital Savviness of Leadership and Why it is important

When trying to implement a digital transformation, it makes a tremendous difference to have a technologically aware senior leadership team. A digitally aware top leadership team is one in which more than half of the senior executives are digitally knowledgeable [43]. According to Weill et al., in terms of revenue growth and valuation, big firms with digitally savvy CEO teams outperformed comparable companies without such teams by more than 48 percent [43].

Digital savvy is a knowledge of the influence that developing technology will have on a company’s success over the next decade gained via experience and study [43]. A critical component in the success of organizational transformation is sharing this understanding across the senior management team [43]. According to an interview with Jean Pascal Tricoire, chairman and CEO of Schneider Electric, “when every firm becomes a digital business, every leader must embrace digital transformation personally” [43]. Tricoire went on to say that “the idea that digital is someone else’s problem is the last thing you want in your team” [43].

Regrettably, the demand for digital savvy at the highest echelons of management has outpaced the supply [43]. In 2019, Weill and colleagues published research that looked at the boards of directors
of 3,228 major U.S.-listed businesses with yearly revenues of more than $1 billion [43]. This research found that only 24% of boards were digitally savvy [43]. As a part of their ongoing research, Weill et al. expanded their analysis to include top management teams from 1,984 big firms worldwide [43]. C-level executives and function and regional territory leaders were part of these senior management teams [43]. According to this survey, just 7% of the firms had executive teams that could be considered digitally savvy [43]. Of the analyzed executive teams, the average top management team had nine members [43]. Only 17 percent of the team members could be considered digitally savvy individually [43]. The survey found that senior executives' digital savvy differed greatly depending on their role and responsibility [43]. According to the research, around one out of every four CEOs and one out of every eight CFOs (Chief Financial Officer) are deemed digitally savvy [43]. Chief technology officers (CTOs) and chief information officers (CIOs) are more likely than other leaders to have this competence, but this isn't a reason for joy [43].

According to the research of Weill et al., the team revealed that just 47 percent of CTOs and 45 percent of CIOs are digitally savvy [43]. The top IT executives' attention is frequently drawn to IT infrastructure and back-office operations rather than the more strategic drive to get commercial value from digital technologies [43]. According to the Weill et al. study, all senior jobs, even those that generally need high levels of technology and technical competence, such as CTO and CIO, have a noticeable shortage of digital savvy [43]. Table 6 displays the most and least digitally savvy executive jobs based on the Weill et al. study.
Table 6 - The Most - and Least - Digitally Savvy Executive Roles (Recreated table from Source: [41])

<table>
<thead>
<tr>
<th>Title</th>
<th>% Digital Savvy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chief Technology Officer (CTO)</td>
<td>47%</td>
</tr>
<tr>
<td>Chief Innovation Officer (CIO)</td>
<td>45%</td>
</tr>
<tr>
<td>Unit President/Geography President</td>
<td>35%</td>
</tr>
<tr>
<td>Chief Operating Officer (COO)</td>
<td>24%</td>
</tr>
<tr>
<td>President</td>
<td>24%</td>
</tr>
<tr>
<td>Chief Executive Officer (CEO)</td>
<td>23%</td>
</tr>
<tr>
<td>Head of Marketing</td>
<td>23%</td>
</tr>
<tr>
<td>Head of Corporate Development</td>
<td>23%</td>
</tr>
<tr>
<td>Head of Human Resources</td>
<td>21%</td>
</tr>
<tr>
<td>Head of Sales</td>
<td>15%</td>
</tr>
<tr>
<td>Chief Financial Officer (CFO)</td>
<td>12%</td>
</tr>
<tr>
<td>Head of Corporate Communications</td>
<td>11%</td>
</tr>
<tr>
<td>Chief Legal Officer</td>
<td>8%</td>
</tr>
<tr>
<td>Chief Compliance Officer</td>
<td>8%</td>
</tr>
<tr>
<td>Head of Investor Relations</td>
<td>6%</td>
</tr>
</tbody>
</table>

This sentiment holds true even for the oil and gas/mining industry. Based on the CISR survey, of the 2019 total digital spending in the enterprise, only 11% went towards strategic (innovation) spending, whereas 45% went towards infrastructure spending (Source: MIT Center for Information Systems Research 2019 Transformation and TMT Survey (N=1311)). Figure 16 provides the complete breakdown of 2019 digital spending in the oil and gas/mining industry.
This evidence points towards a gap in the understanding or implementation of digital technologies in oil and gas/mining industries, which could be driven by leaderships’ lack of digital savviness. Leaders are critical to the success of the digital transformation. It is also imperative that they, like their teams, have the ability to comprehend and communicate in a data-driven world. Leaders are increasingly expected to make data-driven decisions that affect their organization’s performance [44]. Organizations need to focus on establishing data literacy within their leadership teams. Leaders who lack data literacy will continue to be uncomfortable interacting with and using data to make choices. This lack of data literacy can have harmful effects on the organization and trickle down to the employees resulting in the transformational effects never being fully felt [44].

Miro Kazakoff, an MIT Sloan senior lecturer who teaches courses on communicating and persuading with data, stated that “in a world of more data, the companies with more data-literate people are the ones that are going to win” [29]. Kazakoff goes on to state that “data literacy has always been a requirement in successful organizations. It’s just that data illiteracy is more obvious now – or data illiteracy just causes more damage now than it used to” [29]. According to a Gartner study of chief data officers, poor data literacy is one of the top three barriers to building robust data and analytics teams [29]. In contrast, an Accenture data literacy survey of more than 9,000 employees in various roles found that only 21% of people felt confident in their data literacy skills [29].

Several oil and gas operators are aware of this gap, and in response, have launched digital leadership programs in the hopes of improving their organization’s overall understanding of digital technologies and helping to establish more robust strategic business plans resulting in a shared vision leading to strategic alignment. However, it is essential to note that the expectation should not be that everyone working within an organization must be a data scientist per se. Different positions in various firms need differing levels of data literacy [29]. Data literates can think about and act on data, but they aren’t as skilled as data scientists [29]. Data literacy isn’t the only aspect of becoming a data-driven firm,
even though results may be obtained faster. Data literacy is part of a bigger picture that includes data maturity, which refers to executives demonstrating the capabilities they expect from employees. The ultimate goal is data-driven decision-making [29].

While data literacy has become a buzzword, additional factors must come together to build a data culture [29]. According to Piyanka Jain, author and data science expert, “true data literacy should enable one to think and act differently – start by understanding the real business problem and use intelligent insights to solve the right problems” [29]. According to data experts, chief data officers are frequently in charge of literacy programs, but all senior executives must be on board and model the intended outcomes. Piyanka Jain goes on to say that “if you’re not going to be able to be data-driven and hold your team accountable from the top, it’s not going to flow down. Leadership is the key. Data literacy projects shouldn’t be launched without executives being part of the program” [29].

In addition to this, Weill et al. discovered significant differences in CEO digital savvy across businesses [43]. Predictably, media, software, and telecom firms have the greatest percentage of digitally savvy executives (about one-third of senior team members) [43]. Construction, arts, entertainment, recreation, agriculture, forestry, fishing, and hunting had the fewest digitally savvy management team members, accounting for fewer than 1% of executives [43]. While the bulk of senior management teams are not digitally savvy, the few teams with 50% or more digitally savvy individuals have proven to provide an exceptional performance premium when compared to their counterparts [43]. According to the Weill et al. research, they found that organizations that had digital savvy leadership teams experienced 48 percent better revenue growth and higher valuations and had 15 percent higher net margins than the rest of the companies analyzed [43]. However, it is also important to note that companies do not have to simply achieve a threshold of 50% of digital savvy leadership members to start reaping the rewards of performance gains. The study found that as the percentage of digital savviness within the top leadership teams begins to increase, so does the revenue growth and net
Top teams with a digital mindset seek breakthrough performance through innovation, cross-selling, and business change [43]. Firms in the top quartile, for example, earn 59 percent of income from innovations launched within three years, compared to only 18 percent for companies in the lowest quartile [43]. Innovation and company transformation aimed at satisfying consumers' wants and capturing a bigger part of their wallets are early signs of improved financial success in a digital environment [43].

Weill et al. also discovered that top digitally savvy teams achieve industry-leading results in part by fostering rapid learning cultures characterized by test-and-learn experimentation, minimum viable product releases, and evidence-based decision-making [43]. Modular, open, and agile information technology is used to support these approaches [43]. Leading businesses utilize APIs to turn their "crown jewels" (what they do best) into digital services that can be used internally for innovation and externally by partners to create ecosystem value [43]. APIs allow more than half of key capabilities for firms in the top quartile of our analysis, compared to 19% at companies in the lowest quartile [43]. Leaders who are digitally savvy lead differently than those who are not [43]. They've shifted their leadership style from a command-and-control to a coach-and-communicate approach. This change is supported by the widespread use of evidence-based decision-making [43]. Rather than going with their gut or what has worked in the past, digitally savvy top teams build hypotheses and test them, searching for early indicators of success that are linked to financial performance [43]. This enables executives to detect and resolve issues more quickly [43].
Chapter 3 - Digital Transformation Case Studies from the Oil and Gas Industry

This chapter is used to highlight three case studies from the oil and gas sector. The first case study focuses on Equinor and its current digitalization approach. The second case study focuses on Chevron and its remote directional drilling journey in the Permian Basin. The third case study provides a real-life example of applying an analytical method to assess the applicability of a digital initiative for a major oil and gas operator. These case studies will be used to discuss the approach, drivers, challenges, and future initiatives each of these companies has been faced with during their digital transformation journeys.

3.1 - Case Study: Equinor

3.1.1 - Primary Goal of Equinor Case Study Exploration

The primary goal of this case study is to demonstrate Equinor’s current digitalization approach. In this section, Tore Lundell-Nygjelten’s thesis findings will be explored to see how and if they are applicable and generalized across the oil and gas industry. Tore Lundell-Nygjelten’s thesis assumes that Equinor has had several opportunities to capitalize on previously untapped business value by enhancing its digitization approach [6]. Through Tore Lundell-Nygjelten’s research, he wanted to seek out answers to two fundamental questions. His questions were [6]:

- What is Equinor’s current digitalization strategy?
- What efforts can be made to improve Equinor’s current digitalization strategy?

3.1.2 - Historical Context of Equinor

The discovery of the Ekofisk field in 1969 was a significant moment in the oil and gas industry and Norway’s history [45]. The Ekofisk oil field lies about 180 miles southwest of Norway, midway
between Norway and the United Kingdom in the North Sea (See Figure 17 for reference) [46]. The Ekofisk field is a large carbonate reservoir with two zones: 1) Ekofisk, 2) Tor [47]. These two zones are highly porous and fractured chalk, with matrix permeabilities of around one md and effective permeabilities ranging from 1 to 50 millidarcy (mD) [47].

Phillips Petroleum was experiencing a period of stagnation and financial upheaval before the discovery of Ekofisk in 1969 [45]. According to Phillips Petroleum, “earnings were in a slump, management had laid off more than 1,000 employees, and dry holes were hurting the bottom line. Company geologists were excited about the prospects of the North Sea, but the company and its partners had drilled several dry holes offshore Norway in two years” [45].

Phillips Petroleum pondered halting its Norwegian efforts after eleven fruitless efforts to find oil offshore Norway [49]. However, after considerable thinking, Phillips and the Ekofisk licensees agreed to give it one more chance and drill one final hole [45]. Phillips Petroleum used the Ocean Viking to drill what was supposed to be its last well in the Norwegian North Sea on August 21, 1969 [45].
morning of August 31, the well site geologist observed a significant formation pressure increase, and oil began to flow into the wellbore and the mud tanks on the Ocean Viking [50]. According to the well site geologist, “oil was gushing out of the borehole, and it took a while to control it” [50]. To mitigate the potential risk of encountering a well control event due to an uncontrolled blowout, the team decided to plug and abandon the well and resume drilling operations approximately one thousand meters away from this wellbore [45]. On October 25, 1969, the Ocean Viking penetrated an oil reservoir striking oil in the Norwegian North Sea for the first time [45]. On December 23, 1969, Phillips Petroleum alerted the Norwegian government that it had discovered oil catapulting Norway into the oil and gas industry [45]. Ekofisk was a giant discovery not only for Phillips Petroleum but also for the country of Norway. The discovery of the Ekofisk field was of great significance. Not only was the Ekofisk the first commercial discovery of oil and gas for the nation of Norway, but it also led to Norway becoming one of the largest oil-producing nations in the world [45].

The Ocean Viking, pictured below, was one of the world’s first semi-submersible drilling rigs [49]. Ocean Drilling and Exploration Company (ODECO), a forerunner of today’s Diamond Offshore, owned the Ocean Viking drilling rig [49]. Built by Aker in 1966, the Ocean Viking was Norway's first offshore drilling rig [49]. Figure 188 displays a picture of the Ocean Viking while operating in the North Sea.
Initial production began in 1971, and by 1980, there were 18 offshore platforms and 50 operating wells in the Ekofisk field [46]. The Ekofisk field was believed to have more than 3 billion barrels of recoverable oil when it was discovered [45]. Since production commenced in 1971, the Greater Ekofisk Area, which is comprised of four producing fields – Ekofisk, Eldfisk, Embla, and Tor, has generated almost 2,500 billion NOK (2018-kroner worth) in value and produced approximately six billion barrels of oil equivalent from the Greater Ekofisk Area [49], [52]. The Ekofisk field alone has produced 4.2 billion barrels. In comparison, Eldfisk has produced one billion barrels, and other areas in the region have contributed 0.8 barrel oil equivalent [52]. This has resulted in increased oil recovery on the Ekofisk field, which has increased from 17 percent to over 50 percent today, exceeding all initial expectations [52].
Upon the discovery of oil at Ekofisk, Equinor was born. Den Norske Stats Oljeselskap AS - Statoil, the Norwegian State Oil Company, was created in 1972 with the Norwegian government as a primary stakeholder [53]. In 2018, Statoil decided to change its name to Equinor to complement its goals and growth as a diversified energy firm [53]. Equinor has positioned itself to produce value and be a leader in the energy transition in recent years, and key actions were taken in 2020 to shape further the company’s future [54]. Equinor is a multinational energy firm with operations in more than 30 countries [54]. Equinor is not only the world's leading operator on the Norwegian continental shelf but also globally. Equinor specializes in oil and gas exploration, development, and production and has recently started to venture into the renewable energy space focusing on wind and solar power, leading to a broader energy portfolio [54].
Over the last decade, the global oil and gas industry has been subject to financial turmoil. In 2020, the oil and gas industry experienced its third price collapse in the last 12 years (Figure 20). After the first two shocks, the oil and gas industry rebounded, and business continued as usual. However, the most recent downturn combines a supply shock with an unprecedented demand drop and a global humanitarian crisis due to the ongoing COVID-19 pandemic. Currently, the oil and gas industry is entering into an unprecedented and challenging era defined by intense competition, flat to declining demand, investor skepticism, increasing public and government pressure regarding the impact of climate change, and digital transformation. However, under most scenarios, oil and gas will remain the same. As a result of the oil and gas downturns, many companies, including Equinor, began to focus on cost-cutting and process optimization initiatives, which catapulted digitalization efforts into the forefront of most companies’ strategic plans.
Equinor realized that fundamental to the company’s longevity; they needed to focus on the idea of creating value in the next and/or new normal. According to Equinor’s President and CEO, Anders Opedal, “[Equinor is] preparing for a future that will be different from the past. Equinor aims to be a leading company in the energy transition and to build the energy industry of tomorrow” [54]. In addition to Equinor’s desire to be a leading company in the energy transition, Equinor has also recently embarked on its digital transformation journey [54].

Digitalization has been seen as a potential solution across various companies in the oil and gas industry to help address some of the most challenging issues facing the oil and gas industry. The oil and gas industry has had a reputation for being cutting-edge in a variety of technological areas. However, the industry is often plagued by very conservative processes and practices. This traditional oil and gas industry strategy has previously been viable due to significant cash flows and high-profit margins on projects [6]. However, this is no longer a sustainable option, and the oil and gas industry is now trying to find new ways to save money and improve its chances of survival in this new era [6].

3.1.3 - Digitalization in Equinor

Digitalization is driving Equinor’s next wave of improvements in safety and sustainability. Equinor created its Digital Center of Excellence (DCoE) and the digital roadmap in 2017, marking a significant step forward in the digitalization arena [6]. Equinor is regarded as one of the early adopters of digitization initiatives in a somewhat trailing industry due to this digital leap [6]. Equinor’s goal for establishing their DCoE was to act as a “hub for all digitalization efforts within Equinor” [6]. Equinor aims to keep and improve its competitive edge to progress its corporate strategy, constantly offering safe, high-value, and low-carbon operations [6]. Equinor aims to invest in securing “a global leadership position within digitalization. Not because digitalization and innovation are goals in themselves, but because digitalization is a key enabler for [their] strategy” [6]. In recent history, Equinor’s digitalization
efforts have been directed towards the operational side of the more prominent Equinor organization leveraging their experience regarding production digitalization and technical solutions in their offshore operations, which has historically been on the digital frontier [6]. Equinor's unique digital technologies have helped the corporation achieve high safety standards while also considerably increasing revenue. Table 7 provides some insights into Equinor’s operational gains as a result of digitalization and innovation efforts [56]:

Table 7: Equinor’s operational gains due to digitalization and innovation efforts [56]

<table>
<thead>
<tr>
<th>Area</th>
<th>Savings</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Value creation producing fields</td>
<td>&gt; $4 billion USD</td>
<td>50% increase in cash flow improvements – 2020 to 2025 Equinor share pre-tax</td>
</tr>
<tr>
<td>Remotely Operated Factory ™ - Capex Reduction</td>
<td>&gt; 30%</td>
<td>New facility concept compared to conventional</td>
</tr>
<tr>
<td>Automated drilling – Cost reduction</td>
<td>~ 15%</td>
<td>Automated drilling compared to conventional</td>
</tr>
<tr>
<td>Integrated remote operations – Added value</td>
<td>~ $500 million USD</td>
<td>NPV increase based on the production and OPEX effects of the integrated control rooms</td>
</tr>
<tr>
<td>Cash flow improvements already delivered in 2019 and 2020</td>
<td>$1 billion USD</td>
<td>Cash flow improvements from digitalization</td>
</tr>
</tbody>
</table>

3.1.4 - Strategy in Equinor

As mentioned previously, Equinor's business strategy aims to provide safe, high-value, and low-carbon operations [6]. With this in mind, Equinor's strategic vision sees technology and innovation as key to sustaining long-term growth by obtaining the capacity to exploit digitalization possibilities that lead to more efficient and productive operations building upon its values of being open-minded, collaborative, relentless, and compassionate industry leaders [6]. However, Equinor's performance might be hampered if digitization lags behind the sector, as there is no defined digitalization plan in place. As an outsider looking into the organization, it appears as though their digitalization strategy is driven more by the desire to gain operational efficiency than a true “digital” strategy.

To measure Equinor’s current digitalization strategy, Lundell-Nygjelten produced nine guidelines based on his relevant research on directing digitalization [6]. According to his analysis, 21 observations were discovered, leading to the following nine guidelines [6]:
1. Digitalization necessitates an objective comprehension of the external world.
2. The meaning and impact of digitalization on the firm must be clearly stated.
3. A firm-wide awareness of and capability in digital is essential.
4. The firm’s corporate culture must support digitalization.
5. Digitalization demands a greater level of collaboration.
6. In the digital era, business strategy is a continual process.
7. In the digital era, decision-making is more data-driven.
8. Digitalization requires firms to enter uncharted territories.
9. Digitalization is about the continuous management of change.

Based on Lundell-Nygjelten’s study, Equinor’s digitization challenges have several core issues. First, the conclusions of this study are compatible with industry literature, strategy literature, and personal experience(s), demonstrating that the findings apply not just to the industry but also other companies undergoing transition and digitalization initiatives. Second, because of its rigidity, siloed business structures, and potential exposure to an accelerated global market, generalizations to other oil and gas companies are primarily based on the idea that the oil and gas industry as a whole is lagging behind other industries when it comes to embracing digitalization [6].

3.1.5 - Suggestions for the Industry based on Lundell-Nygjelten’s Equinor Case Study

Some critical ideas may be taken from Lundell-Equinor Nygjelten's case study to enhance the broad digital transformation strategy found in the oil and gas sector to address the core causes of the digital disruption. First, Lundell- Nygjelten's research advises that an organization's purpose and effects must be communicated [6]. However, based on the literature reviews performed in Lundell-Nygjelten’s work and this thesis and personal experience, the term "digitalization" has been defined in various ways, making it difficult to know what is meant by its usage leading to digital hesitancy and confusion. As a
result of this lack of definition, to promote acceptance and alignment, the organization must define and enforce a uniform definition of "digitalization" that is compatible with the company's future digitalization plan [6].

Equinor's digitalization effect was shaped by the DCoE and the Digital Road Map. Equinor's digitization impact, on the other hand, is restricted to the operational side of the company, ignoring the administration side [6]. According to Lundell-Nygjelten, “digitalization of the administration needs to be brought under the DCoE’s scope, and lessons learned from production digitalization should transfer over to administrative digitalization leading to lessons learned and best practices being shared across previously existing organizational silos within the organization” [6].

Digitalization ambiguity was another cause for insufficient coordination (i.e., operational silos) and the lack of digitalization direction and strategy inside Equinor's organization. According to Lundell-Nygjelten, value creation can no longer be viewed as linear or ad hoc in today's fast-paced and digitalized industry [6]. Instead, continuous, transparent cooperation inside the company and external stakeholders across the value chain is the only way to achieve this value generation [6]. To achieve this, a circular collaborative ecosystem (CCE) must be built within an organization to encourage this sort of ongoing, transparent cooperation [6]. According to Lundell-Nygjelten’s research, a “CCE has the potential to leverage integrated digital platforms to strengthen the collaboration among ecosystem participants leading to reduced costs, operational transparency, and fast-track innovation” [6].

The development of digitalization governance can enhance insufficient collaboration within a business. Essential governance abilities such as transparency and project continuity are now being developed at Equinor to propagate best practices throughout the enterprise [6]. According to Lundell-Nygjelten’s report, most of Equinor’s governance issues may be remedied by encouraging improved collaboration and communication within the organization [6]. In addition to this, Equinor lacked the necessary collaborative governance to blend technology-enabled and business-enabled capabilities [6].
Equinor’s present digitalization governance focuses only on the operational side of the business rather than converting the company into a technology-enabled, learning, and strategy-focused enterprise [6]. With that stated, it’s also important to remember that digitization isn’t a one-time change management initiative. Instead, it must be considered as a living organism undergoing regular testing, learning, adaptation, and cooperation with all of the system’s key stakeholders [6].

The lack of an overall digitalization plan was the most vehement digitalization governance worry, according to Lundell-research. Nygjelen’s Equinor, like many other oil and gas firms, has a slew of separate, well-funded digitization efforts but no overarching plan to bring them all together [6]. In the case of Equinor, the digital road was described by Lundell-Nygjelen as "paved as you go," but the success of the digital strategy depends on a clear and integrated digital plan [6]. Organizations must invest in the exploration of digital offerings through continued education learning opportunities both inside and outside the organization, as well as adopt trial and error mentalities that lead to future experimentation, efficiency improvements, adoption, and innovation, to keep their strategic digital direction up to date [6]. When looking at the Equinor case study specifically, it seems as though Equinor’s current digitalization strategy could be described as more of an operational effectiveness strategy rather than a digitalization strategy [6]. With a desire to improve operational effectiveness, organizations may overlook the importance of developing a solid strategy and strategic positioning, leading to diminishing returns due to redundancy, failed pilot applications, misunderstanding of the original problem statement, and other factors. To avoid this, it’s crucial to recognize that digital maturity is driven by digital strategy [6]. As a result, the most essential recommendation for an organization is to define a clear and long-term overarching digitalization strategy that aligns with the organization’s digitalization goals and objectives and a leadership emphasis on continuous improvement and management of the defined digitalization strategy [6].
3.2 - Case Study: Remote Directional Drilling

3.2.1 - Historical context

In 2016, Chevron's Permian Basin business unit investigated the discrepancies impacting a fleet of drilling rigs [57]. The absence of consistent operational methods and procedures was the root of most of the performance/cost discrepancies discovered throughout the research. As a result, the team devised strong standardized operating procedures that were adopted across the Permian Basin. The business unit created performance baselines due to these standard operating procedures, allowing the team to identify performance possibilities better. The business unit embarked on a quest to better standardize its processes in March 2018. The idea of remote directional drilling had been discussed in the drilling and completions function. With the digital transformation push at the beginning of 2018, it was the perfect opportunity for the business unit to lean in and use digital technologies to deliver value and truly set its operations apart from its competitors in the Permian Basin. The Remote Directional Drilling Center (RDDC) was initially housed within Chevron’s Decision Support Center (DSC). The DSC is very similar in function to Equinor’s DCoE.

At the start of the project, the Mid-Continent business unit had approximately 20 development drilling rigs working [57]. One of the most difficult issues that the business unit faced with such a large fleet was uniformity throughout the whole fleet. There were 20 distinct directional drillers across the 20 different rigs, which resulted in 20 different interpretations of "what good looked like." As a result, although the business unit had created extremely rigorous Standardized Operating Procedures (SOPs), the business unit frequently witnessed huge performance variations, impacting the wells' total cycle time. Historically, directional drillers were based on a drilling location and were responsible for helping drive the performance and directional drilling operations for a specific rig. As previously stated, this led to numerous perceptions of what "good" looked like, resulting in variable, unrepeatably wells. The Mid-
Continent business unit is now drilling horizontal wells in the Permian basin from RDDC in Houston, Texas, roughly 500 miles away (Figure 21).

Figure 21 displays the location of the remote directional drilling center compared to the Permian Basin

(Original image was obtained from https://commons.wikimedia.org/wiki/Category:Permian_Basin_(North_America)#/media/File:PermianBasin-02.png. Annotations were made by the thesis author)

The RDDC enables the business unit to handle all directional drilling operations for all development rigs operating in various locations. Directional drillers support the rigs via a directional drilling pod. To assist field-based activities, rover teams were created in the field. Picking up bottom hole assemblies (BHA), setting down bottom hole assemblies, troubleshooting problems, and coaching field employees are all examples of field-based operations. The business unit currently has no directional drillers or MWD personnel on-site.
3.2.2 – Transitioning to Remote Directional Drilling Operations

The shift to remote directional drilling and MWD operations was carried out in three stages [57].

The diagram below summarizes the stepwise strategy utilized to deploy remote directional drilling (Figure 22). Phase 1 entailed creating workflow processes and procedures specific to carrying out remote directional drilling operations using RSS tools. Phase 2 entailed creating workflow processes and procedures specific to carrying out remote directional drilling operations using traditional mud motor tools. Phase 3 entailed investigating different technologies/software/systems available on the market that could be used to supplement the remote directional drilling process. The team specifically looked into technologies that supported rig automation and drill bit guidance systems.

![Diagram](image)

Figure 22 Remote center vision - Summary of the phased approach to remote directional drilling (Source: [57])

3.2.3 - Remote Directional Drilling Strategy

With such a large Permian Basin focus, transitioning to remote directional drilling operations has helped the business unit better manage work with its business partners while preserving consistency and repeatability in its drilling operations [57]. The RDDC allows the business unit to keep the same directional drillers while also ensuring knowledge transfer between the directional drillers and the office engineers. Before implementing remote directional drilling, the business unit realized that the directional drilling service providers were not utilizing consistent people on its contracted rigs, resulting in discrepancies in performance. Many people regard directional drilling to be somewhat of an art form. By bringing these highly competent directional drillers into the RDDC, the business unit could methodically record and reproduce what excellent looks like and translate those best practices and
lessons learned to other rigs within the fleet to generate long-term performance improvement and efficiency gains.

Another way of looking at the RDDC is to view it as a process control system that allows for consistent, repeatable wells [57]. It eliminates process variables, or at the very least, seeks to keep them within a certain range. The RDDC has also improved the visibility, communication, and cooperation among those responsible for well execution, such as the directional drillers, MWD engineers, drilling engineers, geosteers, drill site representatives, drilling superintendents, and performance pod engineers, to name a few. It has also aided in the implementation of accountability when it was required. In the past, each side operated in silos, making the best choice they could with the facts they had. They were, however, unable to observe the impact of their decision on others. The team viewed this as a huge opportunity to enhance performance by simply having everyone on the same page. Bringing the directional drillers to the remote center had the objective of establishing consistent, repeatable wells. With the implementation of remote directional drilling operations, cross-functional teams have been able to make faster decisions and communicate lessons learned and best practices more effectively. The benefits of remote directional drilling are:

- Consistent, repeatable performance due to shared best practices and lessons learned
- Increased collaboration allowing geosteering to interact directly with the drilling operations team resulting in a better understanding and execution of well placement
- Reduced footprint at the well site
- Quality of life improvement

3.2.3 A – Future Possibilities for Remote Directional Drilling Operations

Remote directional drilling was initially deployed on wells using RSS applications due to current technology(ies) [57]. Because of this existing technology, the team could deploy remote directional
drilling operations in a few weeks. However, the team recognized that the next step of transitioning remote directional drilling operations to wells using conventional tools (i.e., mud motors) applications would be extremely difficult. Transitioning to traditional mud motor tools necessitated considerable collaboration with drilling contractors and directional firms. The business unit had to shift from directional drillers who used to perform the directional slides on location to drillers executing slides on location. To ensure the success of remote directional drilling with conventional tools, both the drilling contractors and directional drilling service providers needed to provide the necessary support and training to their drillers and directional drillers, respectively. This conventional tool transition required more mentoring and coaching compared to the RSS application.

The operator, drilling contractor, and directional drilling service providers have continued to work together to support the remote directional drilling efforts [57]. In addition to this, the remote directional drilling project has spurred the organizations involved with the deployment to take a deeper look into their product offerings and explore how their products can be made to be more future-proof. As a result of the recent technological improvements, Chevron has begun to explore a future in which directional drillers seldom, if ever, step foot on a drilling rig. With the establishment of the remote directional drilling center, the team is constantly exploring ways to enhance it with bit guidance technologies, rig automation, predictive analytics, and virtual reality to help drive down the well cycle time and achieve the objective of delivering consistent, repeatable wells.

With the increased reliance on technology and remote operations, there needs to be a robust way of imparting the same knowledge and experience that was historically gained by hands-on/on-site work. According to an interviewee in a Journal of Petroleum Technology article, “virtual reality is the only way that we can truly train going forward” [58]. The interviewee went on to add that the application of virtual reality even applies to the drillers on location who are currently implementing the sliding operations [58]. Through virtual reality, the speed at which a directional driller and/driller is
trained could exponentially decrease, resulting in individuals gaining experience quicker. The interviewee goes on to discuss the speed at which directional drillers and/or drillers could be trained through the use of virtual reality technologies.

3.2.3 B - Future of Remote Directional Drilling and Beyond

Before the pandemic, many oil and gas operators had been wary of moving away from traditional methods of drilling operations (i.e., directional drillers located on the rig site) for various reasons. From personal experience, some of these reasons include, but are not limited to:

- “This is the way we have always done it” mental models
- Concerns related to cellular/cell tower infrastructure
- Safety and environmental concerns
- Decreased personnel on location to assist with troubleshooting
- Loss of jobs
- Limited capabilities of current technologies
- Fear of the unknown/ hesitance to change
- Concerns about degradation in performance

However, the looming pandemic caused many companies to reassess their mental models and reimagine their drilling operations. Due to the travel restrictions and work from home mandates that were imposed, many companies would not have been able to maintain their drilling operations if it were not for the technologies that enabled the shift to a remote directional drilling model [59]. Because of these restrictions, directional drilling service providers used their lessons learned and best practices from the remote directional drilling operations to allow for quick adoption and implementation to maintain operations. With Chevron’s remote directional drilling center already being established, the transition to directional drilling specialists working from home was relatively smooth. The recent
pandemic has shown that, when done correctly, digital transformation can help organizations flourish in even the most difficult of situations.

According to Mordor Intelligence’s Directional Drilling Services Market Overview, the directional drilling market is expected to grow at a compound annual growth rate (CAGR) of approximately 6% between 2020 and 2025 [60]. With this expected growth, the most recent oil and gas downturn, and growing reliance on technology and remote work, maintaining and hiring personnel with the knowledge and technical skills required to drill directionally will be a challenge. The future of drilling will be enthralled in drilling and rig automation as well as data analytics. Several directional drilling and drilling contractor service providers are looking to alleviate some of the drilling industry’s challenges by focusing efforts on rig automation. These technologies will eventually help to alleviate challenges with limited competency and inexperienced drillers. Some automated directional drilling methods have been tried in the industry, with encouraging results showing that the technology can radically transform the oil industry. As automated directional drilling advances, oil and gas operators will increasingly recognize it as a technology that will increase drilling performance leading to improved efficiencies, repeatability, consistency, cost reduction, and scalability. The deployment of automated directional drilling technologies will be driven by data analytics and knowledge of the directional drilling best practices and procedures and offset well data and analysis in each location.

Remote directional drilling has also opened up an entirely different world of opportunities to many directional drillers. Before remote operations, directional drillers would have to spend extended periods in very remote places away from their families. With the advent of remote directional drilling, the oil and gas industry has been able to offer directional drilling specialists with a lifestyle that was previously not afforded to them. Directional drilling specialists are now able to lead a more regularly scheduled lifestyle. By making the shift to remote directional drilling, the oil and gas industry, especially the directional drilling service providers, will be able to recruit from a different talent pool, which may have
been previously limited due to the requirements of long, spontaneous, often risky travel to very remote, hazardous locations.

The oil and gas industry is currently at a pivotal point. The industry is faced with multiple challenges, such as the “Big Crew” change, ever-increasing reliance on digital technologies, and the high highs and low lows of economic cycles. However, the downturn caused by the ongoing COVID-19 pandemic is unlike anything the oil and gas industry has ever experienced or the world for that matter. With many firms' existence at stake, as well as a longer-term reduction in petroleum consumption, the oil and gas market's future might look quite different in the coming decades. These challenges ultimately impact how companies try to sustain their operations and manage their workforce leading them to embrace revolutionizing technologies and ideas to ensure that their organizations are future-ready.

3.2.3 C - Importance of Co-Innovation and Co-Creation with Business Partners

The idea of co-innovation and co-creation could be a thesis in and of itself. However, for the sake of this thesis, a brief discussion of co-innovation and co-creation is provided, highlighting the important role that it plays in the digital transformation and the future of the oil and gas industry.

While it is common knowledge among innovative leaders and implementers that a company must innovate or perish, it is often easier said than done when it comes to anything that matters [61]. This sentiment can be applied to all types of organizations, especially those considered to be traditional industries such as oil and gas. We currently live at a period when huge corporations with tremendous resources are equally capable of unleashing disruptive innovation through well-executed acquisitions and strategic alliances [61]. These more established organizations may benefit greatly from tapping into innovation networks that exist outside of a company's walls as a means of accomplishing a digital transformation within their business [61].
However, all businesses require innovation to advance towards an effective digital transformation [61]. According to McKinsey, 70% of all transformation projects fail [61]. Organizational transformations often fail due to a lack of support and buy-in from leadership and employees. According to the 2021 Gartner’s CIO Agenda Survey, “organizations that increase funding for digital innovation are nearly three times more likely to be leading performers than laggards as compared to their peers” [62]. Regardless, businesses will take the risk and make efforts to manage the endeavor toward a good conclusion [61]. Oil and gas organizations need to shift their thinking from inward-looking technology to outward focus, which requires big picture thinking. This is where the importance of systems thinking comes into play. Many experts agree that it is critical to do more than simply move from one technology platform to another or execute business process re-engineering across numerous companywide transformation initiatives [61]. Technology innovation is intended to allow a completely new future state, which may involve new business models and cultural transformation throughout the entire firm [61].

When two (or more) organizations purposefully collaborate to address a commercial challenge, this is known as co-innovation [63]. Co-innovation allows businesses to pool their resources and ideas to create intuitive goods, services, and solutions that benefit everyone [63]. This not only minimizes some of the risks associated with developing new solutions but may also provide firms with shared insights on changing market and industry trends that are critical to the success of their co-innovation strategy [63]. In today’s highly competitive and fast-paced business climate, it is becoming increasingly difficult for businesses to keep up with the speed of technological development and accomplish everything optimally on their own [63]. As the remote directional drilling project progressed, the team grew increasingly conscious of the value of co-innovation and co-creation with their business partners [63].

Collaboration with external partners brings additional views and talents to the table, allowing businesses to anticipate and respond to consumer requirements more quickly [63]. Managers entrusted with different aspects of what a firm needs to become digital may find this co-innovation strategy
appealing, as it contributes to speeding innovation and controlling innovation risks [61]. In practice, co-innovation indicates a firm's purposeful desire to extend its innovation capability to incorporate an external perspective of specialists to make outcomes implicitly more inventive [61]. This also demonstrates a readiness to welcome outside ideas from a vast and diversified ecosystem and support the capacity of the ecosystem's companies to exercise and orchestrate dynamic capacities [61].

However, co-creation and co-innovation are not certain; there are crucial aspects that businesses must examine to ensure their success. These important components are as follows [63]:

- Bringing together appropriate partners and peers from the industry to utilize their knowledge and skills to encourage the exchange of fresh ideas and viewpoints;
- Creating risk-and-reward models that benefit all participants; and
- Using industry and consumer feedback to foster trust and strong connections among partners throughout the co-innovation process.

The formation of co-innovation and co-creation collaborations has numerous advantages. Among these advantages are ([63]; [61]):

- Developing customer alliances;
- Strategic business planning requires long-term partnership;
- Creating a futuristic solution;
- Fostering cross-industry collaboration;
- Creating products and services that are meaningful to the customer;
- First mover advantage is the consequence of a game-changing invention that no one has ever provided before [61];
- A chance to expand human resources or other assets that will help the company develop [61];
- Increasing organizational agility for innovation; and
• Risks, expenses, and best practices are all shared and validated.

Without a question, co-innovation and collaboration will play an important role in driving digital transformation for improved business and consumer results [63]. A scalable and extendable method for operationalizing co-innovation project work provides a useful method for prioritizing and managing the technological complexities and risks that come with solving difficult business issues [61]. Co-innovation is usually seen as a feasible solution to difficult challenges that a single company cannot solve on its own [61]. When the focus of risk is on the effective implementation of new technologies, a co-innovation strategy may benefit businesses [61]. Leadership in charge of digital transformation for their companies should think about how to use co-innovation approaches to coordinate and integrate components from various equipment and business partners.

The case of the Chevron remote directional drilling project is a prime example of a true business partnership driving co-innovation and co-creation between large, traditional organizations. By adopting a co-innovation and co-creation model with their business partners for the remote directional drilling project, the team was able to invite key stakeholders to participate in the design and problem-solving process to produce a mutually valued outcome. This collaboration fostered a one-team mentality allowing the team to focus on the project's innovative goals and expected outcomes. The outcome of this co-creation and co-innovation partnership revolutionized how the business unit and the business partner viewed and executed directional drilling operations. This revolution led to new workflows, processes and procedures, innovative ideas and products, an outlet to overcome consistency and staffing challenges, and technical solutions to complex questions within the oil and gas industry. This example shows that even large oil and gas operators with huge levels of name recognition can embrace co-innovation and co-creation, inviting customer-driven solutions to solve complex problems, leading to agile work changes revolutionizing the oil and gas industry as we know it.
Complex organization development necessitates a wide range of viewpoints and skillsets. All of these contributions must be grouped and coordinated. The term "organization design" refers to the process of establishing a framework that allows specialized individuals and groups to effectively coordinate their efforts [64]. Furthermore, strategy and leadership are crucial in guiding a transformation's overall success. Leadership must develop a transformation plan that gives direction, model helpful behaviors that shape change, and build capacity in both individuals and the organization to drive change. The following section will discuss how designing a strategic digital transformation implementation plan can lead to prioritization efforts, ultimately leading to adoption and further innovation.

3.3 – Case Study: Application of Analytical Method to Oil and Gas Industry
3.3.1 - Background of the Design Structure Matrix (DSM) – Process architecture/organizational

The establishment of remote directional drilling centers has forever changed the traditional upstream landscape of the oil and gas industry. It has pushed the envelope of what is possible when agile work practices, co-innovation, and co-creation methods are implemented. However, as with any change, many questions arise, and one question, in particular, is: how do we drive value creation in this ever-changing, new digital world?

To answer this, organizations need to shift their focus from an inward-looking to an outward-looking approach by adopting systems engineering methodologies. The change to an outward-focused mindset necessitates holistic thinking. By using the systems engineering approach, organizations will have the opportunity to evaluate their current systems from a holistic vantage point and anticipate the ideal system's future state and synthesize how to efficiently close the gaps that exist [21]. Brook Colangelo, executive vice president, and CIO for Waters Corporations, a lab equipment and software company, shares a more simplistic illustration of the importance of holistic thinking. According to Colangelo, “[organizations] have to start designing the streets, the experiences, and the roadmaps for
the destiny that we’re going to drive toward. [Organizations] have to do that by envisioning where all of these things go and sequencing them and showing the entire business landscape” [62].

To do this requires organizations to think differently. According to Steven Eppinger, professor of management science at MIT Sloan, “every company is trying to be more agile – it’s become part of the regular engineering management lexicon” [65]. Agile techniques have revolutionized software development, allowing teams to create quicker, produce faster, and focus on customer demands [65]. According to Eppinger, other systems engineering projects should take a leaf from the agile playbook and rethink how their work is done [65]. DSM was used to expand upon the work performed to stage up the remote directional drilling center. Currently, a proof of concept is underway to understand how Chevron’s DSC can benefit from the use of “smart” E&P environments, which offer collaborative technologies that could have the potential of connecting the entire E&P life cycle. The value proposition for this type of technology is to provide transparent, scalable, protected, and fully managed digital solutions that will potentially lead to the seamless integration of people, data, and software applications across all sectors of the E&P lifecycle. For the purpose of this thesis, this E&P environment technology will be referred to as “Project A.” Project A has been developed by one of Chevron’s business partners (referred to as “BP1”).

Incorporating smart E&P environments offers potential solutions to many of the oil and gas industry’s challenges. One of the major challenges present in the industry is the ability to effectively coordinate operations among teams. Coordination efforts are often the source for many surprises and poor program performance seen within an organization. For instance, two teams frequently discover too late that they did not effectively coordinate key product design aspects, resulting in an integration difficulty that causes the program to be delayed. In addition, poorly coordinated teams may experience gaps (one thinking the other is working on something) or overlaps (redundant work). A more systematic approach to addressing coordination and integration is essential when designing an organization or a
product. To better understand this proof of concept and test the applicability, a collaborative technology subcategory was selected. The team used the straightforward modeling technique known as Design Structure Matrix (DSM). DSMs are used to manage system design complexity to achieve competitive advantage. Using this technique, an organization can identify highly interactive groups of components/elements/functions that can potentially form good modules. This process can lead to a deep understanding of complex systems allowing for the complexity to be more easily managed, enable parallel workflows, and create additional options. DSM methods have proven to be an efficient matrix-based modeling and modularity analysis approach. DSMs are a highly flexible network modeling method with extensive applications in engineering management and many other fields.

3.3.2 - Discussion of the DSM Analysis

In the case of this thesis, the DSM was compiled to test not only Project A’s applicability but how redundant or relevant DSC support is to Chevron’s business units. The DSM was created from the perspective of the Decision Support Center (DSC) current offerings using the IR (inputs in rows, outputs in columns) convention leading to an information exchange model. Thirty-six individual elements were established, which led to 605 information exchanges. These information exchanges are noted by “x” marks in the DSM shown below in Figure 23.
Table 1: DSM that was generated to explore the DSC’s current offerings

Some modularization was performed based on the components of the Project A environment but has been removed from this thesis for IP protection. The “Name/Elements” (Column E) were grouped into their respective Project A components (i.e., monitoring and visualization, interpretation, analytics, and insights). The DSM is unidirectional in a way. The outputs have been mapped because the connectedness of the inputs was mapped. No sequencing, but strong dependencies are shown.

Modeling the current state of the system is a necessary way to begin. Before reimaging a process and capabilities, it is important to first develop a progressively deeper understanding of the system behavior, interactions, and sensitivities in the context of the stakeholder needs and the
operational environment. Only then can one begin to identify non-intuitive gaps/opportunities and begin to improve upon the processes. As mentioned previously, the numerical information exchanges were tabulated during the analysis (605 information exchanges). Today, the vast majority of those 605 interactions are done by humans/manually.

This DSM shows that the system is more connected than initially thought, which is interesting and potentially advantageous because it speaks to the complexity of the interactions of the dependencies within the system. Before this work was completed, these relationships largely lived within the mental models of individuals working inside the DSC and the drilling and completions function. This often resulted in additional coordination between all parties and time-consuming communications to align these mental models – some of this less productive coordination can go away now that this DSM model (Figure 23) exists.

When looking at the modules, one thing that is evident is that there is significant connectivity across the components of Project A. Based on this, it would be hard for BP1 to jump in and start developing one aspect of Project A further without understanding the holistic picture. This is the essence of systems thinking and is by no means trivial. This is why organizations must balance top-down with bottom-up approaches – had the team developed the modules in a piecemeal (bottom-up) approach, the amount of changing requirements - as a product development unfolded – may have become insurmountable. This DSM is tangible, value-adding work and averts non-productive time of resources because we have improved upfront system definition.

3.3.3 - How can the areas highlighted via the sections lead to prioritization efforts?

The DSM provides a common representation of how things interrelate, which could provide both Chevron and BP1 with a powerful roadmap to further develop Project A. Although this DSM may seem disconnected from Project A, one can see the DSM as a really valuable starting point, allowing those involved to understand the dynamics that exist within the DSC/system as a whole. Ultimately, it
leads to understanding all of these components, elements, interactions, and dependencies to develop and deliver the best product.

It is also important to note that this DSM was created capturing both explicit and implicit knowledge. However, implicit knowledge is where the true value of the DSM work comes into play. Using a DSM allows the teams to create a shared context and improve the speed of decision-making and coordination. Getting all of this information into a single structure is a valuable visual aid for people to begin to understand the dependencies and interconnectedness of the system. By using this type of modeling, Chevron and its business partners will now be able to better understand the connectivity of the components/elements and how changing one element can lead to potential changes to many other components/elements. This understanding will lead to potential improvements in costs, organizational visibility, reduced task redundancies, invisible lost time, and partnership relationships.

3.3.4 – The DSM value proposition
The DSM work that was performed proves that a little modeling may go a long way, and the business can benefit from having this competence in the proper areas of the organization. It is not necessary for an organization built for integration to become a strict bureaucracy. Individuals in a big, complicated program, on the other hand, require a suitable degree of structure and/or strategy to be innovative, efficient, and effective, as demonstrated by the remote directional drilling project. Integrative mechanisms, when used correctly, aid creativity and process rather than hinder it. According to Dougherty, “people in innovative organizations know what their jobs are, who they report to, and how they should do their work because they can imagine what to do and how to do it and because they can adequately imagine what others will do” [66]. Such a vision necessitates a well-designed organization.

With the DSM serving as a visual aid, people will now have a better understanding of the interconnectedness of the system, which might not have been obvious previously. The DSM can support
product development and help highlight the cascading effect, which can impact various elements within the system. The DSM will help provide improved change management. As a result, the Project A development team’s throughput of value-added work will improve, and unnecessary rework cycles can be avoided in the future. The outcome of this DSM is important to the Chevron/BP1 partnership going forward. It is important to note that the DSM should not be viewed as a conversation limiter but rather a conversation initiator. The work performed in this DSM should be used to help inform the design of the Project A product development process.

With the digital age upon us, organizations need to start adopting new ways of assessing opportunities. The application of new technology to do things in new ways is what digital transformation is all about. Digital transformations are very involved and often plagued by redundant efforts, loss of efficiencies, and lack of understanding. By integrating systems engineering methods into current workflows, procedures, and practices, organizations can evaluate their current systems from a holistic perspective. With this incorporation, organizations should be able to hypothesize the ideal system’s future state and synthesize how to most efficiently close the gaps that exist. The DSM case study presented in this thesis showed how the proposed systems engineering methodology could be applied to organizations seeking to find inefficiencies within their operations and workflows. This analysis is intended to show how organizations can invest in their digital transformation and bring awareness to the specific areas that often result in organizational and system tensions. Using the DSM allows organizations to focus on creating more productive, synchronized teams and helps an organization to see the whole-product solution in the correct business context. In addition to this, the systems engineering methodology can be applied to digital transformations that have been adopted within organizations to determine how well the organization’s digital strategy aligns with the organization’s strategic vision. In many organizations, operational value streams are the main process systems that business unit customers use or even care about. Organizations need to map out solutions to those
processes to establish a clear understanding of how these solutions provide value to their customers. By gaining a better understanding of the architected system and how connections and interactions impact the ecosystem, the methodology can be used to assess digital tools leading to improved prioritization efforts and future adoption.

The most valuable characteristic of the DSM is the transparency it offers to the organization. Using the DSM will help promote internal visibility related to day-to-day progress and share progress externally in the interest of receiving user feedback. This new level of transparency will challenge the expectations of the organization. This may cause discomfort for some within the organization. However, it will also help drive efficiency and promote an understanding of how organizations strive to meet their goals. This level of organizational scrutiny can drive transparency and accountability. Holistic thinking will be deployed, driving consensus by interacting with engineering and other functions. In addition to this, it will allow an organization to manage the requirements of the expected value by working closely with the key stakeholders involved, leading to improved transparency. The oil and gas industry has productivity, cost, and safety opportunities to capture with the digital transformation. To experience the benefits of these new digital technologies, the oil and gas industry must focus on the interconnectivity of the multidisciplinary subsystems. Other world views will be a lot harder for an oil and gas company to fully embrace and/or acknowledge. One of these examples is viewing the customer at the center. This is very difficult for an oil and gas company because the end customer is often difficult to define and identify. Many organizations in the IT realm have started to consider the people who are using the digital tools as the end customer. There is no easy solution for who the end customer is for an oil and gas company, and it doesn’t help, at least in the short term, to start thinking about the person who is driving the car as the end customer. However, organizations must define a starting place to move forward on their digital transformation journeys. The DSM has to be thought of as a way of developing
an integrated customer-centric model that can allow an organization to relentlessly prioritize against its strategic intent.

A DSM can help an organization reach its digitization, digitalization, and digital transformation objectives by providing a model that can help foster creativity and systemization in addressing the oil and gas industry challenges. The challenges confronting many oil and gas organizations and their digital transformation are inextricably linked and interdependently feed. While it is impossible to isolate and untangle these challenges individually, the goal of using the proposed technique of DSM is to assist an organization in providing some insights on key elements of the complex transformational journey towards digital maturity [67].

Decision processes can become cumbersome in a mature and complex organization, where responsibilities and functions are often unclear. Complex products necessitate complex organizational structures [64]. Complexity appears as a plethora of components and relationships. As a result, as product complexity rises, effective organizational design and integration become more difficult [64]. After constructing a DSM model to describe an organization’s system, the second major advantage is its adaptability to analyses ways to prescribe a better system architecture. It’s vital to emphasize that the DSM is a static depiction of interactions among organizational units; it depicts the interactions between integrated product teams (IPTs) that exist at any particular time [64]. Subsequent DSMs could be established to allow the organization to understand how communication pain points grow and recede within the confines of the organization’s operations and workflows [64]. By comparing the subsequent DSM models, the drawbacks experienced by some of the interactions identified on the DSM may predict the possible need for a reorganization or, at the very least, a reevaluation of which integrative mechanisms (IMs) are most appropriate [64].
Although the DSM may not be the answer to all the challenges the oil and gas industry currently faces, a DSM is very good at helping an organization standardize its processes, which is a precursor to digital transformation. The DSM technique will help take an organization down to the task level providing a simple and concise way of representing complex systems, and it is amenable to powerful analyses such as clustering and sequencing [68]. Typically, DSMs are used to map out what an organization currently offers. DSMs can help an organization capture value that has already been created within a specific system. DSMs could provide a way of helping an organization identify where automation and standardization could provide efficiencies within current operations and workflows.

After all, an organization must first quantify what it has to establish a DSM in the first place. DSMs are very good at analyzing what an organization has and helping them to drive efficiency improvements from there. Through the use of a DSM, potential areas could be exposed, identifying areas that need work. However, a DSM is probably not suited for broad innovation where an organization looks to make big changes. Innovations that provide a step-change in performance sometimes need a new way of thinking about the organization. A DSM could be considered a targeted innovation tool specifically targeted towards efficiency and not towards new revenue streams.

The DSM presented in the case study helped provide a compact, easily scalable, and intuitively accessible representation of a particular system architecture within Chevron. This thesis does not aim to present the DSM methodology as a definitive solution for the oil and gas industry. However, it is a different way for organizations within the oil and gas industry to look at what they currently offer. By using the DSM as a starting point, organizations will potentially establish a more streamlined approach allowing them to accomplish their digital transformation goals. Organizations should consider potentially incorporating a DSM into their strategic plan to help illustrate the strategic vision. The DSM fits into a general world view of the oil and gas industry around efficiency, but it will not help as much with step-changing innovation. A DSM is not going to provide an organization with the tools for a big
innovation. However, it can facilitate the standardization of operations and workflows within an organization, an important precursor to digital transformation. A DSM could potentially help point out where a large innovation might be useful to an organization.

Simply put, a DSM can be seen as one tool in a large toolbox that can help identify inefficiencies and streamline efforts within an organization. A DSM is a tool much like agile methods. These tools can potentially help an organization innovate, but DSMs and agile methods alone will not get an organization to innovate. What agile methods can do in this notion of iterating rather than one fell swoop approach to IT is: 1) makes one more responsive to the people you are working for and/or with; 2) because there are cross-functional teams, it means that there are more diverse viewpoints in any one project; And, 3) because an organization is working in a sprint type model, one theoretically can stop a project before the entire project is completed. It can be seen as a piece of innovation, but it is not innovation itself. However, if an organization is working towards implementing a digital platform, a DSM could help provide huge potential to an organization. DSMs have the potential to help make an organization’s digital platform run better. However, the platform must work with a DSM and agile methods and ensure that the data is all consolidated. Suppose an organization is looking to implement a digital platform and they have not worked to consolidate all of the data. In that case, these operations, workflows, and processes will still be fragmented, resulting in many different ways of doing the same thing. If this is the case, then the platform will not be an innovation but rather a high-tech way to access the organization’s data cluster – essentially a high-tech way to access an organization’s spaghetti.

The DSM can help make discipline more of a habit within an organization. One of the hardest things to change in a transformation is the people working inside an organization. If an organization is able to encourage its employees to change their habits and think about conducting their work differently, the digital transformation will be much easier. An organization’s use of the DSM technique should be more
focused on establishing disciplined ways of working. Incorporating the DSM technique into an organization’s operations and workflows is a step in a process, not the ultimate solution.

An example of this can be found in post-implementation reviews (PIR), also commonly known as debriefs in the world of drilling operations. PIRs can be considered a real disciplined approach to capture lessons learned and best practices. Through the analysis of organizations that have a very strong discipline in terms of conducting PIRs, companies that say they are effective at conducting regular PIRs are good at doing a lot of other things. This is not to say that the PIR is important or makes the organization good at what they do but rather that the PIR serves as a marker of discipline for an organization. PIRs are very important because an organization will not get value out of the projects performed unless the completed projects are studied, leading to the capture of best practices and lessons learned. If an organization can foster discipline at this stage, it is more likely than not that the organization will have discipline in other areas of operation or workflows. However, the goal for an organization should not be to be so disciplined that they cannot think outside of the box. A big step-change in innovation will require that an organization sometimes allows its employees to think outside of the box. It is a balancing act between maintaining discipline while encouraging creativity.

Some of these big step-change innovations in the oil and gas industry have been seen in the recent developments in directional drilling and hydraulic fracturing. In recent decades, both of these innovations have played a huge role in the efficiency and economic improvements in the oil and gas industry. Despite these innovations being industry game-changers, organizations have still been able to identify additional areas for efficiency improvement. With many organizations in the oil and gas industry steadfastly focused on gaining efficiencies in directional drilling and hydraulic fracturing operations and workflows, tremendous amounts of hydrocarbons have been extracted from shale formations which were previously thought to be uneconomical. The DSM technique is a tool that fits very well with the way oil and gas companies think of the world in terms of efficiency and productivity. If a DSM is
conducted on its own, it will not be particularly useful for an organization. However, organizations need to consider incorporating tools, such as the DSM, to have a true strategic plan that fully characterizes their organizational goals. These types of tools will help highlight the motivations behind a strategic plan, which can assist with transparency, leading to improved buy-in and adoption from the individuals working within the organization. Also, small wins can help increase commitment and keep people focused on the bigger task. It is imperative that those working in the lower echelons of an organization are able to influence management to incorporate this type of discipline into its operations and workflows. A DSM could be viewed as a precursor to a platform discipline. Going forward, organizations need to focus on how they can get leaders to incorporate discipline into what the overall enterprise strategy may be. It is not the expectation that senior management is discussing DSMs. One would never expect a CEO or top management team to get excited about seeing a DSM. However, it would be more exciting for those supporting the senior leaders leveraging DSMs and other systems engineering methodologies to drive future discussions and support the ultimate strategic vision of the enterprise through their use. By incorporating tools such as the DSM, organizations can add to their corporate resilience.

By using this approach, the organization will be able to establish their organizations' current state (or baseline state), allowing them the opportunity to benchmark against what their future state will look like in the digital transformation environment. By establishing the difference between these two states, the organization will be able to map out the interactions of the systems allowing them to evaluate the interconnectedness and relationships that exist within the system. By performing this mapping task, the organization will establish a more structured, systematic way to assess, pilot, and implement new technologies leading to further operational improvements.
3.3.5 - Forward Steps

The DSM documented in this thesis can function as a living model and serve as a compelling roadmap for the DSC. Moving ahead, Chevron should empower its teams to use the DSM for continuous improvement purposes by incorporating new information and data as it becomes available to the team. More specifically, the organization should consider using this DSM to capture changes based on the current Project A roadmap and act as a repository for future engineers to continue to work from. The DSM may also help identify changes to the project’s complexity, potentially allowing organizational leaders to better estimate the resources required to implement technological improvements. A practical next step would be to create a Delta DSM to compare today’s design to Project A’s future architecture. A Delta DSM would help the organization better understand the architectural dynamics that exist across different product generations. This information might then be used to improve product evolution for flexibility and reduce change costs throughout the product lifecycle. However, the Delta DSM exercise is beyond the scope of this thesis and is an opportunity for future work and exploration.

Chapter 4 – Conclusion

4.1 – Analysis and Discussion

Several developments are poised to alter the oil and gas industry as we know it. In the coming decades, technological improvements, environmental concerns, social trends, and government policies will impact the future demand for oil and gas, which will pressure an already overstretched industry. Because of these pressures, the oil and gas industry will continue to walk the line of difficult decision-making for the foreseeable future. The major question many are asking is how the future oil and gas ecosystem will look and how current businesses will use their core strengths to survive and perhaps grow from these new difficulties. In this thesis, I hope to have been able to convey an understanding of digitization, digitalization, digital disruption, and the important role leadership plays in getting an
organization to a future-ready state. Organizations must be focused on positioning themselves well enough to take on the challenges presented by the digital transformation.

As more and more companies begin to embark on their digital transformation journeys, retaining efficiencies and ensuring competencies is imperative to the organization’s overall success. In order to fully reap the benefits of digital transformation in the oil and gas industry, firms must analyze, invest in, and deploy both soft and hard automation technology and embrace and encourage more agile work methods [69]. From personal experience, drilling operations typically account for approximately 45-60% of the total well cycle time and 50-70% of an oil and gas company’s capital spending. Drilling operations are often regarded as the most critical and complex operations performed in the entire oil and gas value chain [69]. With the criticality of drilling operations, operations must be performed right the first time to minimize such things as the potential long-term drilling-related impacts on the completion and workover of the well and the non-productive time associated with problems that may arise during drilling operations. Drilling operations may also present significant health and safety risks and often involve an intricate web of interfaces between multiple business partners working together to deliver a single well [69]. With drilling and completion operations being a major component in oil and gas well development expenditure, many companies are developing technologies that have the potential to bring significant improvements to all aspects of well construction, from streamlining core processes to strengthening frontline capabilities to improving the overall organizational model, including the ever more critical business partner interface [69]. Despite the monetary investment required for these new technologies to come to fruition, oil and gas companies need to focus on the significant operational changes that will need to take place to ensure the potential successful implementation of these new technologies in their ongoing effort to digitally transform [69].

In recent years, the oil and gas industry has taken drastic steps to maintain its profitability, especially during the most recent downturns. Organizations are taking the necessary steps to position
themselves to adopt technological advancements. According to a McKinsey study published in 2018, well spending across most basins was 40-50% lower than the 2013 and 2014 levels [69]. This reduction in spending can be further broken down into the following three buckets [69]:

1. lower unit prices resulting from overcapacity in many supply categories in recent years - notably, offshore rig rates in the first quarter of 2018 were nearly half of their 2013 highs
2. lower drilling activity in general, especially in the area of exploration
3. operating model adjustments and real productivity improvements in well delivery

These cost reductions are the result of several different initiatives within the oil and gas industry. Some operators have decided to trim staffing to match lower activity levels, as seen with the most recent downturn related to the oil glut created by the ongoing COVID-19 pandemic [69]. While other operators opted to focus on simplifying key processes and well designs for a greater percentage of their well portfolio, others elected to focus on standardized design processes and procedures for a larger portion of their well portfolio [69]. In addition to these, a few operators have also focused their efforts on improving frontline practices and capabilities to realize real operational improvements [69]. These initiatives were highlighted in the case studies presented in this thesis and display the importance of the corresponding changes required for a digitally enabled operating model to truly be successful. These initiatives have placed drilling and completion organizations in a position to adopt digital change at scale [69]. With the recent recovery in drilling spending and the ongoing supply chain disruptions, the next wave of digital transformation is even more imminent [69].

At this point, it is important to stop and more deeply discuss the listing of the reduction in spending previously listed. For the purpose of this thesis, this list has been reordered from the original McKinsey study by how much an individual oil and gas company can impact the reductions in spending. The first bucket, the lowering of unit prices resulting from overcapacity, is market-based and is much harder to
control and/or predict, as seen with the recent COVID-19 pandemic. Lowering unit prices is an economic decision where an oil and gas operator is a part of this economic environment. However, a specific oil and gas operator does not have a lever to pull in terms of overcapacity. This is where the prisoner’s dilemma comes into play regarding questions such as what the oil and gas industry does with overcapacity. The prisoner’s dilemma is a helpful tool for strategic decision-making because it gives a framework for understanding how to achieve a balance between cooperation and competition [70]. The second bucket, lower drilling activity, is an organization’s decision right to decide whether or not they want to increase or decrease their drilling activity. During times of overcapacity or under capacity, an organization could potentially decide to decrease or increase production, respectively. The final bucket and impetus for this thesis is the operating model adjustments. This bucket offers the biggest lever for oil and gas companies.

Operating model adjustments are not dependent on the economic environment or what an organization’s competitors are doing. An organization always has the opportunity to make its operations and workflows more efficient and focus on productivity. This speaks to where oil and gas operators have agency. These organizations have some agency under capacity and typically more under drilling activity. However, these organizations do not have to consider what their competitors are doing when discussing operating model adjustments and productivity improvements. The first two buckets require an organization to game out the system. The digital transformation provides oil and gas companies the opportunity to continue working on their operating model adjustments.

By integrating systems engineering methods into current workflows, procedures, and practices, organizations can evaluate their current systems from a holistic perspective. The DSM case study presented in this thesis showed how the proposed systems engineering methodology could be applied to organizations seeking to find inefficiencies within their operations and workflows. Systems engineering can be used to assess digital tools leading to improved prioritization efforts and future
adoption. Using the DSM allows organizations to focus on creating more productive, synchronized teams and helps an organization to see the whole-product solution in the correct business context. In many organizations, operational value streams are the main process systems that business unit customers use or even care about. Organizations need to map out solutions to those processes to establish a clear understanding of how these solutions provide value to their customers.

The oil and gas industry has productivity, cost, and safety opportunities to capture with the digital transformation. Systems engineering methodologies can help capture these opportunities by offering the oil and gas industry a new way of viewing decades-old problems and challenges. Using techniques, such as a DSM, will help take an organization down to the task level providing a simple and concise way of representing complex systems. One of the most valuable characteristics of the DSM is the transparency it offers to an organization. Using the DSM can help promote internal visibility related to day-to-day progress and share progress externally in the interest of receiving user feedback. A DSM could also potentially provide a way of helping an organization identify where automation and standardization could provide efficiency gains within its current operations and workflows. DSMs are a tool that fits very well with the way oil and gas companies think of the world in terms of efficiency and productivity.

However, this thesis does not aim to present the DSM methodology as a definitive solution for the oil and gas industry. Rather, it is a different way for organizations to look at what they already offer. DSMs are simply one tool in a large toolbox that can help an organization identify inefficiencies and streamline efforts within an organization. A DSM can be seen as a piece of innovation, but it is not innovation itself. Incorporating the DSM into an organization's operations and workflows is a step in a process, not the ultimate solution.
As oil and gas operators begin to contemplate the implications of their digital transformation and the coming changes to the upstream sector, all the key stakeholders must be engaged closely with the ecosystem to adapt to the disruptive trends. By engaging with business partners early on in the development process, designs can be streamlined, allowing for operational efficiencies to be maintained and minimizing the disruptive and/or redundant operational efforts, leading to potential increased costs and hindering widespread adoption. In the digital age, operators will also need to focus more on establishing partnerships that help promote technology innovation not only within their organizations but also within their business partners’ organizations. Operators need to be willing to support testing and deployment efforts for new technologies and potentially fund research and development efforts.

By establishing these business partnerships, the oil and gas industry will be priming itself for fit-for-purpose operating models for individual operators. As has been addressed throughout this thesis, there is now enormous value on the table for key players who are willing to engage in digital transformation. Many of these big shifts are expected to unfold fast, brought in solely by the rate of technological advancement. Industry leaders need to align to these digital/technology trends, socialize a common vision across their organization and the industry as a whole, and develop a comprehensive strategy to adopt these changes swiftly so as not to fall off the wagon. The energy market and demand for fossil fuels may differ from what the oil and gas industry has previously experienced. Still, the route to successful digital transformation is long-lasting, and the fundamental principles of success have not changed.

The oil and gas industry’s future may rely on long-term business partnerships and open platforms for all major stakeholders within organizations. By changing the way organizations think about data as an asset and innovation, the oil and gas industry may potentially find itself in a similar situation as the human genome project. Twenty years ago, the human genome was a government-funded database that many companies were interested in exploring. The human genome data was made public. Many
researchers began building diagnostic tools, exploring different therapies, and developing new pharmaceutical drugs leading to companies or individuals filing for patents for their new developments. The challenge with making the human genome data public was that there needed to be one group that started the initial spark of sharing data to support the overall innovation within the sector.

The human genome project has many similarities to the current oil and gas industry digital transformation. Many companies are very diligent with their data confidentiality to maintain their competitive advantage. However, there is an incentive here when discussing the sharing of data. If companies felt other companies were contributing data and were better off contributing their data, more organizations would potentially support the effort and share their data. This type of feedback could result in the opposite of the prisoner’s dilemma. However, it is important to understand that it is extremely challenging to get something like this started within any industry, not only the oil and gas industry. In addition, open data cannot be used unless good platforms have been established, leading to data-sharing. According to Barb Wixom, data-sharing, which is akin to open data, needs: 1) curated content; 2) designated channels, which includes the data platform; and 3) controls [71]. This is where the digitization, digitalization, and digital transformation piece becomes extremely important for an organization to get right.

National oil companies (NOCs) are at the heart of the petroleum economy of the Middle East and North Africa (MENA) nations [72]. NOCs invest in oil and gas projects, generate fiscal income for governments, and provide a wide range of public services [72]. Some of the region’s NOCs include some of the most advanced oil firms globally, such as Saudi Aramco, Qatar Petroleum, and Abu Dhabi National Oil Company (ADNOC) [72]. Country dynamics in the region vary considerably, which impacts the different risks they face and NOCs’ potential responses [72]. Many NOCs have strong business and university ties, making them ideal candidates for implementing an open data platform. NOCs have the means and opportunity to mirror the gains of the human genome project, with parallels in terms of
government funding and centralized datasets. This contrasts to a market like the USA, where data is private, proprietary, and segregated, making long-term strategic partnerships more challenging.

However, this may become a more common option in the oil and gas industry especially coming out of the Middle East, simply due to the nature of oil and gas companies and work in the region. Moving forward, open data platforms may become imperative for the oil and gas industry to compete and thrive in a digital world.

More data is one thing. Open data is another and is something that is often misunderstood. For the oil and gas industry, the benefits of having access to global reference datasets are enormous [73]. Open data platforms would help provide transparency, innovation, economic value, efficiency and reduce environmental impact within the oil and gas industry. Open data platforms enable people to use the data without the normal restrictions, which provides them with the freedom to build products and innovate. Being open also gives the whole supply chain visibility of upcoming operations, enabling proper planning and better allocation of resources [73].

Many oil and gas organizations are working towards establishing a digital company platform. However, establishing a digital platform should not simply be about ridding the organizational system of costs but rather a good platform that will let the collective innovate. At some point, the organization can consider establishing a platform where external developers can capitalize on the standard methods, lessons learned, and best practices to enhance interoperability between various service providers. However, this is difficult to execute. To implement this effectively, organizations need to ensure that the foundational components of the platform are in order, which is where digitization and digitalization play an important role. The oil and gas industry needs to be more focused on establishing well-defined, true digitization and digitalization strategies than simply wanting to gain operational efficiencies through digital offerings. Organizations must view digitization and digitalization not as a one-time change management initiative but rather as a living organism undergoing regular testing, learning, adaptation,
and cooperation. The oil and gas industry can no longer adopt a "pave as you go" attitude [6]. The success of the digital strategy depends on a clear and integrated digital strategic plan.

In addition to big data efforts, there is also an automation revolution underway in the oil and gas industry. Like most automation endeavors, this revolution is driven by the demand for improved efficiency, reduced costs, and enhanced health, safety, and environment (HSE). The fast-paced drilling operations taking place in E&P require improved process efficiency. Given the oil and gas structure that is present in the Middle East, it may allow several countries such as Saudi Arabia and the UAE to leverage an open data platform to drive operational improvements, efficiency gains, and reduce operating costs significantly, ultimately leading to new innovative ways of performing drilling operations. I hypothesize that the oil and gas industry will begin to see large improvements in the realm of rig automation coming out of the Middle East in the next 5 to 10 years due to the nature of the nationalized operations in those countries and the announcements of recent strategic partnerships such as, but not limited to:

- ADNOC’s partnerships with Baker Hughes and H&P
- Saudi Aramco’s partnerships with Nabors and Rowman

These partnerships are strategic moves made by these two specific NOCs and provide the opportunity for collaboration to become more localized in the drilling sector and enhance drilling operation capabilities in these two countries.

Through the research, it is difficult to glean insights into ADNOC and Aramco’s strategic plan. However, in the case of ADNOC, they have explicitly stated that they have signed the strategic partnership agreement with Baker Hughes to enable and support the growth and development of ADNOC’s subsidiary, ADNOC Drilling. With ADNOC’s plan to further grow its rig fleet, enhance services and expand domestic and regional operations, they continue to refine the way they work, leveraging
smart drilling techniques and engineering solutions, building their capabilities so that they can strive to be even more cost-efficient and improve performance leading to an increase in wells being drilled [74]. This is the first time ADNOC has partnered with an international strategic partner to take a direct equity stake in one of its current service companies [74]. This collaboration will allow for both organizations to gain access to a slew of new commercial prospects, including the possibility of providing comprehensive drilling services outside of the UAE [74]. This cooperation is another significant step in ADNOC’s group-wide transformation and value creation initiative, which tackles the changing energy landscape and ensures that the business stays resilient and adaptable to capitalize on market possibilities [74].

Although it is not explicitly made apparent from the research, some may assume that these NOCs bring in business partners to further develop and exploit rig automation. The business partners brought in can be considered industry leaders in the digital transformation and rig automation space. This partnership speaks to the new and expanded approaches to strategic partnerships and co-investments and the more proactive management that many more organizations within the oil and gas industry should consider embracing. In the future oil and gas industry, partnerships will be a key step for capturing more value from upstream growth and the substantial increase in the number of wells required to fulfill the worldwide need for energy. The oil and gas industry needs strong, innovative teams that work smarter to take us into the next frontier. The case of ADNOC and similar NOCs speaks to the importance of exploring transformative business models, establishing well-defined strategic plans, and working smarter.

With announcements such as ADNOC and Aramco’s being publicized within the oil and gas industry, this is where the idea of morphing business models comes into play. Some organizations may begin to experience a shift in considering themselves more of a supplier and much less like an omnichannel. At this time, a traditional oil and gas operator may consider themselves an ecosystem driver in some areas of the business/process. They have an ecosystem. They bring in service providers and orchestrate the
big picture process resulting in an internal modular producer for the operator. The operator could develop this as a service that is only used internally. Still, if they are thoughtful about it, they could decide whether or not there are areas in the world that they are not competing in and could offer this service externally. In some ways, because of the business-to-business (B2B) nature of the interactions needed to develop internal tools, the need for a great customer experience is often lessened. Traditionally, oil and gas operators could be considered their own customers. However, now that they have the capability and could develop it, they could potentially plug and play different business partners into their system. This could lead to an operator becoming a modular producer and potentially lead to the creation of another revenue stream for the organization resulting in significant changes to its traditional business model(s).

With these changes in business models, oil and gas operators would no longer be focused solely on the exploration and development of oil and gas wells for their specific organizations, but rather the organization would now be providing a technology to do that for other companies. For example, this technology could be potentially applied to areas where the operator does not own the lease rights, but they have a tool that they could offer to a company that will help streamline their processes. However, the organization may determine that this is a technology that is too importation to share due to potential fears of copyright infringement. At this point, contracting will become critical. Sometimes these concerns can be handled through contracting, often resulting in products and services being white-labeled. White labeling is the term used to describe a fully supported product or service that is manufactured by one business and sold by another [75]. The latter firm buys white-label items and services and does not trademark them [75]. Grocery stores frequently sell cereals and other items under their own brand name at a reduced price compared to competing brands [75].

Many companies across all industries “white label” their products and services. One specific example of this can be found in Fidelity. Fidelity has a white-labeled trading platform. The Fidelity
platform is core to them, but other companies out there are using the Fidelity trading platform. This is a very interesting type of strategy. Several companies have bought and integrated the Fidelity trading platform and use it as their own. This is an example of a complex modular producer. However, it is not the easiest modular producer. This type of development would be revolutionary to the oil and gas industry as it would now put the operators in the same space as the service companies of the world. Operators would essentially be offering their in-house developed platforms as a service. This would be an interesting strategy for the traditional oil and gas operators to explore, especially if an organization could get data-type assets. However, further investigation needs to be undertaken to better understand what this looks like and is out of scope for this particular thesis.

These business model issues cannot be undertaken unless the organization has established great technology. The way oil and gas firms conduct business is changing. Some of the changes that are being experienced in the oil and gas industry include, but are not limited to: 1) the establishment of more strategic business partnerships; 2) the implementation of operation and workflow automation; 3) the utilization of agile methodologies; And, 4) the development of digital company platforms. Despite these changes, many organizations are still attempting to hold on to the old ways of doing business while adopting digital solutions that focus on improving operational efficiencies. The key piece here is the technology that is offered by the organization. As discussed, DSMs may not be the answer to all the challenges the oil and gas industry currently faces. However, using a DSM can help an organization highlight the need for a digital platform. In addition to this, DSMs can also help organizations start thinking about their digital platforms and what they would like to do with the digital platform. For example, a digital platform will allow an organization to establish modules that can be reused again and again. However, establishing these types of modules will be difficult, if not impossible, to do with an older platform. An old, clunky platform cannot be expected to deliver this type of value creation for an organization. This is where the business model discussion is absolutely imperative to the success of an
organization. This is a new idea to the oil and gas industry and needs to be explored more to truly understand its future applications.

The drivers for digital transformation should not necessarily be only cost-driven. It is more related to how an organization works smarter with their efficiency gains, productivity, predictability, etc. The two bases for working smarter are:

1. How do you automate what is automatable and what is easy to automate?
2. How do you provide your people with the data to make better decisions?

The idea of working smarter is about automating and evidence-based decision-making. Working smarter is really trying to free individuals working within an organization from the heroics piece of it all and get them to a place where the organization has decided that the processes and procedures that are in place are the best way to do something; operations have really been streamlined, and the organization can now automate the work where it can. Simultaneously, the organization must take the data and consolidate it to bring it to a position where individuals can use it. This deep understanding will move organizations away from the past heroics – every well is drilled differently every time. However, in the beginning, one can see why this may be the case because an organization does not have enough use cases and no way of classifying data and information. At this stage, it is all experimental. This has been commonly the case when moving into a “new area.” However, new areas in the oil and gas industry are getting harder and harder to find. Therefore, it is critical to leverage the lessons learned, best practices, and experiences from other areas and apply them to these “new areas” is critical.

At this point, the oil and gas industry should be exploiting what it has and thinking about working smarter, not working new. This is particularly relevant when considering the oil and gas industry's problems in terms of acquiring fresh talent. Organizations must examine data to ensure that the individuals we have within them use the best available data and are comfortable using and making
choices based on it. Previously, businesses had to ask themselves questions such as what can we build? How can we build it? [76]. However, those are past questions, and organizations need to ask themselves: What should we build? How should we build it? For example, should the organization consider building using APIs, using components and modularized code, or bespoke? Or, can we buy it? And if so, do the benefits of buying outweigh the benefits of building? Leaders must question how they can control the chaos of data to extract meaning [76]. As design environments get larger and more diversified, they become potentially more useful while becoming more difficult and time-consuming to explore [76].

In the past, many companies in the oil and gas industry have had plenty of money and built very bespoke systems. However, going forward, organizations must ask themselves do they need a bespoke system to achieve their goals. Or, can they buy something and adjust it to their specific needs? Many companies in industries outside of oil and gas have started to look at ways to not build bespoke systems but rather focus on only building a system if they make sense to the organization. A mixture of all of these ideas is currently being implemented in the oil and gas industry. In many industries today, there is a push to move towards the cloud and go with systems that are not so heavily customized at the beginning stages of implementation. Typically, these systems are often customized around the edges along the way. However, there are going to be some instances where customization makes sense. An organization should only seek to customize in instances where they get a huge bang for their buck. More than likely, this customization will not fall in an organization’s operations and workflow efficiency areas but probably in the areas where the organization innovates. Improvements in efficiencies will be the result of standardized platforms.

The oil and gas industry needs to focus on merging the gaps by establishing cross-functional teams that will/can work together to establish platform(s) that will drive business productivity and success. Cross-functional teams bring things together. Cross-functional teams also bring data into the
decisions much earlier, allowing iteration to occur earlier, ultimately saving time and money. The most difficult part for the oil and gas industry will be the idea of iterating and experimenting due to the monetary investment required. In addition to this, the oil and gas industry has to be motivated by the innovation that has always existed but appears to have been lost or forgotten due to economic pressures and recent global turmoil. The drop in oil prices has prompted a call for change, and the new leaders will be at the forefront of this effort. It's time to put innovation back to the forefront of the oil and gas sector.

Oil and gas operators need to be more open to the trial-and-error mindset while maintaining their employees' utmost health and safety and the environment. Organizations must recognize that adoption is a process that includes not just the choice to adopt but also how the organization decides to proceed with adoption. It's crucial to describe this adoption in terms of its level, rate, or degree. The more the adoption process is understood, the more probable it is that adoption issues will be handled, resulting in initial deployment and subsequent innovation inside the company, which is where modularity analysis using techniques such as the design structure matrix can play a crucial role in prioritization efforts leading to improved adoption and further innovation within the oil and gas industry.

4.2 – Final Comments

The oil and gas industry can use digital transformation to increase its innovation and better analyze its performance. There is a lot of room for new improvements in the upstream industry, particularly in drilling operations. With the recent advancements in computational geometry, data science, machine learning, and robotics, technology has the potential to enable stronger, more natural connections between systematic design and the drilling performance space [76]. The oil and gas industry also has to contend with intensifying pressures from public perception related to climate change.
Currently, the oil and gas industry is at the cusp of a paradigm shift. However, there is no consensus on what this shift will look like in the coming years. Many organizations are making pledges to prepare for a lower-carbon future. Today, we are seeing countries, such as Australia, pledging to be carbon neutral by 2050. Others are trying to phase out fossil fuels completely. Digital technologies could be used to explore options for the future, such as carbon capture, flaring technology to reduce emissions, smart grids to conserve energy, or integrating renewable energy sources with oil and gas.

However, further studies should be conducted to better accomplish the oil and gas industry’s goal of digital transformation. Some recommendations for future research directions are, but are not limited to: 1) the identification of the financial benefit of various digital technologies as they are adopted across the oil and gas value chain; 2) the understanding of the implications that systems engineering will have on a digital transformation specifically in the oil and gas industry; 3) the exploration of data ownership for future drilling automation work; 4) the development of more robust ways of imparting the same knowledge and experience that was historically gained by hands-on/on-site work due to the increased adoption of remote operations specifically in drilling operations; 5) the development of a profitable relationship between the many benefits of a digital platform; And, 6) the expansion of the DSM work conducted in this thesis leading to a delta DSM, which will allow the team to better understand the architectural dynamics across multiple product generations (i.e., metrics for the number of new deleted, changing components from one product generation to the next).

The digital transformation along with climate change initiatives will push the oil and gas industry out of its comfort zone. However, the oil and gas industry must be prepared to embrace the discomfort to compete in the future. With the ongoing COVID-19 pandemic hanging over the globe, there’s no better time than now to appreciate the advancements made in the oil and gas industry over the last year and a half. The COVID-19 pandemic has had a huge impact on innovation as companies looked for new ways to enhance their business processes and procedures while protecting their customers' and
workers’ health and safety. As employees, customers, and consumers adjust to what is considered the “new normal,” innovation has never been more vital to a company.
Bibliography


