University of Stavanger

Faculty of Science and Technology

MASTER'S THESIS

Study program/ Specialization: Offshore Technology - Industrial Asset Management	Spring semester, 2012 Closed
Writer: Ole-Erik Vestøl Endrerud	…………………………………………… (Writer's signature)
Faculty supervisor: Professor Jayantha P. Liyanage, University of Stavanger External supervisor(s): Mike Herbert, ConocoPhillips	
Titel of thesis: Value Creation Through Collaborative Operating Environments	
Credits (ECTS): 120	
Key words: Collaborative Operating Environments Integrated Operations Inter-Organizational Relationships Virtual Teams Distributed Knowledge Management Collaborative Decision Making Integrated Work Practices	Pages: 88 + enclosure: 1 Stavanger, 15th of June 2012 Date/year

Value Creation Through Collaborative Operating Environments

by

Ole-Erik Vestøl Endrerud

A Thesis
Presented to the Faculty of Science and Technology
of University of Stavanger
in Fulfillment of the Requirements for the Degree of

Master of Science
(MSc)

University of Stavanger

Faculty of Science And Technology

2012

Abstract

The aim of this thesis was to identify drivers of value creation in collaborative operating environments with emphasis on the business relation between operator and service providers, through 1) learning from literature and lessons learned form various industries, 2) identify improvement potentials in the business relationship between operator and service companies in an existing collaborative operating environment for drilling projects through a case study, and 3) recommend solutions to capitalize on these potentials.

Chapter 2 presents a review of important elements that drives value creation in collaborative operating environments: inter-organizational relationships, management of distributed knowledge, collaborative decision support, and integrated work practices. Chapter 3 contains lessons learned from various industries including space and aeronautical, military, oil and gas, and automotive. In Chapter 4, results from the case study are presented together with identified improvement potentials. Recommended solutions to realize these improvement potentials are presented in Chapter 5.

The literature review and case study has shown that knowledge integration in virtual teams and collaborative decision support tools can make large contributions to future value creation. It was also discovered through the case study that one of the drivers of performance in these drilling projects was the level of trust between service companies, and between service companies and operator. Another interesting observation was that even though most service companies were competitors, they collaborated in problem solving as partners.

Maybe one can say that today, service companies compete on having the best possible product and service solution. Whilst in the future, softer characteristics are valued more; like trust, partnership history, quality, complementary capabilities, common values and goals, etc.

The level of implementation was also looked upon, and according to OLF's model the collaborative operating environments studied is moving towards generation 2, and according to Vindasius' model is moving towards a transformational collaborative environments.

KEYWORDS: collaborative environments, collaborative operating environments, integrated operations, inter-organizational relationships, virtual teams, knowledge management, collaborative decision tools, integrated work practices, oil and gas industry

Acknowledgements

I have worked on my thesis with dedication and inquisitiveness, with obliging and supportive supervisors and other contributors, from February to June during 2012. It has been a delightful, heuristic and enlightening effort with hard work and long hours.

I want to honor ConocoPhillips for providing me with an intriguing and challenging topic an challenge, and a special thanks to Mike Herbert – my supervisor at ConocoPhillips – for many interesting and rewarding discussions, and for sharing his valuable time whenever needed. In addition, thanks to all persons and companies that participated in my case study.

A special honor and thanks to my faculty supervisor, professor Jayantha P. Liyanage, for guiding me through an exigent thesis, and for providing inspiration and support along the way.

Lastly I want to thank my wife Elisabeth for being encouraging and compassionate during long days of hard work. Behind every great man is a greater woman.

Stavanger, 15 June 2012

Yours sincerely,

Ole-Erik Vestøl Endrerud

Table of Contents

List of Figures

List of Tables

List of Abbreviations

BP	British Petroleum
CBM	Condition Based Maintenance
CM	Condition Monitoring
COP	ConocoPhillips
CODIO	Collaborative Drilling in IO
COE	Collaborative Operating Environments
HSE	Health, Safety and Environment
ICT	Information and Communication Technology
IO	Integrated Operations
KM	Knowledge Management
KMS	Knowledge Management System
MAS	Mobile Agent Systems
NASA	National Aeronautical and Space Agency
NCS	Norwegian Continental Shelf
NCE	Norwegian Centre of Expertise
NODE	Norwegian Offshore Drilling Engineering
OLF	Norwegian Oil Industry Association
OEM	Original Equipment Manufacturer
SME	Small to medium enterprise

Chapter 1
Introduction

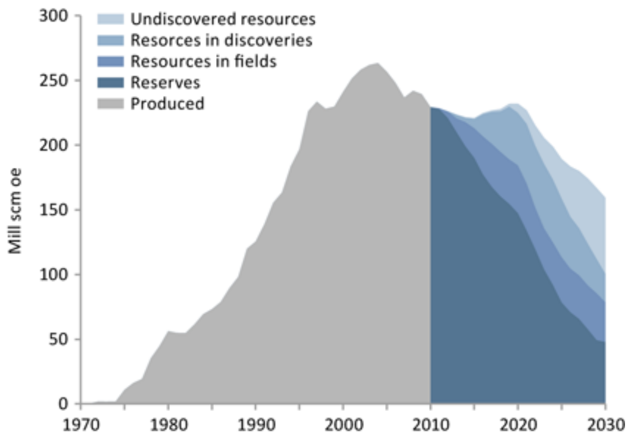

Figure 1-1 Historical petroleum production and forecasted production to 2030 on the NCS [2]

1.1 Background

Hydrocarbons are the most important energy resource in the world today, especially oil and more recently gas. Energy is one of the driving forces for development of societies and economies, and is besides food and clean water the most important resource for human kind; nevertheless, this resource becomes scarcer every year. The Norwegian petroleum industry has existed for forty years now, ever since 1969 when Phillips Petroleum struck oil in the chalk reservoirs of what is known today as Ekofisk [3]. Since late 80's and early 90's the industry has seen a decline in the rate of large discoveries, and a majority of fields on the Norwegian Continental Shelf are mature [2]. The production profile for the Norwegian Continental Shelf has shown decline since 2007, as seen in Figure 1-1, and both industry and government efforts are made to increase oil recovery from brown fields, and develop new reserves and fields to slow down the production decline [4, 5].

Many of the large elephants – very large petroleum fields – like Ekofisk, Statfjord, and Troll are in a life phase where cost effectiveness, novel technological solutions, and increased oil recovery are crucial for profitability and extended lifetime.

A consequence of aging fields and facilities are lower profit margins due to higher water breakthrough and rising operational costs, hence fields are eventually shut down.

Business environments in which oil and gas producers operate in are not characterized by thriving competition between operators, where the producer with the best product succeeds, as in other manufacturing industries. It is rather a setting where development, operation and maintenance of assets, e.g. wells, reservoirs and production facilities, are critical success factors for safe, reliable and profitable operations. Operations of assets are seen in a long-term perspective for oil and gas producers. A field is typically designed for 40 years of production; hence, operations and maintenance are key cost and success contributors during a field's life cycle.

To cope with increasing operational risk and lower operational margins collaborative operating environments can introduce novel innovations in business models, inter-organizational relationships, and technological solutions that will improve decision making, effectiveness, HSE, reliability, and optimize production leading to increased recovery, lower operational costs and extended field life [6]. Collaborative operating environments is not a new operational concept, but has been introduced to the oil and gas industry during the last decade since the millennium. Military, aviation, and aerospace industries have long traditions for using collaborative operating environments extensively – with success.

In Norway the Norwegian Oil Industry Association – OLF – established a working group in 2003 to look at the potential for eOperations on the NCS, as a means to handle increasing complexity and declining production, named "eOperations - the 3rd efficiency leap [4]." To take on the importance of this matter the Norwegian Petroleum and Energy Ministry highlighted in White Paper no. 38:2003-2004 on Petroleum Activity, the importance of Integrated Operations as an initiative to increase recovery and prolong the life of petroleum production on the NCS [5].

OLF produced two reports, one in 2006 and one in 2007, that indicated that implementing collaborative operating environments had a value potential of 300 billion Norwegian kroner (NOK), assuming an oil price of 55 USD per barrel of oil [7, 8]. In recent years an oil price above 100 USD per barrel has been reality, indicating that collaborative operating environments have a value potential of approximately 550 billion NOK, or approximately one sixth of the Norwegian Pension Fund.

1.2 Problem description

It is evident that a rising cost level on the Norwegian Continental Shelf along with a declining production of petroleum resources is contributing to an increased business risk for operators. On the other hand, it is shown by OLF [7, 8] that large value creating potentials lies in reengineering operational models to capitalize on information technology, inter-organizational collaboration, and smart solutions in collaborative operating environments.

Oil and gas service companies have a strong impact on an operator's value creation in their operations. Drilling operations is no exception; they require many specialized services provided by leading companies. One has found several areas of improvement in the business partnership and collaboration between service companies and operators, addressing the opportunities for additional value creation in collaborative operating environments.

1.3 Scope of the thesis

This thesis aims to highlight drivers of value creation in the business relation between operator and service companies in collaborative operating environments that is used as a new operating model in the oil and gas industry, to achieve optimized operations and reduction of risk in a modern business environment.

ConocoPhillips have reengineered their operating model, and this thesis will identify value creating opportunities in the collaboration between ConocoPhillips and key service companies to achieve collaboration, optimized operations, and enhanced value creation.

Objectives of work

The first objective of this thesis is to look into how several factors contribute to value creation in collaborative operating environments by learning from industry lessons learned and literature (Chapter 2). Inter-organizational relationships will be investigated to determine how such relationships can capitalize on value creating potentials in collaborative operating environments. Thereafter, this thesis investigates how management of distributed knowledge is an important factor in realizing value creating potentials in collaborative operating environments. The next topics of investigation are collaborative decision tools and integrated work processes to look into their contribution to reaching enhanced value creation in collaborative operating environments. The literature review is concluded with examples of lessons learned from various industries, to highlight possible challenges and solutions in operating through collaborative operating environments (Chapter 3).

The second objective is to perform a case study of ConocoPhillips' collaborative drilling environment to identify value creating potentials in their inter-organizational collaborative relationship with the involved service companies (Chapter 4).

And lastly, the third objective is to recommend improvement solutions to capitalize on value creating potentials, and create a win-win scenario for ConocoPhillips and service companies operating in collaborative operating environments (Chapter 5).

1.4 Limitations

The limitation for this thesis has in generally been to look at the business relation between operator and service companies in the oil and gas industry, with the following explanations:

1. In the state of the art literature review the limitation has been to look at business-to-business transactions and networks, virtual teams, distributed knowledge management in business networks, the latest developments in collaborative decision tools, and development of integrated work processes in the oil and gas industry.

2. The case study has primarily focused upon the relationship between operator and service companies in one existing collaborative operating environment in the oil and gas industry. This was an adequate scope for a project of this length.

3. Industry lessons learned have been limited to investigating known applications of collaborative operating environments in other industries as well as the oil and gas industry.

4. This thesis will not focus on the optimal design of physical and virtual facilities, such as technological infrastructure, operations centers, etc. Especially on the technological side it is an assumption that the required technological infrastructure is available, as it is on the Norwegian Continental Shelf today.

1.5 Research methodology

Literature review

The primary goal of Chapter 2 was to do a literature review of available theory on relevant topics for collaborative operating environments. The method used was to search through papers in various databases online and library books. In Chapter 3 the primary goal was to identify lessons learned in various industries. To achieve this a broad search was initiated through discussions and search for papers on relevant topics.

In addition, discussions with thesis supervisors and other scholars were used to establish the body of the literature review, and the search for lessons learned in various industries.

Case study

In the case study in Chapter 4 the inter-organizational network consisted of ConocoPhillips and its group of key service companies that collaborate on drilling projects in the Ekofisk area. ConocoPhillips, field operator, is the primary nodal company in this collaborative drilling environment. This statement can be justified by the following reasons:

1. ConocoPhillips is mostly connected to suppliers with strong cohesive ties, while cohesive ties between suppliers are weak. Intellectual property is guarded by suppliers in ties between suppliers, probably because of a competitive nature between them. However, suppliers are inter-connected because they share information and data from drilling operations. Moreover, suppliers share of their intellectual property with the operator – ConocoPhillips – on a much broader base, such as equipment dimensions and specifications.

2. ConocoPhillips is the owner of these operations.

3. On the other hand, contract strategies indicate that service companies offer functional services and thus balances risks and create a win-win situation.

The case study was conducted through observations in the facilities of ConocoPhillips, and through group interviews with 2-4 managers or professionals from each company separately. Interviews were purely qualitative and were used to establish three criteria: 1) Level of integration between ConocoPhillips and service company, 2) Decision environment and work practices, and 3) Relationship health. These three categories were divided into sub-categories.

One service company was located in their own physical facilities collaborating in a virtual facility with other service companies and ConocoPhillips both offshore and onshore. Two service companies were located at ConocoPhillips' own facilities in Tananger, and had the possibility to collaborate both virtually and physically. Two service companies operated key business processes for ConocoPhillips, while the last service company delivered support functions to the drilling process.

Chapter 2
Value creation in collaborative operating environments

Figure 2-1 The NASA mission control room in Johnson Space Center, US and a NASA astronaut from the Discovery Space Shuttle mission ST-121. Courtesy of NASA [9]

This chapter is a state of the art literature review of available theory on different aspects of collaborative operating environments. First, a suitable definition of collaborative operating environments will be outlined looking at various definitions from different organizations and literature. Secondly, a review of theory on inter-organizational relationships as an important performance driver in collaborative operating environments is addressed. Thirdly, the literature review will focus upon knowledge management in collaborative environments as a value creator. Fourthly, the literature review will investigate how integrated work processes evolve in collaborative operating environments, and how collaborative decision support systems present an opportunity to enhance value creation.

2.1 Definition: Collaborative Operating Environments

Prior to carrying out a thorough investigation of available knowledge in the literature, a proper definition of collaborative operating environments is needed for readers to share the author's perception of collaborative operating environments. Many different terms for collaborative operating environments flourish in different industries and literature, examples are: Integrated Operations, Digital Fields, Collaborative Operations and eOperations. In this thesis collaborative operating environments will be used throughout the text.

Oxford Dictionary of English defines *"collaboration"*, *"operation"* and *"environment"* as:

- Collaboration – *"the action of working with someone to produce something"*
- Operation – *"control the functioning of a machine, process, or system"*
- Environment – *"the setting or conditions in which a particular activity is carried on"*

Using these words as baseline, a definition of collaborative operating environment will be:

> *A particular setting, physical or virtual, where partners actively work together to control the functioning of a machine, process or system with the support of advanced application technologies.*

This definition includes people working together in physical facilities, virtual facilities, or both, supported by advanced application technologies, which is the key enabler for collaborative operating environments. Examples of collaborative operating environments are onshore operating centers with collaboration rooms, video conferencing capabilities, simulation tools, visualization tools, remote operation capabilities, and online-shared workspaces, that are a used to collaborate between dispersed locations and across organizational borders in real time. The National Aeronautical and Space Agency (NASA) Mission Control Center at Johnson Space Center in Houston is a good example, illustrated in Figure 2-1, where maintenance engineers, rocket experts, psychologists, mission managers, etc. can communicate, see live video from space and receive scientific data from astronauts hundreds of thousand kilometers away, while supporting astronauts while performing their mission.

Furthermore, "the action of working together with someone" also implies that unit-to-unit, and business-to-business relationships are important for value creation in collaborative operating environments, and integration across traditional organizational borders is important. Many of the benefits of collaborative operating environments are consequences of how third party participants, like service companies or contractors, are integrated across disciplines and functions in the operator's organization. An article from McKinsey – one of the largest consultancy companies in the world – stated in their business journal, McKinsey Quarterly, that [10]:

> *"Highly networked enterprises were 50 percent more likely to fall in this high-performance group than other organizations were".*

This underlines how important collaborative organizational relationships are for business performance. In the oil and gas industry in Norway, the Norwegian Petroleum and Energy Ministry defines Integrated Operations in their White Paper no. 38:2003-2004 on Petroleum Activity as [5]:

> *"Use of information technology to change work processes to achieve better decisions, remote control equipment and processes, and to move functions and personnel onshore".*

This definition also includes the use of information technology or advanced application technologies, which is the primary enabler for collaborative operating environments. It is the rapid development of information technology and application technology that has made it possible for industrial actors to use virtual collaboration solutions to perform complex operations. Advanced technology is no longer reserved for NASA. However, they have used collaborative operative environments for space missions ever since the Apollo program.

Massive amounts of data are transferred from facilities offshore to onshore operating centers through fiber optic cables, analyzed in advanced visualization environments and used for decision support in real time. Experts from different parts of the world in dispersed locations solve challenges real-time in a web interface. Everything requires advanced ICT solutions and application technologies.

Remote operations are included in this definition, which as a part of collaborative operating environments bring the controlled facility closer to the experts onshore, i.e. in an onshore operation center. Meaning operators or experts onshore can use increased situation awareness to interfere in for example drilling operations when they see a challenge, and avoid safety issues by optimizing the well path real time. However, the author made a quick oral survey in a large oil and gas service company on what they define as collaborative operating environments, and the answer from most of them was: "controlling the platform onshore, and removing people

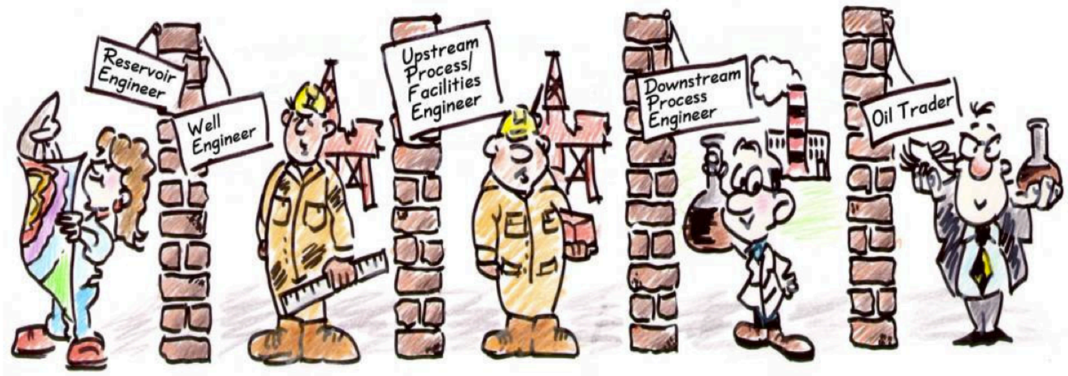

Figure 2-2 Traditional silo structure. Courtesy of British Petroleum [11]

Figure 2-3 Integration between functions, disciplines, and organizations create a novel and collaborative operational environment. Courtesy of British Petroleum [11].

from the platform". It is very important to understand that collaborative operating environments are not remote operations, but remote operation is a part of collaborative operating environments. Tyberø, Allen and Helgesen provided a paper on successful remotely operated cementing operations from an onshore operation center [12]. The result of remotely operating cementing operations was lowered operating costs and higher health, safety, and environmental (HSE) performance.

Another feature of the Norwegian state's definition of Integrated Operations is to move personnel onshore, which is positive from a health and safety point of view, but might be one of the barriers yet to overcome for collaborative operating environments in the oil and gas industry; to trust enough in technology and equipment reliability to leave platforms hundreds of kilometers out of reach of human hands. What if something goes terribly wrong and manual operations are required?

In the Norwegian oil and gas sector ConocoPhillips – a global oil and gas producer – has reengineered their operational model into a collaborative operating environment in operations of the Ekofisk field center, the largest oil field in Norway. ConocoPhillips define Integrated Operations as:

> *"A reduction of risk and improved operating performance achieved by people effectively collaborating across disciplines and geographies in an environment of continuous improvement".*

What is interesting in ConocoPhillips' definition is the inclusion of continuous improvement, which indicates that knowledge management affects performance in collaborative operating environments. Vast amounts of data, knowledge and experience is generated during operations, and a knowledge management system and strategy is a crucial part of collaborative operating environments, as a way to handle and utilize this knowledge capital for value creation within organizations and operational teams. Figure 2-2 and Figure 2-3 illustrate in a very simple but good manner the objective of collaborative operating environments; integrate people for safer and optimized operations through better decisions by breaking down "walls" between functions, disciplines, and organizations in the business environment.

Table 2-1 Summary of definitions of collaborative operating environments

Summary of definitions of collaborative operating environments	
ConocoPhillips	A reduction of risk and improved operating performance achieved by people effectively collaborating across disciplines and geographies in an environment of continuous improvement.
Norwegian Petroleum and Energy Ministry	Use of information technology to change work processes to achieve better decisions, remote control equipment and processes, and to move functions and personnel onshore.
The author	A setting, physical or virtual, where partners actively work together to control the functioning of a machine, process or system with the support of advanced application technologies.

The six elements of collaborative operating environments

Collaborative operating environments have six elements: *human*, *organization*, *technology, work practices, facilities*, and *network*s. All these six dimensions have to be in place to a degree in order to create a collaborative operating environment and affect value creation. *Humans* have a central role in a collaborative operating environment; at the top of the food chain. Which was appropriately said by Mueller, McClelland and Anvir [13]:

> *"It is people who make collaboration happen, not work processes, tools and applications".*

Operations are created, controlled and modified by humans. Algorithms and computers cannot compare itself to the human brain, but serves as an instrument for performing repetitive tasks. In a chronicle about stock market robots Aspaas talk about algorithms and computers' noteworthy role in today's financial industry, but underlines so pertinent that [14]:

> *"…the right hemisphere is man's comparative advantage over the computer. It work with unity and coherence, and should make us well equipped to tame Lady Algorithm."*[1]

This calls for a human-centered design of collaborative operating environments in order to realize a fail-safe socio-technical system in order to optimize performance of these environments [15].

An *organization* is the framework in which people work together with a particular purpose or goal. It is team structures, division of labor, job tasks, knowledge management systems, and culture. In order to grasp the full benefit from collaborative

Figure 2-4 The six elements of collaborative operating environments

[1] The left hemisphere controls logic and language, while the right hemisphere controls creativity and feelings.

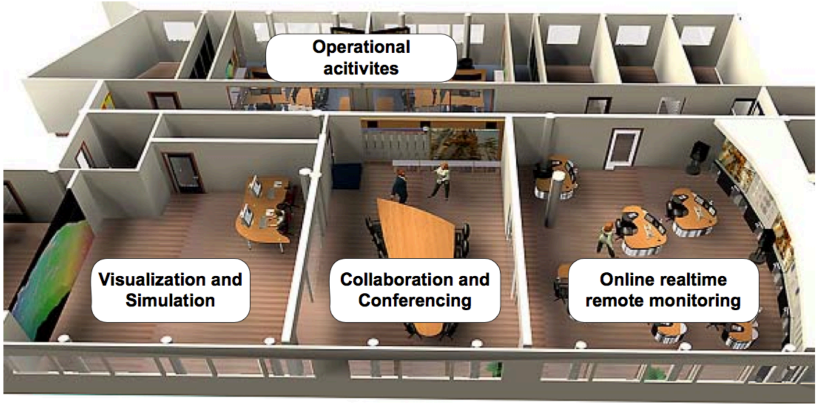

Figure 2-5 Example of an onshore operation center [6]

operating environments, substantial organizational reengineering have to be made.

Technology has been an important driver and enabler for integrated operations along with increasing complexity of operations in the oil and gas industry [6, 16]. ICT has developed in a tremendous pace the last twenty years and advanced technology is now at a cost level and physical size that make it applicable in everyday life and work. Real time 3D visualization, remote sensing, and decision support tools are examples of technologies that are important in a collaborative operating environment.

Facilities are virtual or physical environments where collaborative operations are effectuated. A good example of a physical facility is onshore operation centers with collaboration rooms, remote monitoring rooms, visualization rooms, and special operation rooms, as illustrated in Figure 2-5. Virtual facilities are social media, shared virtual work areas, virtual meeting rooms, generally called groupware.

Networks or inter-organizational relationships drive performance in collaborative operating environments and are the connection and integration of departments, organizations and industries to make use of distributed knowledge and competence to enhance collaboration and decision-making.

Work processes are the glue that couples together the five preceding elements; humans, organization, technology, facilities, and networks. Work processes creates a setting and a way of reaching company goals, it is a recipe for excellent performance. Traditional work processes are outdated and inefficient in collaborative operating environments, and there is an urgent need to implement integrated work processes to unleash the full potential of collaborative operating environments. Information are available at the fingertips of operators and decision makers, and functions and organizations are closely linked together calling for new ways of working to solve challenges and optimize operations.

Level of implementation of collaborative operating environments

Collaborative operating environments have formally been defined in the preceding pages, but it is convenient to further categorize different levels of collaborative operating environments. OLF launched a concept of implementation level for integrated operations in their report on integrated work processes [17], illustrated in Figure 2-6. Collaborative operating environments can be divided into a small-scale group and a large-scale group, defined as local and global respectively.

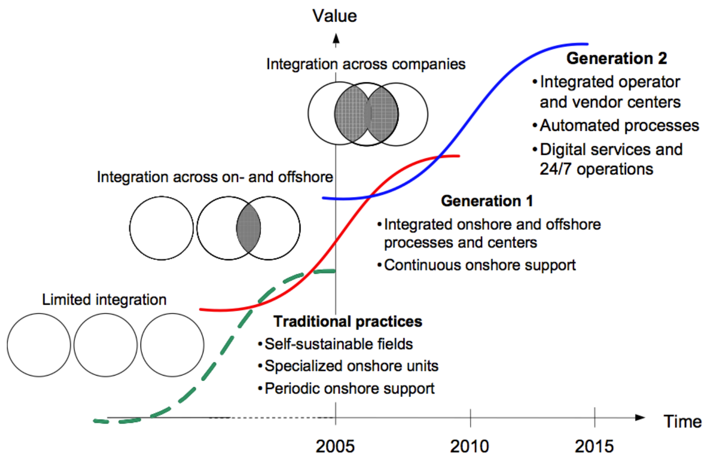

Figure 2-6 Levels of collaborative operating environments. Courtesy of OLF [17].

Local collaborative operating environments include what can be done in one single organization, which can also be referred to as integration of the onshore and offshore organization. This is defined as 1st generation collaborative operating environments by OLF (ref. Figure 2-6). For example ConocoPhillips has an onshore operating center where they monitor, simulate, and operate the Ekofisk field by collaborating across departments and centers supported by collaborative technologies. For example, 3D visualization onshore using real time data from down hole sensors is used to simulate the best well trajectory real time, or a turbine expert working in production optimization onshore is helping the offshore maintenance crew troubleshooting a malfunctioning gas turbine generator. This collaboration is made possible by collaborative application technology and integrated work processes within the organization.

Global collaborative operating environments also include what is done between two or more organizations. This is defined as 2nd generation collaborative operating environments by OLF (ref. Figure 2-6). The growing need for improved oil recovery, deeper waters and harsher environments introduce the need for advanced services and operations to cope with this increasing complex challenges and risks. This need is not something an operator can cope with alone with a traditional operation model. Thus, operators are forced to focus on core competencies and tasks, and outsource tasks to service companies and third party contractors with skills and capabilities to perform desired tasks at a high and satisfying level. This is the new operating model of collaborative operating environments, to gain benefit of many for better decisions, and sharing risks and benefits for optimized operations, HSE, quality and profit. Collaborative networks between organizations introduce challenges, such as governance, trust, and safety of information sharing, and access to information and knowledge. These are challenges that will be addressed further in forthcoming chapters.

Vindasius [18] proposes another framework for understanding performance value from different implementation levels of collaborative operating environments. This framework defines three levels, shown as curves in Figure 2-7. The graph in Figure 2-7 has two axes, performance value and time, that show how performance value evolves over time. "*Field of Dreams*" is not a level, but the curve is included by Vindasius for illustrative purposes. Vindasius say "Field of Dreams" is the hopeful

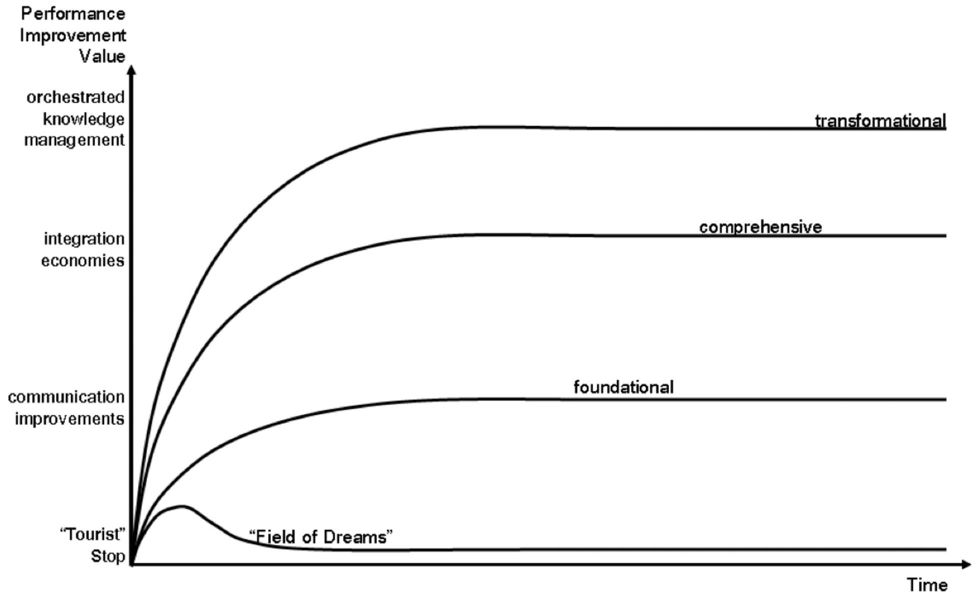

Figure 2-7 Shows the three levels of collaborative operating environments, represented by the three curves: transformational, comprehensive, and foundational.

creation of a collaboration room with audiovisual conferencing capabilities by managers expecting people to "fight" for the right to use it, but however ends up as a stop on visitor tours to check out the fancy screens. In that sense it is apparent from the graph that performance value increases because of early enthusiasm however quickly diminish.

The lowest level of collaborative operating environments is 1) *foundational*. Foundational implementation means the implementation of communication technologies to bring offshore facilities into the onshore office and vice versa, with capabilities to share information (e.g. documents, images, etc.), and integrate functional and disciplinary organizational silos (as in Figure 2-2). It could typically be audiovisual conferencing, handheld cameras, shared file servers, common access to UHF radio, et cetera. This level of collaborative operating environment results in cost savings due to less travelling onshore/offshore, less offshore bonuses, easier coordination across onshore/offshore organization, scarce expert resources can be utilized on several assets, and improved HSE performance due to less personnel offshore and increased situation awareness.

Furthermore, the next level is 2) *comprehensive*. A comprehensive level of collaborative operating environments has all the capabilities of the foundational level, in addition to a comprehensive integration of data from assets and operations, creation of automated and robust alarm systems, and possibilities for transforming data to information and visualize it customized for the end user. On this level, data is taken from all service companies – i.e. drilling, geosteering, mud logging, condition monitoring, etc. – to create a better total picture of asset operations, and make it available to for example onshore drilling centers and specialists. This system creates an enormous amount of data, and a robust and intelligent alarm system is needed to sort out important information, e.g. trends, of importance and notify relevant persons. Vindasius [18] points out that customizable visualization of data is essential, because different functions and levels in an organization need to look at different data, and maybe at different scales. Comprehensive is probably the level the oil and gas industry are at today, where a high number of service companies and operating companies have developed such capabilities and organizational restructuring.

The last level is 3) *transformational*, which is the highest level of performance value according to Vindasius [18]. At this level information and data is available to everyone within the collaborative network, and accessible from everywhere at any time. At this point everyone is truly virtual as in always available and updated, no matter location or time zone. Thoroughly and standardized integrated work processes are automating workflows, and advanced decision support tools are available together with 3D visualizations and highly customizable information visualization. This system is also highly instrumented with advanced and intelligent sensors and equipment, like intelligent wells, and operation and maintenance are condition based.

Vindasius model can be used – and will be used later in the case study of the business relation between ConocoPhillips and service companies – to see how far the implementation of collaborative operating environments have come.

2.2 How virtual inter-organizational relationships contribute to realizing value potentials

The term virtual can be used in many circumstances, for example as in digitization of physical objects or environments as in virtual reality in online gaming. However, in this thesis virtual refers to distributed competencies or business processes that are integrated in order to exploit new opportunities [19]. Sieber [20] puts virtual into the actual context:

> *"Virtuality is the ability to offer customers a complete product or service, where the enterprise itself only owns some of its competencies. Other required competencies are achieved through collaboration. Concentrating on their core competencies and joining others in networks, these enterprises are able to produce more complex, yet still customized, goods."*

Collaborative networks have different characteristics and drivers of value creation depending on the level of collaboration. In local collaborative operating environments integration between functions and organizations in virtual teams is decisive for value creation. In global collaborative operating environments virtual collaborative networks will affect value creation.

In this section a literature study on virtual collaborative networks will be presented, with emphasize on how such networks can contribute to value creation, and their importance in collaborative operating environments. Next a study of virtual team theory and key factors for high performance and value creation is presented. Virtual teams are the core operational units in a collaborative operating environment.

2.2.1 Value creation through virtual collaborative networks

Implementation of collaborative operating environments as a business and operational model will lead to forming of inter-organizational relationships and collaborative networks, where companies can get immensely interconnected, as illustrated in Figure 2-8.

In the modern business environment characterized by increasing complexity, rising costs, globalization and rapid growth of collaborative application technologies, companies see potential in outsourcing non-core functions, and as a consequence joining supply chain networks [1]. Especially for the industrial service industry, this implies that small to medium enterprises can cluster together to take advantage of distributed knowledge among network members, and stand out as a large enterprise – namely a virtual collaborative network. Large operators have to put more focus on being excellent at core competencies, thus requiring services from 3rd party contractors to perform functions [19], often specialized and complex functions [1]. For example in drilling, specialized personnel from Schlumberger is contracted to perform geosteering, meanwhile the operator does production planning.

Gereffi, Humphrey and Sturgeon [1] look at global value chain networks and have identified a current trend of increased outsourcing and focus on core-competencies, which is one of the benefits of implementing collaborative operating environments. Gereffi et al. [1] state that:

> *"…the most important new features of the contemporary economy are the globalization of production and trade, which have fuelled … the vertical disintegration of transnational corporations, which are redefining their core competencies to focus on innovation and product strategy, marketing, and the highest value-added segments of manufacturing and services, while reducing their direct ownership over 'non-core' functions such as generic services and volume production".*

In Norway there are several examples where collaborative clusters have increased value creation substantially: NCE[2] Norwegian Offshore Drilling Engineering cluster in the south of Norway, where a large offshore competence cluster have grown to become world leader in its sector [22]; NCE Systems Engineering in Kongsberg is a similar cluster that has emerged, which has lead to enhanced competitive advantage and innovation in the systems engineering industry [23]. Virtual collaborative networks are one tactic for small and medium enterprises

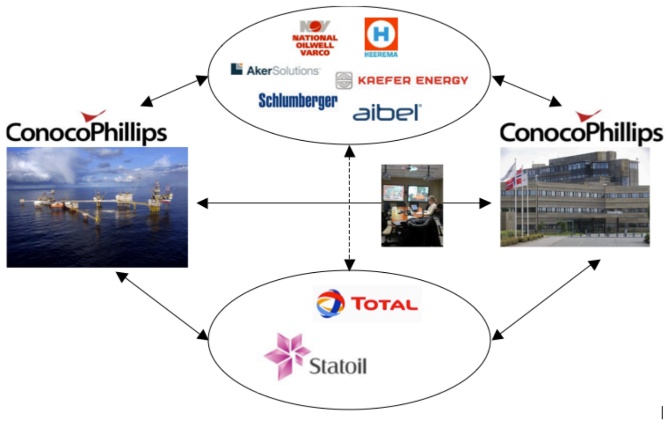

Figure 2-8 Interconnectivity in an operations network.

[2] NCE – The program Norwegian Centers of Expertise (NCE) is established to boost innovation in the most expansive and internationally oriented industrial clusters in Norway. The program is intended to target, improve and accelerate the ongoing development processes in these clusters. 21. Innovation Norway. *An ambitious programme.* [cited 2012 02.03.2012]; Available from: www.nce.no.

(SME) to come in contact and engage directly with large enterprises and gain a competitive advantage [24]. Thompson say [25]:

> *"Big Fish (large corporations) and small fish (SMEs) simply don't get along in the real world, because Big Fish constantly swallow and consume small fish without even noticing it. The Virtual Enterprise Network (collaborative networks) creates a symbiosis, a living, mutual beneficial relationship among dissimilar organisms, where the participants, big and small, can thrive together in the 21st century world of extreme competition. … Big Fish desperately want and need the innovative products, services, and thinking that specialized small fish bring."*

In traditional inter-organizational interactions, for example between an oil and gas operator and a service company, the acquiring party such as a large operator view service contractors and OEMs as providers of services and technology and not full partners. As Thompson [25] highlights: supply chains are not virtual collaborative networks.

Partner versus provider perception

The difference in perception between partner and provider has implications for communication and decision-making, knowledge and information sharing, partaking in risks and benefits, incentive systems, and commitment. Figure 2-9 illustrates the differences between the two perceptions, where organizational borders are cut and clear in the provider circle, and each company has an information and knowledge boundary. However, as relationships move towards partner status, boundaries are blurrier and there exist no information and knowledge boundary. If a company is

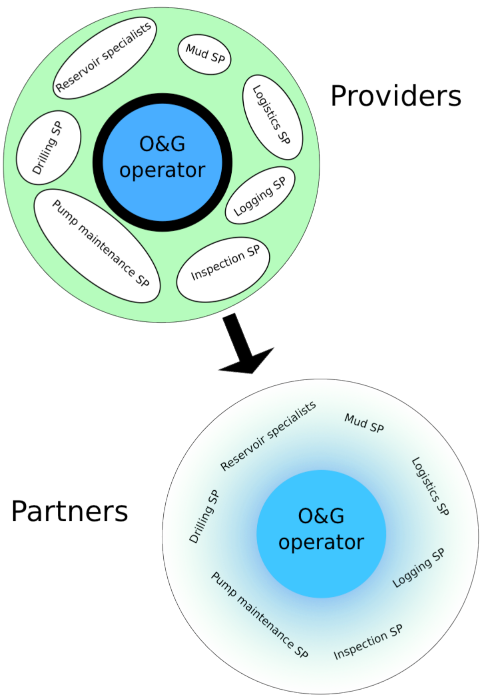

Figure 2-9 Partner versus provider perception

considered a partner, communication is not command-based but rather information-based, and decisions can be made by partners based on information. This enhances the ability to cope with a dynamic operating environment and deal with operational risks and opportunities swiftly as they develop. As a consequence of considering a company as partner, not provider, decision-making authority must be transferred from operator to 3rd party contractors, which entails a great deal of trust between partners. However, decentralization of decision authority is essential for collaborative operating environments to be effective and cope with dynamic complexities.

Knowledge and information sharing are key elements in a collaborative operating environment. As previously mentioned, communicating through information and not commands will produce better and faster decisions, and enhance value creation. Furthermore, knowledge sharing will encourage and stimulate continuous learning and improvement in collaborative operating environments. Operators in a virtual collaborative network can share experiences and knowledge and make use of each other's expert knowledge, which contribute towards optimizing operations and boost value creation. In addition, 3rd party contractors and service companies can develop system solutions and share experiences to optimize service offerings.

Operators can together with 3rd party contractors and service companies develop solutions industry needs, and solve operational challenges through collaboration for enhanced value creation. If network members are considered partners, an operator-contractor symbiosis arises, with open sharing of information and experiences for training and continuous improvement, and active collaboration. In Figure 2-9, the thick circle around oil and gas operator in the provider circle illustrates a wall of secrecy and information restraint. This has vanished in the partner circle, thus illustrating an open sharing of information and knowledge between partners. In Section 3.4 a good example of how knowledge management can lead to increased value creation in a collaborative network of companies is presented.

When companies are considered partners the incentive scheme have to be changed, and becomes more complex and fundamentally different from a traditional provider point of view. Providing a conventional product is an easily quantifiable unit that can be paid per piecework, plus traditional product support. Providing a functional service as in a partner point of view is far different. In a functional service perspective service companies have to take care of providing itself with products and product support (i.e. maintenance, spare parts, etc.). For example, instead of providing a drilling machine, service companies provide a borehole or drilled meter per day. Functional services can create a win-win situation in the business between operator and service companies, owing to the fact it removes opportunistic motives for service companies. Asset specificity[3] and complexity can introduce opportunism that require safeguards to be put out in order to create a win-win situation [1]. In order to succeed, an incentive system tailored for this purpose must be compiled. So as to move from

[3] Asset specificity is usually defined as the extent to which the investments made to support a particular transaction have a higher value to that transaction than they would have if they were redeployed for any other purpose [26. McGuinness, T., *Markets and Managerial Hierarchies*, in *Markets, Hierarchies, and Networks*, G. Thompson, et al., Editors. 1994, SAGE Publications Ltd: London.]. For example, if a manufacturing company needs to invest in a new machine specialized to make a special car part only usable in a Lada it is a very asset specific investment. But if the car part could be used to make car parts for all car models in the world it is very asset un-specific.

1st to 2nd generation and into a transformational collaborative operating environment it is inevitable to create a win-win situation in the business between operator and service companies.

Performance drivers in virtual collaborative networks

Gulati, Dialdin, & Wang [27] define three dimensions that have major impact on the focal company's performance in a business network: *centrality within the network*, *configuration of ties*, and *partner profiles*. Each of which affects a company's performance in virtual collaborative networks.

Centrality within the network

One can distinguish between three categories of *centrality within the network*. In traditional social network literature degree centrality refers to the quantity of connections between the focal company and other companies in the network. This is only a number of how many connections a focal company has the possibility of exploiting, although do not present useful information about connections. However, degree centrality is a qualitative measure of how visible a company is within the network, and high degree centrality increases the chance of receiving valuable information and new opportunities [27].

Closeness centrality refers to the mean geodesic[4] distance between a focal company and other members of the network, and can be perceived as how fast information moves from the focal company to other network members [28]. “betweenness” centrality is the last centrality measure, and can be regarded as a measure of the extent to which a company has control over information flowing between other network members [28]. In a virtual enterprise network or collaborative business network centrality will affect performance and value creation, especially by controlling direction of information flow and how fast important information is acquired. In operating oil and gas facilities fast and reliable information is crucial in order to achieve well-informed decisions for optimized production and value creation. In addition, having high degree of centrality will also positively affect learning and continuous improvement for a company, because experiences and knowledge is received fast and new innovations find its way to the company for utilization in operations.

Configuration of inter-inter-organizational ties

Configuration of inter-organizational ties for a company in a network is vital for value creation and performance. Especially two categories of tie configuration are highlighted by Gulati et al. [27]: cohesive ties versus bridging ties, and strong ties versus weak ties. If company A is considered in Figure 2-10, the cohesive ties in A's network are the ones enclosed in the red cloud. A cohesive tie connects the focal company with another company that is at least connected to one other partner of the focal company [27]. For example, company A is connected to company B and C with a cohesive tie because company B and C are also connected. A bridging tie connects the focal company with a company with no ties to other partners of the focal company, seen in Figure 2-10 as the ties enclosed by the green cloud. As an example, company A is connected to company E with a bridging tie because company E is not connected to other partners of company A. Cohesive ties can lead to lowered

[4] Geodesic denotes the shortest possible line between two points on a graph.

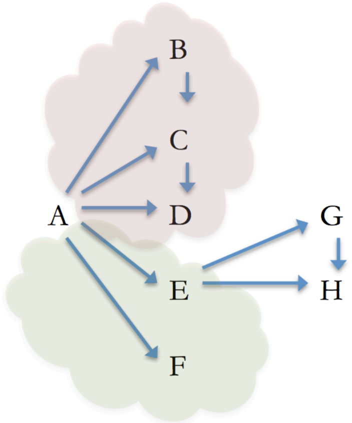

Figure 2-10 Cohesive versus bridging ties [27]

transaction and coordination costs through a shared set of social norms and sanctions among cohesive partners [27]. In addition, trust and transparency is probably increased in a cohesive partnership and as a consequence a higher degree of integration will develop. However, cohesive ties do not favor new impulses and innovation. And a network with many cohesive ties inter-company alliances may form as e.g. trade alliances. Bridging ties offers information and control benefits for the focal company [27], because of the lack of ties to other partners of the focal company. Hence, bridging ties offers high "betweenness" centrality. Moreover, bridging ties can bring new thoughts and innovations to the focal company. A coarse conclusion can be that companies that operate in a stable and long term environment, e.g. oil and gas operators, favor cohesive ties. On the other hand, companies that need to be innovative to sustain a competitive advantage, e.g. OEMs, may favor bridging ties.

Companies with strong ties interact frequently and directly, while weak ties is characterized by infrequent interaction and distance between companies [29]. Strong ties promote trust and reciprocity. However, many strong and few weak ties may hinder innovation and new thinking, and can create a resource dependency [27]. Innovations can come from companies with weak ties, because they don't interact frequently and directly, and do not influence each other extensively. Strong ties may be favored in a stable environment, while weak ties may be favored in an innovative and dynamic environment. In Table 2-2 the different combinations of inter-organizational ties are summarized.

Partner profile

A *partner profile* is a binary dimension between the focal company and a specific partner. Gulati et al. [27] identified that ties to high status companies would positively impact company performance, and that it is especially relevant for SMEs. In the oil

Table 2-2 Inter-organizational ties matrix

	Strong	Weak
Cohesive	Strong unions Frequent interactions Few new impulses	Infrequent interactions Very few new impulses
Bridging	Frequent interactions Access to new companies and knowledge	Highly innovative Many new impulses Infrequent interactions

and gas industry these statements fit well, and a small service company with contracts with e.g. Statoil or British Petroleum (BP) would probably attract attention from other large operators. Moreover, in relation to collaborative operating environments, high status ties can have a positive effect on trust between partners in a collaborative operating environments, which is important e.g. in granting authority to take decentralized decisions by service companies.

Gulati et al. [27] also identifies technology distance as a partner profile parameter. Technology distance is defined as the similarity between two companies' innovative activity [27]. However, in relation to collaborative operating environments this definition can be built onto to fit this context. Technology distance can have two dimensions: One, the similarity between innovative activities; two, the technological capability matching between partners of a collaborative business network. Because, technological capabilities are essential in order to utilize collaborative business network, it is important that two partners have the same technological infrastructure and implementation of technology in their work practices. ConocoPhillips cannot effectively collaborate with its service partners if there exist a deficiency in communications or computers lack the ability to process the needed data. If innovative activities are similar, hence the technology distance is low, partnering companies loose the chance to share new knowledge and create novel innovations. On the other hand, if innovative activities are distant, companies can capitalize on potential sharing of new knowledge and innovations to overcome critical challenges and enhance value creation. In the oil and gas industry, such innovations could be oil recovery technologies, which can be decisive for value creation.

Third and lastly, companies can through partnering up with the right company access new network branches, as illustrated in Figure 2-10 where company A partners with company E, and subsequently gaining access to new network resources, possibly form another industry. Because of access to new network resources, a company can gain both a strategic advantage and access to new knowledge.

Governance of virtual collaborative networks

The last topic to be addressed is network governance. Network governance is defined by Jones, Hesterly and Borgatti [30] as:

> *"Inter-company coordination characterized by informal social systems rather than by bureaucratic structures within companies and formal contractual relationships between them, to coordinate complex products or services in uncertain … environments."*

In other words network governance is important for sustainability and value creation in a collaborative operating environments because it provides coordination among network members. Network governance is directly affected by the relationship contained in a collaborative operating environments partnership. Previously in this section it was mentioned the difference in how operators perceive service companies; partner or provider. As will be shown, this perception will again determine what type of network governance present in a collaborative operating environments.

Gereffi et al. [1] conducted a literature review on governance in global value chains, and identified five basic types of network governance based on three factors. These factors are interesting too look at because they can facilitate at least a qualitative determination of what type of network governance inherent in the collaborative operating environments partnership. *Factor A* is the complexity of information and knowledge transfer required to sustain a particular transaction or operation [1]. *Factor B* is to what extent the information and knowledge can be codified or standardized, to make it less complex [1]. *Factor C* refers to the capabilities of partners, and can be somewhat related to capability matching (also referred to in *partner profiles*). Saying these factors are binary values either high or low Gereffi et al. [1] identifies the five different types of network governance actually found in the real world: 1) *markets*, 2) *captive value chains, 3) hierarchy, 4) modular value chains*, and 5) *relational value chains*.

1) *Markets* are characterized by low complexity, high standardization, and low capability requirements. Hence, products and services are offered by many service companies and are fairly standardized. These are for example providers of standard details or catering services on a rig, and not relevant for collaborative operating environments.

2) *Captive value chains,* this type of network governance are characterized by high complexity, low standardization, and low supplier competence. Consequently, the operator needs to invest in supplier competency, and exert a high level of explicit coordination and control. This is typical for small companies with a specialized competency. Because the operator has invested capital in supplier competency and asset specificity probably is high, the service company is "captured" in a relationship with the operator that is tough to break. For the oil and gas industry this is not that widespread, but could occur in a collaborative operating environments if a company wants to acquire a very specialized expert competency.

3) *Hierarchy* is a type of network governance where the competence to perform a service or produce a product cannot be found among suppliers and the task is excessively complex, thus forcing the operator to produce the service or product in-house. This leads to a traditional vertically integrated company with high degree of explicit coordination from top management and downwards in the organization. One can clearly see that hierarchy is the traditional management and operational structure in the industry.

4) *Modular value chains* are one of two forms of network governance that fits the collaborative operating environments model well. This form of network governance arise when services or products inherits a modularity. For example, a drilling operation has an inherent modularity because different modules (e.g. cementing, logging, geosteering, etc.) of the drilling operation can be picked apart and substituted by a similar module from another provider. Modular value chain governance appears when supplier competence is high, information is easily codified or standardized, and the interfaces between modules are standardized. With suppliers, having the capability and competence to support full complex modules of product or service it do not require much explicit coordination[5]. This enables the transferring of decision authority to service partners and operational teams, which was also identified as an important factor for effective operations through a collaborative operating environments.

5) *Relational value chains* is the last form of network governance and highly relevant for collaborative operating environments. When products or services are to complex to be codified and supplier capabilities are very high relational value chains can arise. In the oil and gas industry operations are increasing in complexity and suppliers are highly competent in their specialized areas – drilling, logging, fluid

[5] Explicit coordination means that decisions and transactions are tailored to a specific relationship between partners in a collaborative partnership. This is opposed to implicit coordination, which is coordination by the "invisible hand" exerted by for example market mechanisms. Increasing explicit coordination increases the cost of switching partners.

control, modeling, etc. – which provides a strong motivation for operators to outsource functions outside their core competencies. I.e. acquire complementary capabilities from highly competent suppliers. The governance of relational value chains is primarily through reputation, social norms within the relationship, but also by fines or costs for the contract breaking party as part of an incentive system [1]. Gereffi et al. [1] also points out that exchange of complex information and knowledge is done through frequent face-to-face meetings, which is a feature of collaborative operating environments. Relational value chains will because of a strong mutual relationship and the abovementioned exchange of information and knowledge be characterized by high explicit coordination. Hence, cost of switching suppliers for an operator can be high [1], and relationships are more prone to be long-term. Relational value chains can have an increased trust between partners inherent, and allow for a transfer of decision authority thus increasing possible autonomy in the operations, which can lead to higher efficiency and enhanced value creation. To draw a parallel back to the aforementioned differentiation between partner and provider point of view, relational value chain governance will imply that the supplier is considered as a partner.

On the next page a figure from Gereffi et al. [1] can be seen, summarizing the five types of network governance discussed in the previous pages. The figure shows the relationships suppliers have with its sub-suppliers and contractors in the modular and relational value chain, although they have not been included in the previous discussion about network governance. In the figure the arrows and its direction represents movement of information, knowledge and control, and the thickness indicates how much information and knowledge are shared in the relationship. The figure arranges the five governance types after degree of explicit coordination and power asymmetry. Moreover, for the two types –relational and modular – identified as relevant for collaborative operating environments it is evident that both have a balanced power asymmetry, much due to the complementary relationship and complexity of operations. However, though it seems control is equally balanced for the two types of governance the cost of switching to another supplier is not large enough in most cases in the oil and gas industry to allow for a very opportunistic behavior from the suppliers.

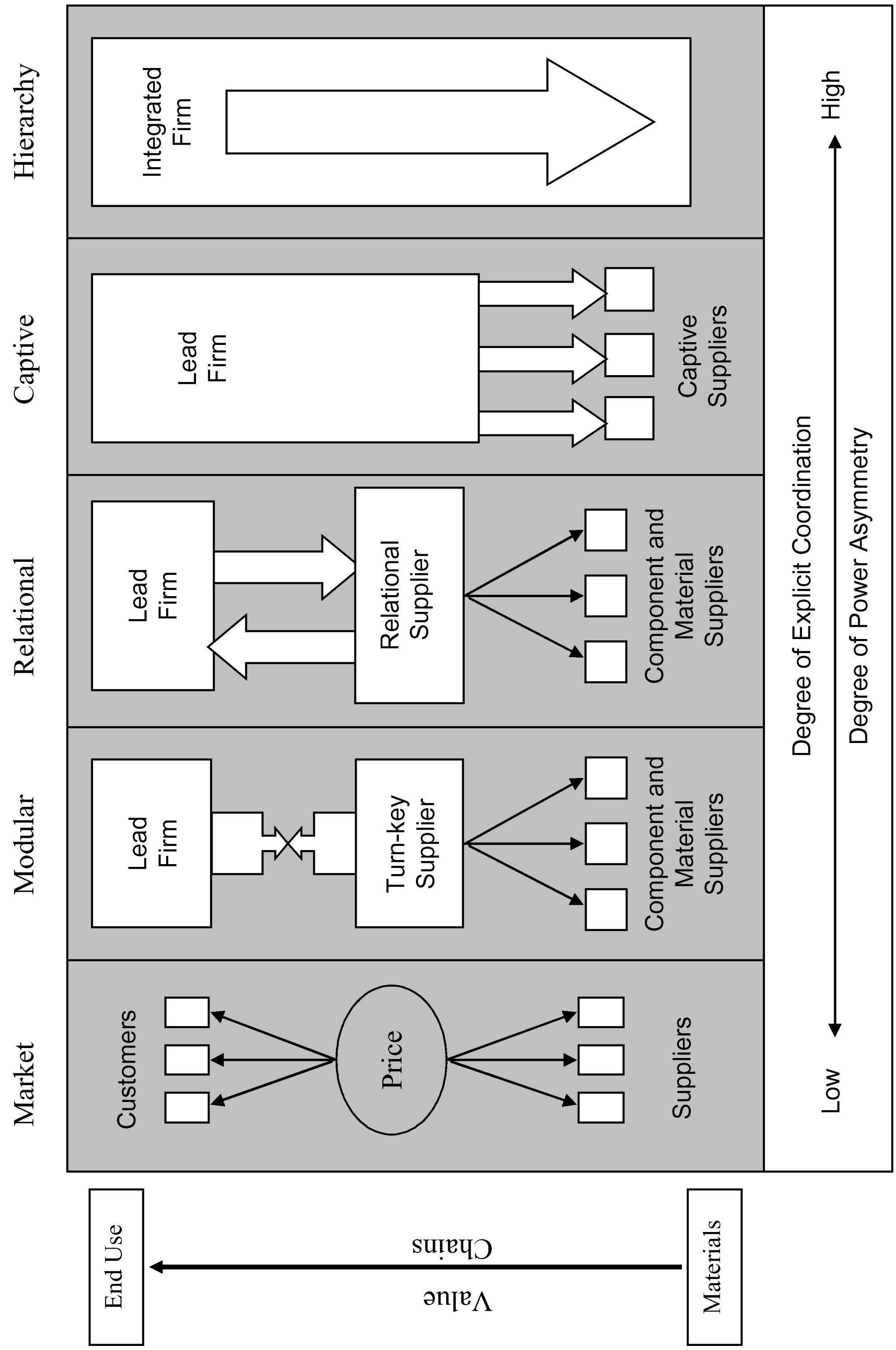

Figure 2-11 Five types of network governance [1]

2.2.2 Virtual teams in collaborative operating environments

Business-to-business networks and transactions can be said to have a large impact on performance in collaborative operating environments, because it is decisive for effective collaboration. Virtual teams are the macro level implementation of business-to-business networks in operational environments. Organizational teams have changed greatly in recent decades. This is caused by the rapid development of advanced ICT solutions, increasingly complex operations, and the introduction of virtual collaborative networks between operators and service companies. For example, in the oil and gas industry sticking a straw down in the ground and wait for oil to seep out is no longer the case. In addition, the space industry is moving from lunar missions and establishing earth orbiting space stations to manned space missions to Mars. Streamlined static organizations do no longer exist in the modern industrial environment thus requiring organizational teams to change accordingly and adapt.

Traditional teams

However, before elaborating on a new form of organizational teams a characterization of traditional teams and its shortcomings are in place. A comparison of traditional and modern organizational teams is summarized in Table 2-3. According to Thompson [31] and Ale Ebrahim et al. [24] the operational and business environment are so different in modern world today, much caused by novel and innovative communication and information sharing technologies. Only during the last decade there has been an exploding upward trend for social media and communication like Facebook, Twitter, LinkedIn, etc. that connect people across time zones and geographical location. Virtual communication have shown to have a special ability to mobilize and coordinate people over large distances, like during the Arab Spring in 2011 when millions in the whole Arab world came out demonstrating against long sitting dictators.

Traditional organizational teams are located in one location with a fixed size and mostly composed by members of the same organization, with complementary capabilities [24]. Communication is mostly done through face-to-face meetings and conversations. Important decisions are taken at a higher hierarchical level, and one single leader often governs a team by a control and command strategy. A single-leader control and command structure is simply not handling the highly dynamic and complex operational environment present in the modern world today. It is a bottleneck that needs to be eliminated to increase effectiveness of organizational

Table 2-3 Comparison of traditional and virtual teams

	Traditional teams	Virtual teams
Structure	Static Organizational boundaries	Dynamic Integration
Governance	Command and control Centralized decision authority	Collective leadership Decentralized decision authority
Communication	Face-to-Face	Communication technology
Presence	Physical, in situ	Dispersed Virtual
Coping with change	Slow	Quick

teams.

Characteristics of virtual teams

The ability to defy time and space through information technology facilitates a drastic change for organizations in the modern world – and for organizational teams. However, organizations still apply the same traditional mindset for virtual teams [24]. Thompson [31] and Ale Ebrahim et al. [24] both agree it is rare to find organizational teams where everybody knows each other personally. Ahuja and Galvin [32, 33] indicates that in 2001 in USA alone, some 8.4 million employees were members of one or more virtual teams or groups.

Time and Distance = 0

Some team members work from a location in USA, some from an office in Bergen, some from an operation center onshore in Stavanger and some from a control room offshore. This example is taken from a real life application in the oil and gas industry in Norway. Because virtual teams are able to break away from time and place, one can obtain a virtual capacity of distributed knowledge and skills, which is far larger than what is obtainable in a traditional setting [33]. The reason is access to talent and professionals from a far broader market than before. Being geographically dispersed and not limited to working 9-5 will introduce challenges as well as opportunities. Many experts claim that virtual teams come with a risk of opportunism [24, 31, 33]. It is much easier to break a virtual appointment than an appointment agreed upon face-to-face. There is also a risk of team members hiding away from responsibilities and engagements. Moreover, a virtual team stretching over several time zones and working with more than one shift will have the ability to turn night shifts into day shifts thus saving costs. However, for teams not working shifts it can be a challenge when team members are situated at different time zones, for example as one team member goes to bed another starts the work day. This happens especially in situations where a common decision needs to be taken.

Team composition

Thompson [31] also highlights that team members to a much larger degree are a mix from different organizations, different functions and different cultures in modern organizational teams. Where organizational borders was clear and cut in the past, they have now become blurry and less significant, as was also discussed in the previous section and shown in Figure 2-9. This integration comes with opportunities and challenges. A challenge is that some people are not comfortable speaking in large gatherings, and especially not with a large number of unknown people. On the other hand, when organizations are integrated knowledge can be shared between partners, a company can get access to complementary functions and skills needed in its operation, and a company can get access to new network resources.

Governance

The governance structure has to depart from a traditional hierarchical single-leader command and control structure in order for virtual teams to be effective [31, 34]. However, some also see this as a disadvantage for virtual teams [24]. In order for virtual teams to be flexible and high on personal initiative, decision authority have to be decentralized and transferred to the collective leadership of the team. The team leader is not removed, rather takes on a mentoring role for the team and leave decisions to the collective leadership. For example if a well problem occurs, it should be unnecessary to wait for instructions from a manager high up in the hierarchical organizational structure. It is too much waste of time. In addition, a collective leadership will utilize more of the capacity inherent in a team, especially for a knowledge worker team where knowledge and experience are important resources. Thompson [31] say virtual teams need to receive information, interpret this information and make a decision based on that information. The optimal situation is when a team picks up a news bulleting of relevance, interprets and acts upon it together consequently solving a problem swiftly through collaboration.

Communication

Communication in a virtual team is very different from traditional teams. While traditional team members can meet over a coffee in the coffee-corner at work and discuss a problem or idea, i.e. face-to-face communication, virtual team members communicates through video conferencing, phone calls, Voice-over-IP, instant messaging, etc. In the oil and gas industry, it is usual to communicate over UHF radio as well. Therefore, communication in virtual teams is less personal and a good collegial relationship is probably harder to achieve, especially when the level of geographical dispersion is high and team members do not meet personally at all. This can affect the trust within the team, which is decisive for effective communication, successful interactions, and motivation to perform their responsibilities [24]. It is highlighted by Bergiel et al. [33] that high level of trust clear communication are key elements of success for virtual teams. However, scientists at Queen's University in Canada have managed to create 3D holographic communication that might generate the same effect as face-to-face conversations in the future [35].

Decision support

A last point that virtual teams enables due to heavy usage of information technology is advanced collaborative decision support tools, which are computer algorithms based on decision theory and distributed knowledge management systems. Decision support tools and integrated work processes are elaborated upon in Section 2.4 .

Virtual teams are not widely used in today's world, but there exist some good examples of successful virtual teams. The best example the author found was crisis teams or task forces put together in a short period of time, consisting of experts on various fields relevant to the task, people from different organizations, different functions, different cultures, connected with the means of information technology and forced to work together over long distances due to time constraints. Teams like this

Figure 2-12 Pictures of a small piece of the operations after the Deepwater Horizon accident. Pictures found in [36] [37].

can be found during natural disasters where medical personnel, fire and police departments, national guard, military, etc. have to effectively collaborate to save human lives and important assets. In the oil and gas industry when big disasters occur like the Macondo incident and Deepwater Horizon accident, virtual teams are established working across onshore and offshore organizations aided by ICT in a large scale to stop a leaking well and clean up the largest oil spill in history. Pictures of the accident are shown in Figure 2-12.

2.3 Distributed knowledge management in collaborative environments

If all the fancy screens, collaboration rooms, fiber cables, professionals and facilities are removed collaborative operating environments boils down to information and knowledge. Resulting from advanced information and communication technologies is an ability to reach far outside traditional organizational and even geographical boundaries to access distributed knowledge. In addition, data and information in a large scale is integrated from all network participants to form a broad picture of the current state of operations. This information and knowledge can be utilized in planning, decisions and training to continuously improve value creation and business performance. In this section challenges regarding knowledge management systems in collaborative networks is presented, and relevant theory is investigated.

Previously virtual teams have been investigated in the context of collaborative operating environments; hence it is relevant to seek theory on knowledge management systems in virtual teams. In Chapter 3 Industry lessons learned a case from Toyota – world-class car manufacturer – is studied to see how Toyota have been able to increase its own value creation as well as its supplier network by focusing on high performing knowledge-sharing networks. First comes a definition of knowledge management and knowledge management systems. Second, knowledge management in virtual teams is investigated.

What is knowledge management?

Knowledge management is a set of strategies and processes to capture, distribute and apply experiences, lessons learned, information, and know-how to continuously improve performance and value creation in business processes and operations. A knowledge management system (KMS) is an information technology-based framework to support knowledge management processes [38].

Why do organizations implement a KMS? It can be explained by Figure 2-13. Curve 1 represents a company with a functioning and effective KMS, shown by the increasing value creation after each project. The curve has a relatively steep positive trend, where experiences and lessons learned from project 1 are captured and deployed in project 2, etc. Curve 2 represents a company without a KMS. Value creation is increasing during one project as knowledge is obtained as it endures. However, the company does not capture this knowledge, perhaps it stays with temporary virtual team members from a supplier or simply is forgotten. In other words, the company has to start over again, making the same mistakes again. Yet, a

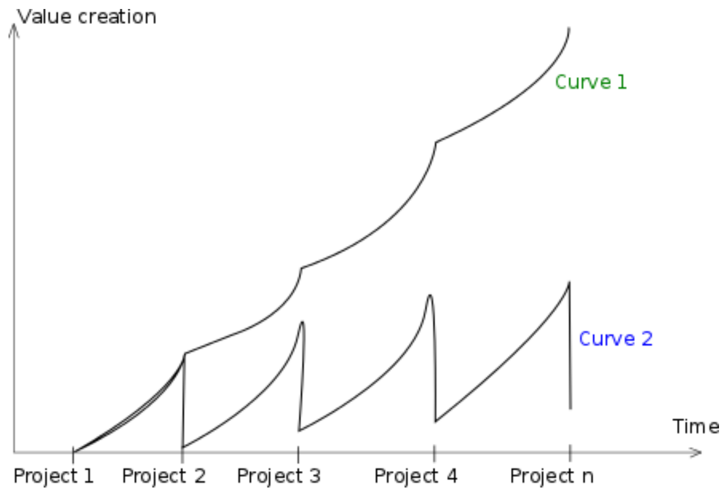

Figure 2-13 Curve 1 represents an organization with a KM system, whilst curve 2 represents an organization lacking a KM system.

small portion of knowledge is internalized by the company thus a small positive trend is shown following each project.

Therefore, a company that effectively creates, captures, distributes and applies its knowledge will experience a greater value creation than its competitors. In that sense, knowledge management enhances a company's innovative capability to overcome complex challenges and create value. According to Alavi and Tiwana [38] knowledge management is composed of three processes: 1) knowledge creation, 2) knowledge codification, and 3) knowledge application. The first two processes are not directly contributing to value creation, because creating a knowledge repository without integrating it in decisions and problem solving is not doing anything except simply existing. These three processes will be developed further in the discussion about knowledge management in virtual teams.

Data versus information and knowledge

It is important to distinguish between data, information, knowledge and even wisdom. Figure 2-14 adapted from Dwyer et al. [39] show the difference both in volume and value to organizations of data, information, knowledge, and wisdom. Data is the lowest form of the four. Data is raw facts collected from sensors or other inputs from various applications, and cannot in most cases contribute value before it is sorted, interpreted and analyzed.

Sensors pick up a stimulus often in the form of electrical resistance or voltage, which is interpreted and transformed into another more useful unit, like temperature, vibrations, movement, strain, conductivity, or pressure. These data can be plotted into data series and for example trends can be identified. Data is converted into information, which is a more refined and "decomplexified" form of data [39]. Sometimes a large amount of data is needed to get useful information, illustrated by a large block at the bottom of the hierarchy in Figure 2-14. Information can be presented to a professional who can act upon it. For example, a mud engineer can see a trend in mud weight deviating from the plan, and notify the drilling supervisor and drilling team onshore and offshore.

Knowledge is systematized and understood information. When a person has internalized information and has an understanding for what and why concerning a type of information it has become knowledge. For example, when the mud engineer in

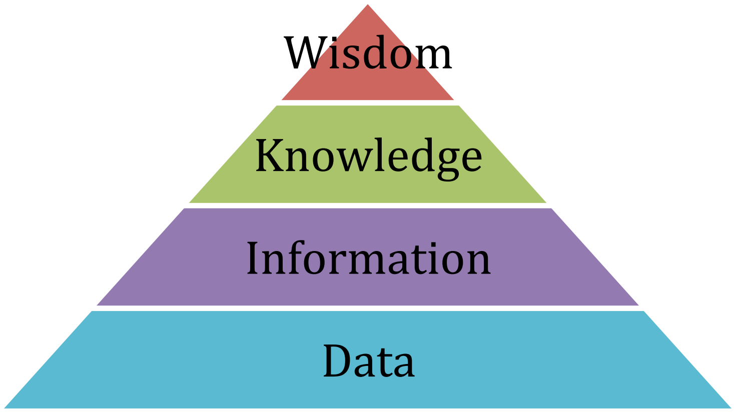

Figure 2-14 Value of data, information, knowledge, and wisdom. Decreasing value from top to bottom.

the previous example spots a mud weight trend he or she had seen before and had an understanding for why this could be happening, he or she would be able to make a better decision on how to solve this problem. After enough knowledge and experience has been collected a person is granted wisdom, and this person will be regarded as an expert in his or her field.

Types of knowledge

According to scholars in organizational learning there exists two main types of knowledge [38, 40]: i) explicit knowledge, and ii) tacit knowledge. Explicit knowledge is written procedures, instruction manuals, organizational routines, plans, and other information embedded in the organization. Tacit knowledge – the know-how – is experiences, lessons learned, and specific information contained within individuals and experts, or individual organizations if collaborative business networks are considered. A large difference between experienced professionals and rookies is the difference in tacit knowledge. This tacit knowledge have the highest contribution to value creation, and is a key resource to acquire, store and integrate in operational teams and organizations in order to be innovative and solve complex challenges. Dyer and Nobeoka [40] say that motivating partners of business-to-business networks to share their tacit knowledge is one of the most difficult challenges in order to realize an efficient knowledge management systems.

Virtual teams are a dynamic part of distributed knowledge systems

The advanced information and communication technologies present in collaborative operating environments, and virtual socialization processes in modern operational environments create a situation where acquiring distributed knowledge and applying it on complex challenges is the key for value creation and performance. Liyanage [41] presents a model of "Hybrid Intelligence" saying that modern complex business environments requires companies to acquire core distributed knowledge in order to achieve sustainability and performance, and these processes are extensively supported by "virtuality" orchestrated by modern information and communication technology and socialization processes within business networks. And an important process for sharing and applying knowledge is the socialization process between professionals, experts and teams.

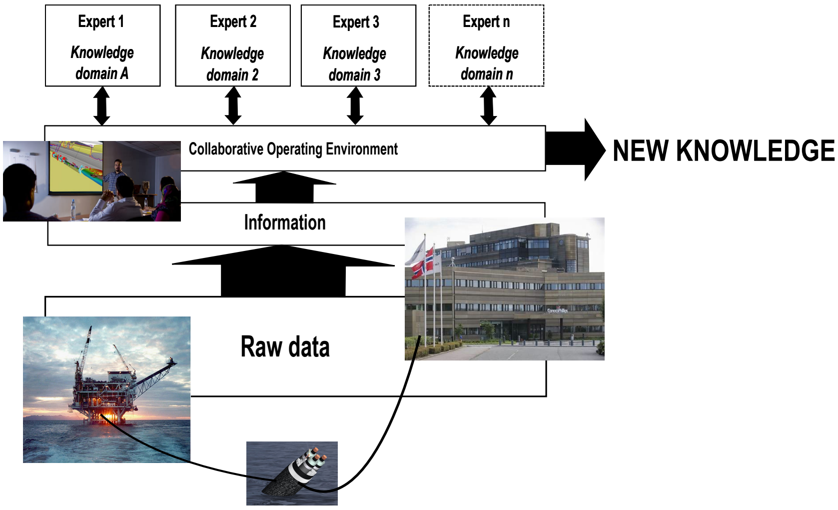

Figure 2-15 Knowledge creation process

As mentioned in the definition of knowledge management, it consists of three processes [38] illustrated in Figure 2-16: 1) knowledge creation, 2) knowledge codification, and 3) knowledge application. These three play an important role in value creation especially in knowledge intensive industries and operations, e.g. drilling and well interventions.

Knowledge creation is the process where different domains of knowledge – or domain ontologies – come together and develop new domains of knowledge [38]. Domains have different degrees of similarities. If two domains are very similar it is called an upper ontology rather than domain ontology. An example of domains of knowledge can be drilling engineer A from company A has developed a specific know how and company routines from deep water offshore operations in the Gulf of Mexico, while drilling engineer B from company B has developed a specific know how and company routines from offshore operations in the North Sea. In other words, they have developed two separate domains of knowledge – or ontological domains. When these two professionals collaborate on problem solving with dissimilar domains of knowledge, new ones can appear as a hybrid between engineer A and B's ontological domain.

This knowledge creation is also fed on information generated from data gathered in operations real-time and historical data. An illustration of the knowledge creation process is shown in Figure 2-15. One can say that knowledge creation occurs in a social context [38], like a collaborative operating environment, and the socialization processes within this social context will affect the effectiveness of this knowledge creation process. For example trust, communication skills, culture, etc. will affect the socialization process. Socialization in virtual teams it is supported by ICT. For example socialization can occur through Web 2.0 solutions (Facebook, Twitter, etc.), virtual meetings, problem solving, etc.

Knowledge codification is processes and mechanisms to formalize and internalize tacit information, and can also be referred to as knowledge capture. Examples of knowledge codification are creation of knowledge repositories, like databases of lessons learned, or simply writing down a step-by-step procedure. Knowledge codification is also heavily dependent on the technological capabilities of the knowledge management system. It has to capture knowledge from several network partners, and from an extremely large set of data sources and operations, and is thus dependent on standardization of data and data transfer protocols in order for different software and systems to communicate and effectively transfer data.

Figure 2-16 Knowledge management process

Knowledge application is what generates value, and where knowledge is put to use to solve a problem or challenge. In the knowledge application process distributed parts of knowledge related to the problem at hand have to be either gathered or it has to be integrated within an organizational entity, like a team. Alavi and Tiwana [38] highlights knowledge integration as an important element in knowledge application, because knowledge integration is more effective with respect to time. Distributed knowledge that needs gathering must be found at first, then transferred to where needed, and at last applied. Based on the characteristics of collaborative operating environments knowledge integration can be facilitated by advanced ICT and KMS.

Knowledge integration is defined as [38]:

"The synthesis of individuals' specialized knowledge into situation-specific systemic knowledge."

In other words one can say that knowledge integration bring together distributed experts' and specialists' tacit knowledge to apply it on a project or problem, by creating a common understanding and common knowledge for the challenge at hand. This distributed tacit knowledge can be put down in organizational routines or directives for non-experts to use it, or it can be integrated through organizational teams [38]. Routines and directives will not generate as much value as teams because in teams distributed knowledge are brought together in a more dynamic and socializing context. One of the important parts of knowledge integration in teams is that in order to be efficient, team members need to know who knows what and where this knowledge is located, as well as creating an environment for rich and effortless socialization. If knowledge integration is realized, companies can achieve specialization by forming experts and specialists and utilize them on several projects for sufficient flexibility through "virtuality" [42]. In virtual teams there exist additional challenges in knowledge integration because socialization occurs in a virtual and dynamic context. Alavi and Tiwana [38] identified four knowledge integration challenges in virtual teams: i) constraint on transactive memory, ii) lack of mutual understanding, iii) failure in sharing and retaining contextual knowledge, and iv) inflexibility of organizational/network ties.

Knowledge integration challenges in virtual teams

The first challenge is *constraint on transactive memory*. Transactive memory can be explained as information about who knows what. As previously discussed, in order for effective knowledge integration team members need to know who inherits what knowledge and where they are located. Creating a transactive memory in a team means that every team member do not need to know everything necessary to solve a problem, but become specialized on a narrow field. In addition, transactive memory requires that every team member have a common understanding together with the rest of the team. To develop transactive memory people have to socialize, and especially problem solving and collaboration leads to increased transactive memory. Nevertheless, in virtual teams this socialization process is a lot different from face-to-face interactions. First, lack of direct contact and observation of other team members is unfavorable. Second, the dynamic and temporary nature of virtual teams limits collaborative history between people. Third, cultural diversity and diversity of experiences and specializations constrains development of transactive memory. Proposed solutions to overcome the challenge of constraint transactive is to create a form of "yellow pages" where all experts have a profile with skills, experiences, etc. [38]. In view of modern online social networks, e.g. Facebook or LinedIn, and Web 2.0 technologies such a solution is easily available already. Finding an expert with the required specialization is not too difficult.

The second challenge is *lack of mutual understanding*. Virtual team members come from many different organizations and nations and are often not located at the same physical location, hence a common understanding and language is difficult to achieve. Proposed solutions to do something with this challenge is to arrange joint training events between partners [38] and create a glossary of common expressions and words[6]. Later in the Toyota Case (ref. Section 3.4) practical examples is presented on how to create joint training events to create a mutual understanding and common goals.

The third challenge is *failure in sharing and retaining contextual knowledge*. Contextual knowledge is knowledge about how surroundings, machinery or a problem looks like. For example if a mud pump fails offshore it is difficult for a specialist onshore to guide technicians offshore by phone without knowing exactly what equipment is damaged, how the area around looks like, what systems it is connected to, what the damage looks like, etc. For a reservoir specialist in Norway to guide a reservoir trainee in Indonesia is difficult if the specialist in Norway do not have a clear vision about how the surroundings are, geological history, faults and cracks, etc. Simple solutions exist today because mobile technology has become affordably to procure in large

[6] See for example Schlumberger Oilfield Glossary www.glossary.oilfield.slb.com

scale. Many offshore fields are today equipped with handheld video cameras for real time video and audio feed from offshore to an onshore support center. In addition, 3D models of rigs, platforms, ships, etc. are available to gain contextual knowledge, and even a full virtual reality is under development by an operator at the NCS. Also 3D visualization of wells and reservoirs is a good source for contextual knowledge.

The fourth challenge is *inflexibility of organizational/network ties*, hence the combination of weak ties (innovation) and strong ties (symmetric knowledge integration). Inter-organizational ties have been discussed in Section 2.2.1 , and weak ties are characterized by infrequent interactions and distance, while strong ties are characterized by frequent interactions and close relationships often involving a lot of trust. When an organization or company is to choose either to maintain weak or strong ties it creates a dilemma; choose between innovation capabilities or strong knowledge-sharing pathways among network partners. Having many and robust communication pathways and frequent socialization, hence benefitting knowledge sharing, describe strong ties. Weak ties generate opportunities for receiving new inputs not affected by the network's old thoughts and ideas. To balance these two types of inter-organizational ties virtual teams can create strong ties and maintain weak ties through ICT. The solution is to create a social network or Web 2.0 solution to accommodate for rich and simple communication between different experts, professionals, managers, teams, etc., with historical logs to provide trust between two persons without much prior history together [38]. In addition, creating a knowledge repository and a blog function where network members can share thoughts and ideas can maintain a weak tie. A solution like this can generate strong inter-organizational ties while maintaining a weak tie as well.

2.4 Collaborative decision support and integrated work processes in collaborative operating environments

In order to capitalize on opportunities for value creation through collaborative operating environments a high level of implementation should be realized. Requirements for moving into a generation 2 and transformational level of implementation is to integrate service companies and operator through integrated work processes, focus on data integration and visualization, and collaborative decision-making. Below is a discussion of collaborative decision tools and integrated work processes to realize value potentials in collaborative operating environments.

Collaborative decision support realize value

When looking at collaborative decision support tools a small introduction in decision theory is relevant to address some of the challenges arising from implementing collaborative operating environments; hence more participants in decision-making, real-time data, a large decision space, and ultimately more stakeholders to consider.

Fjellheim, Bratvold, and Herbert [43] distinguish between decision outcome and decision quality. A good or bad decision outcome is something that is valued relative to another outcome in the real world. Decision quality is valued based on available data and information at the time the decision was made. The logical conclusion could be that more information gives higher quality decisions. Nevertheless, this is not true. Information overload and data quality are two important components of decision quality. An experienced drilling supervisor said that the top priority for their onshore drilling center was to ensure their operators and supervisors got high quality operational data to base their decisions and models on. Information quantity positively correlates to decision quality – up to a maximum point. From this maximum additional information will contribute to lowering decision quality. When there exists an information overload an individual will easily get confused, ability to set priorities is affected, and make it harder to recall prior information [44].

Furthermore, decision process complexity has two dimensions [43]: decision complexity and coordination complexity. Decision complexity addresses the difficulties inherent in the decision itself; like uncertainty of outcome, number of options, uncertainty in information, et cetera. Coordination complexity is related to issues with number of decision makers, communication, team structures, et cetera. In virtual teams coordination complexity is often a challenge due to dispersed multi-disciplinary teams.

To cope with increasing decision process complexity and information overload a new model for collaborative decision-making is proposed – Collaborative Drilling in IO (CODIO) [43]. The mission of CODIO is to handle data integration and visualization, improved awareness and collaboration, support faster and better decisions, and work process compliance. CODIO addresses coordination complexity in virtual teams by helping to effectively filter and transfer information, and create a mutual understanding in problem solving [45]. Figure 2-17, adapted from Fjellheim et al. [43], illustrates the collaborative decision support tool framework. Starting with the core, a dynamic decision model based on Bayesian networks (see [46] for more on Bayesian networks) computes the maximum expected utility from a specific situation, hence giving a recommended action. The dynamic decision model is continuously updated by information from real-time operational data, knowledge repositories, and experts.

Two important work processes interact with the dynamic decision model: a collaborative decision making process, and a decision implementation process. First, the collaborative decision making process updates the model through discussions and problem solving among experts in the virtual team onshore and offshore. For example, a drilling team senses a problem coming up and discusses various solutions that they feed into the CODIO dynamic decision model to get a recommended solution for this problem. Second, the decision implementation process is responsible for realizing the agreed upon solution at the problem location. In the example above this could mean adjusting parameters on the drilling equipment, for example drill string rotation per minute (RPM), et cetera. This leads the discussion on to the next section on integrated work processes.

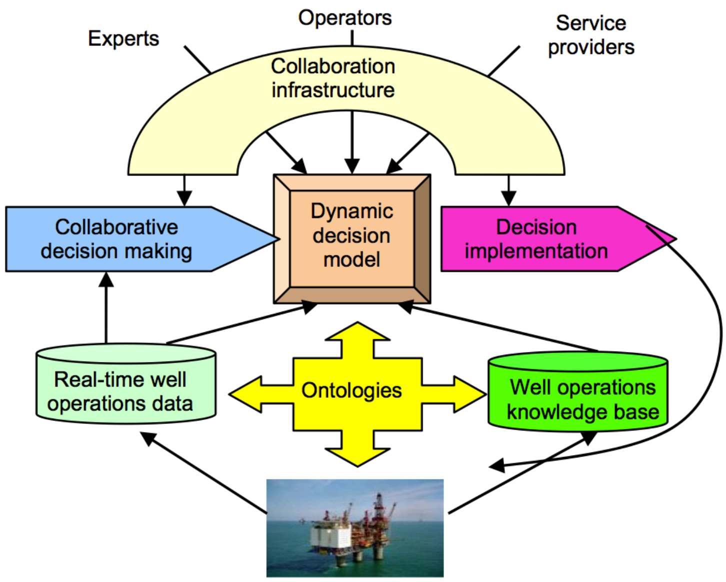

Figure 2-17 The CODIO framework [43].

Integrated work processes in collaborative operating environments

T-Ford was produced in a mass production plant where a chassis came from a station down the production line, specific parts was put on to the chassis in one station and sent to the next station. Nobody cared or interfered with the other stations, no information or knowledge was transferred. This traditional and very individual work practice worked fine for this situation characterized by low complexity and recurring operations. However, now as complexity has increased dramatically in e.g. the oil and gas industry it no longer fits its purpose. Here is where integrated work processes and collaborative operating environments find its payday.

Traditional work practices are divided into functions and disciplines, and are very much decentralized and individual [47]. In addition, traditional work practices have a limited interface with others and to the functional areas. In modern complex operational environments faced today, traditional work practices are ineffective and compromises good decisions and value creation.

In order to capitalize on developments of ICT and opportunities in the oil and gas industry, especially with aging fields and assets, integration across functions and disciplines both within the organization and with other potential partnering supplier organizations have to be prioritized when implementing collaborative operating environments. Figure 2-18 illustrates an example of an integrated work process with four disciplines involved (reservoir, geology, directional drilling, and drilling supervisor) where the blue bracket indicates a collaborative decision making process. This illustration also indicates roles and responsibilities of each discipline.

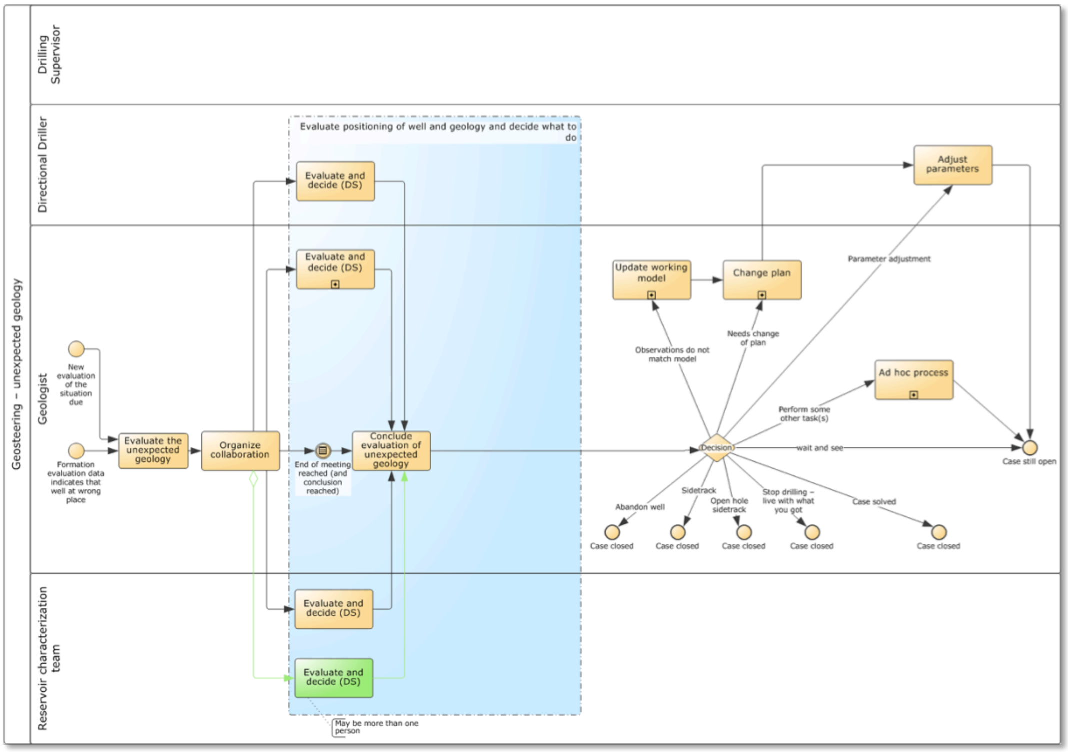

Figure 2-18 Illustration of an integrated work practice. Courtesy of ConocoPhillips.

2.5 What value creating potentials and challenges exist?

If all the abovementioned elements of collaborative operating environments are implemented and capitalized on, several value creating potentials are realized. In addition, there exist several challenges when implementing collaborative operating environments in the oil and gas industry. A summary of value creating potentials and challenges is presented in this section.

Value creating potentials in collaborative operating environments

According to White Paper no. 38:2003-2004 on Petroleum Activity [5] operating costs have to be lowered to slow down production decline on the Norwegian Continental Shelf, and increase recovery from mature fields. Lowering costs on the NCS has a large potential with collaborative operating environments. OLF published two reports, one in 2006 and an updated one in 2007, on the value potential for integrated operations. The report from 2006 say [7]:

> *"The study concludes that IO represents a potential of 250 billion NOK. The basis for the calculations is a discount rate of 7% and a price path as given in the national budget (NB2006) which assumes an oil price of 55 USD/bbl which decreases to 34 USD/bbl in 2015".*

The report emphasized that if appropriate measures were not initiated in the near future, this value of 250 billion NOK will diminish drastically. The updated report from 2007 increases the value potential to 300 billion NOK [8]. What is easily understood is the enormous value potential in implementation of collaborative operating environments. Furthermore, today in 2012 the oil price for a barrel of Brent Crude is 125 USD, which is more than double what was assumed in 2006, meaning the value potential is even higher today. Optimizing production, better understanding of reservoir performance, drilling optimization, and optimizing maintenance realize the value potential. And if examined closer, better decisions are made with better information and use integrated and distributed knowledge are the reasons for these benefits.

A very good example of how integrated work processes and virtual collaboration can enhance efficiency and lower costs come from the military industry. Joint decision-making in virtual environments reduces the number of iterations in planning across departments and geographical location, by not having to send plans back and forth between different geographical locations and departments [48]. In addition, experts do not have to travel long distances to get to the problem; the problem seeks the expert. This will release a large capacity of distributed knowledge.

Benefits from collaborative operating environments are not only related to economics. Another important benefit is something the oil and gas industry in Norway strive very hard to cope with – HSE. From the fact that collaborative operating environments bring more eyes to the table and result in improved decision-making, HSE incidents decrease drastically, and production regularity increase considerably. A major operator on the NCS presented six graphs showing this movement towards improved HSE in their operations, shown in Figure 2-19.

Challenges with collaborative operating environments

As written earlier the NCS is a mature oil province with aging assets. Forty years of operations and various patching and modification introduce many different

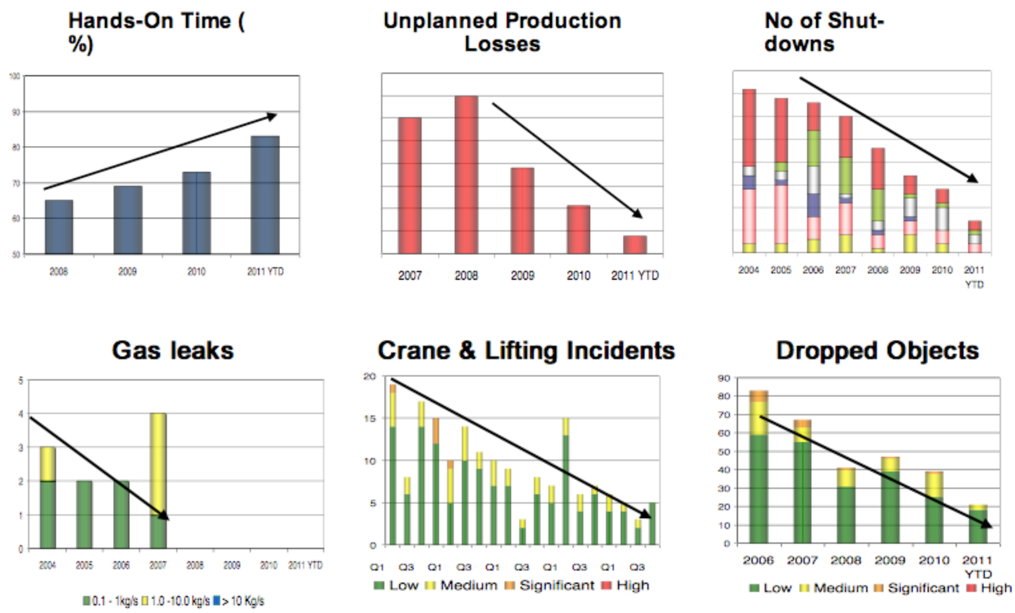

Figure 2-19 Realized benefits from implementation of collaborative operating environments in a major operator on the NCS.

systems, combining new and old, and different suppliers and technologies. Furthermore, when new sensors and measurement equipment, ICT equipment, etc. is to be integrated together with the old equipment interface and compatibility challenges will arise. For example, condition based maintenance require vibration and temperature sensors or particle counters to allow for monitoring of equipment. Maybe an operator implemented small scale condition monitoring in the 90's, and now these old vibration sensors have to be replaced or integrated into the new system. The cost of retrofitting aging assets with new monitoring capabilities may not qualify for an investment, and a consequence is that personnel in-situ has to manually monitor equipment and record information [17]. This is of course less effective as having hard-wired equipment installed, and can constrain the use of condition monitoring.

Considering humans in collaborative operating environments many challenges arise, especially in the implementation and adaptation phase. Trust in the technology and work practices in collaborative operating environments is gained over time. In this sense, this novel and innovative way of working have to gain workers' trust before the investment paybacks start showing and benefits are realized. New work practices and collaborative technology and environments have to be integrated in the daily work flow and workers need to have a motivation for utilizing collaborative operating environments and the integrated work processes instead of the traditional work routines. BP experienced with collaborative operating environments in the 90's, and investigated the effect of coaching their collaboration teams in this pilot project. What was experienced was that the one team that did not receive coaching on the benefits and how to use collaborative operating environments, ended up not using the tools at hand at all, because they did not see why to bother [49].

Operations in the petroleum industry are categorized as 24/7 operations. The process facilities and drilling operations are not shut down during nighttime and personnel onshore have to be online at all times to offer support and problem solving.

Networks between organizations introduce challenges, such as network governance, trust between partners, and safety of information sharing and access to information. Network governance will change drastically with adoption of collaborative operating environments as business model, and will have implications for contract strategies and value creation. Traditionally information is considered as power, and secrecy between companies is normal, yet very inefficient. Large-scale integration of collaborative ICT solutions will introduce more transparency as the industry move towards the 2nd generation collaborative operating environments. A very interesting study supported by the European Union – SustainValue – looks at sustainability in manufacturing networks and address some of the challenges in networks [50], which is very relevant in collaborative operating environments. Business network challenges and literature will be studied in Chapter 2.2 .

A challenge is to create a business model and contract strategy to create a relationship between operator and service company that is not based on control and command, but rather a win-win situation with risk and reward sharing.

Benefits from collaborative operating environments are realized because of, among other, availability of information. Hence, one of the main challenges in an operating environment like this is to integrate information and gather experiences and competences in a systematic way, and make it easily available when needed. The knowledge management system is crucial for performance in collaborative operating environments.

Table 2-4 Challenges and value potentials

Challenges	Value potentials
• Retrofitting of old platforms • Adaptation to collaborative technology • Implementation of new work practices • Understand the benefits of collaborative operating environments • Adapt to 24/7 operations onshore • Change governance in B2B relations • Effective management of distributed knowledge • Tailor new incentive systems	• Enhanced HSE performance on platforms • Optimization of production, reservoirs and drilling. • Enhanced equipment regularity • Improved recovery of hydrocarbons • Extended field life • Availability of experts and personnel

Chapter 3
Industry lessons learned

3.1 Collaboration on the battlefield

Humans have fought wars since the beginning of our era, and much of our technological and organizational innovations are spin offs from military applications. For example the Internet is a consequence of establishing an intranet among dispersed units within the US Military. Another example is how munitions of war industries contributed to modern forms of project management. There are also some similarities between the development of the oil and gas industry and military operations; increasing complexity and risk in operations [51]. Military operations have developed from two line-ups on each side of a field in the 17^{th}-18^{th} century battlefield to advanced drone attacks and large-scale espionage and intelligence operations across the whole world, which includes cross-functional and organizational collaboration.

Howley [48] presents a good paper on lessons learned from experiences from operations on the Balkans in 1999, and relevant examples are used below. Howley [48] highlights many of the same benefits to military operations as has been seen in the oil and gas industry: optimization of processes, utilization of synergies, improved situation awareness, lead time reduction, "smart pull" of plans, and enhanced decision making.

Virtual environments

A very interesting feature worked on by the US Military is to set up a virtual environment where collaboration on problem solving, planning, etc. can be achieved without physical boundaries like time and space. This has a lot in common with video games, where a complete virtual reality is present for players to perform actions together with others and interact with virtual surroundings. When planning this virtual environment the military emphasized the importance of keeping the surroundings or boundaries as close to real as possible. Hence the office building should look like a physical office building, rooms should be positioned in a traditional landscape, computer screens and white boards should have an interactive possibility, office furniture should be present, etc. From a human factors point of view this would contribute ease the adaptation phase of such a new way of working because of familiar surroundings, and make it more comprehensible for people without a lot of experience with such environments from games.

As pointed out earlier, lack of face-to-face interaction will affect trust and communication in virtual teamwork and contribute to a lower performance. Henceforth, such virtual environments where you can physically seek and interact with coworkers and engage in problem solving help overcome some of these challenges related to virtual teamwork.

A last point worth mentioning is that by using such virtual environments, information one needs in for example drilling, like pore pressure or string bending, can be presented within a virtual drilling center on large screens where people from service companies can log onto this virtual drilling center and access this information. Instead of having to transfer information along fiber optic cables, routers, access points, etc. one can simply access everything from this virtual center where supplier network partners only need an interface to access this virtual center.

Collaborative mission planning

If the idea of materializing virtual reality in virtual offices as talked about above is set aside, virtual represents defying time and location to collaborate on problem solving, planning, etc. By introducing virtual teamwork the US Military have managed to change the planning process from sequential to parallel. The traditional planning process was a sequential or even reciprocating procedure where every separate unit or functional silo made a small part of a large plan without consideration of other silos needs or constraints. Similar to Frederick Taylor's Scientific Management or Henry Ford's assembly-line model of mass production. At the end of the plan "assembly line" a decision maker reviewed the plan, having to balance all needs and constraints at the same time. If something needed revision it needed to be sent back for the respective unit to do so. A very time consuming process if viewed from a modern standpoint.

However, virtual teamwork have as mentioned revolutionized this traditional planning procedure for military purposes. Now units, functional silos, and other stakeholders can meet together with decision makers in real time whenever needed on short notice to make plans in collaboration over a virtual meeting place or groupware. As Howley [48] highlights in his paper this saves considerable time and effort, and provides everybody with immediate feedback.

In the oil and gas industry a similar transformation has occurred and tools have been developed to aid this in the branch of collaborative decision support to provide the planning and decision process with information and knowledge available to make good plans and decisions.

3.2 Collaboration across space in NASA

National Aeronautical and Space Agency – NASA – have collaborated over extreme distances in space missions since the sixties. Apollo was the first manned space mission to land on the Moon, and NASA's exploratory space missions have been ongoing since. Space missions require collaboration across several disciplines and functional areas, and are sensitive to time. When a problem arise it is highly likely that it needs to be resolved very quickly to avoid loss of human lives and several billion dollars of taxpayers' money. In order to operate safely and to detect challenges early data quality from sensors in space has to be high and communication and information transfer across space must be safe and robust.

The space industry has a lot of similarities with the oil and gas industry. First, space missions require high capital investments in space vehicles, equipment, launching facilities, operation centers, training facilities and communication equipment. This is similar to investment in production facilities, wells, export pipelines, etc. needed for production of hydrocarbons. Second, the time horizon for acquiring assets and start up production in the oil and gas industry, and acquire space vehicles and communication equipment and do mission preparations is often a decade. As a consequence the technology planned for usage in the first design phase is often outdated and unusable when operations are about to be commenced. Third, the space industry and the oil and gas industry are high-risk operations and very complex.

Because of technological development and the increasing need for collaboration across dispersed locations NASA focus on coming up with novel and innovative decision support tools and knowledge management systems based on automation and intelligent software [52]. To improve collaboration in space missions NASA Ames have developed a set of tools over the last ten years. Especially one of them can be relevant for oil and gas operations and are discussed beneath.

Use of mobile agent systems

Mobile agent systems (MAS) in space missions and scientific operations are one of the priorities in NASA, and are developed to support manned Martian missions in the future. MAS was developed to compensate for time-delays and periods of communication silence between earth personnel [52]. MAS are basically a personal computer that fits in a backpack, with characteristics of expert systems and even artificial intelligence. MAS are fitted with technology like GPS, spoken dialogue system, headsets, cameras, etc. It is supposed to provide astronauts and ground personnel with decision support, knowledge management and automation of routine tasks as log taking, and sending and receiving data when satellite contact with earth is established. Among possible features of MAS are to collect and store mission data, and the ability to integrate data, information and knowledge from several sources like video, pictures, voice memos, logs and scientific data.

The communication capabilities of MAS enabled a new mission model at NASA with real time collaboration between scientists, astronauts, ground personnel to do research and problem solving on the fly across enormous distances [53]. In addition to the abovementioned integration of different sources of information, NASA discovered that this new model allowed for integration of more information, e.g. weather forecasts, information from the Internet, etc. [53]

An actual example of this application was during hurricane Katrina in the US. During the emergency operation of this devastating storm NASA's MAS aided in connecting VoIP and video to the different participants of this operation, and it proved successful [53].

The concept of multi agent systems could be utilized in offshore environments for maintenance or problem solving in the field. Today handheld video cameras and UHF radios are used to visualize challenges for onshore support personnel, but could be taken a step further and For example equipment data, maintenance history, operational parameters, pictures, logs, etc. can be used by personnel working in the field offshore.

3.3 Collaborative experiences from the petroleum industry

British Petroleum (BP) was one of the early pioneers on collaborative operating environments. Cohen [49] presents an early example of benefits from virtual teamwork in collaborative operating environments:

> *"On a cold day on the North Sea in 1995, a group of BP Exploration drilling engineers had a problem. Equipment failure had brought operations to a halt — and because they couldn't diagnose the trouble, they faced the prospect of taking the mobile drilling ship (leased at a cost of $150,000 a day) back to port indefinitely. Instead, they hauled the faulty hardware in front of a tiny video camera connected to a newly installed computer workstation. Using a satellite link, they dialed up a BP drilling equipment expert in Aberdeen. To him, the problem was apparent, and he guided them quickly through the repair. The down time, as it turned out, lasted only a few hours."*

This example demonstrates how beneficial it is to have the ability to visualize a problem, transfer this information to an expert in another location and effectively solve the problem. This episode was enabled due to an early initiative from BP called "Virtual Teamwork". However this example show a great benefit of collaborative operating environments it is more interesting to look at BP's early experiences with implementation of "Virtual Teamwork".

Coaching

BP created five separate teams; each was allocated groupware[7] and appropriate facilities. Managers at BP emphasized that in order for "Virtual Teamwork" to be a success considerable efforts had to be undertaken to include and take care of the human part in design and implementation of this novel operating model. Mueller et al. [13] also stress the importance of human centered design and implementation from experiences with Shell's collaborative operating environment efforts. For this reason half the BP project's budget was spent on coaching of team members. Having said that, only four out of five teams received coaching (due to budget constraints).

[7] Groupware is software and tools to enable collaboration across time and location. Examples are instant messaging, e-mail, online forums, video conferencing, etc. Modern versions of groupware are often referred to as Web 2.0.

The goal of coaching is facilitating an easier adaptation of new technology and work practices offered by collaborative operating environments. Coaching ensures motivation to utilize this opportunity to streamline and increase effectiveness, and is a great way to make professionals understand how this new environment can benefit them. Mueller's experience is that coaching requires two coaches – one lead coach and one support coach – in order to be effective [13]. The lead coach (could for example be the project manager) has overall responsibility for management coaching, organize coaching and collective learning meetings, as well as one-on-one coaching of team members. The support coach is then responsible for conducting coaching on a more individual level, to promote behavioral change in each individual, preparing documents and logistics. Mueller [13] argues that because virtual teams in collaborative operating environments are disjointed from time and space two coaches ensures enough flexibility to overcome the challenge of multiple locations and different schedules.

As coaching was applied to four out of five teams in BP's project a very clear and interesting observation was done. When implemented in the four teams that received coaching motivation and enthusiasm increased at high pace and adaptation of new work practices and technology happened fast and seamless. On the other hand, the team that was exempted from coaching saw a radical drop in motivation and enthusiasm, and all the fancy technology was quickly discarded. In other words, this team experienced the previously mentioned "Field of Dreams" scenario (ref. Section 2.1).

Vindasius [18] presents a good collection of lessons learned from implementation of collaborative operating environments in the oil and gas industry. Below is a discussion about data integration and expert alarm systems, and selecting the right people to work in a collaborative operating environment from Vindasius.

Data integration and expert alarm systems

With reference to Section 2.1 a collaborative operating environment can be characterized as foundational, comprehensible, or transformational, where transformational is the most advanced form. In order to achieve a transformational collaborative operating environments companies have to put emphasis on data integration and implementation of expert alarm systems [18].

First, data integration is processes to capture and distribute data and information across all partners of the operational network. Effective data integration ensures that all information about all processes and operations are accessible from everywhere at any time. Parallels can be drawn between data integration and multi agent systems in NASA as presented in Section 3.2 . In addition, data amounts tend to be enormous in collaborative operating environments and a robust and automated system for data quality needs to be in place. A model can be extremely good and precise, but garbage in equals garbage out. Professionals and researchers on collaborative operating environments say that new data protocols, e.g. WITSML[8], enable data to be transferred from all vendors, suppliers, service contractors, and facilities in real time independent of software and hardware [18, 39], which is important for data integration. All of the data gathered is not relevant to all functions, teams, professionals and experts. Some teams or centers may need to see the same data as another team or center, but in a different format or representation. High

[8] WITSML - Wellsite Information Transfer Standard Markup Language

quality data integration ensures that data can be moved around, and data visualization manipulated and customized by anyone with that interest at any time. This ensures enough flexibility of data representation. Another important feature is that data and information transfer have to be rapid, in order to reach where it is needed fast enough. Vindasius say [18]:

> *"A comprehensive or transformational collaborative operating environments should aspire to enable any drilling, operations, technical professional or manager to query the system at any time, drill into any of the data streams, change the view, check the logs for historical events or flags, and/or capture a current set of data streams in a modeling application to simulate alternative scenarios for predicting and planning changes and interventions."*

Second, amounts of data and information are lightly speaking huge. Overflow of information and data can lead to a situation where a person is unable to distinguish important data or information from unimportant [43]. As Vindasius highlights in her lessons learned a robust and intelligent alarm system that can correlate events and filter planned versus unplanned events is a must if a company wants to achieve a comprehensive collaborative operating environments [18], and achieve the benefits of improved decision making and enhanced performance.

Selecting team members

A last lesson learned of interest is selecting team members in collaborative operating environments. In order for a team or center, e.g. drilling or production optimization center, to perform well it is important for center or team leaders with primary responsibility for a project, asset or function to make the respective collaborative operating environments facility his or hers primary work space [18]. This is primarily because the collaborative operating environments facility, e.g. an onshore drilling center, is one of the main hubs in the operational network. And when this person is needed it should be natural to come to the respective center to locate this person.

Companies that are doing a real effort in implementing collaborative operating environments and want to succeed, select there most experienced and high performing professionals to work in the collaborative operating environments [18]. A collaborative operating environments is as mentioned above a primary hub in the operational network and a place where the best and scarce expertise in the company can be utilized on many projects and assets simultaneously. It does not imply that young professionals can work in the collaborative operating environments, but its primary function is not to serve as a training ground [18]. At last a citation from Vindasius that sums up a lot about collaborative operating environments and how it works:

> *"In the end, regardless of who sits in the collaborative operating environments, in whichever location, the collaborative operating environments is meant to support a cross-functional, multi-disciplinary team."*

3.4 The Toyota Case – Distributed knowledge management in collaborative supplier networks

Toyota is one of the world's largest automotive manufacturers. And in 2012 the corporation employed over 320.000 people. To achieve its success Toyota relies on a reliant and high-quality network of suppliers for parts and equipment and car dealerships. General Manager for International Purchasing at Toyota, Michio Tanaka, highlights one of the reasons for Toyota's success [40]:

"I think we are better at learning."

As this citation clearly suggests Toyota places great emphasize on knowledge management. Research on manufacturing networks suggests that manufacturing networks in Japan have been superior in transferring production-enhancing knowledge throughout the whole network [40]. A strong focus on continuous improvement in every part of a manufacturing network will contribute toward higher performance and enhanced value creation. However, these are fine words that need to be put to life through mechanisms and routines for knowledge sharing, and that is what Toyota succeeds in doing.

Three dilemmas in knowledge-sharing networks

Dyer and Nobeoka [40] put focus on three dilemmas associated with knowledge sharing in networks.

The first dilemma is how to motivate network members to actively participate in the network and openly share tacit and valuable information with the rest of the network. Companies tend to be very restrictive with sharing tacit and practical know-how that can be regarded as intellectual property and is important for competitive advantage. Moreover, if one company is disinclined to share its tacit knowledge, other companies will be reluctant to provide their tacit knowledge for the greater good of the network. As mentioned in Section 2.3 knowledge creation occurs when two or more knowledge domains interact. If several companies share its knowledge domain new and innovative knowledge can arise, and companies can build on each other's successes and innovations. Maybe one can say that today companies compete on having the best possible product and service solution, but in the future softer characteristics are valued more; like trust, partnership history, quality, complementary capabilities, common values and goals, etc. In the oil and gas industry traditional service companies and OEMs can be very restrictive in sharing valuable knowledge with non-paying customers, and tend to work as single nodes with few knowledge sharing inter-organizational ties.

The second dilemma is what Dyer and Nobeoka refers to as the "free rider" problem [40]. As mentioned above in the first dilemma a successful knowledge-sharing network creates common goods as a consequence of knowledge domain interaction. In a large network this can lead to the possibilities for companies to participate without contributing to maintain or create these public goods, while at the same time utilizing these public goods. The issue of free riders is more likely to occur in networks like Toyota's manufacturing network or supplier clusters like NODE or SE Kongsberg, because more members makes it easier to hide away.

The third dilemma is how to maximize knowledge transfer among network participants. In order to create a high performing knowledge-sharing network processes, routines, mechanism for sharing knowledge have to be in place. Creating such pathways for members to communicate is probably one of the most difficult of these dilemmas to deal with [40].

Toyota's solutions to dilemmas

Toyota has managed to overcome these three dilemmas to create a value creating and performance enhancing knowledge-sharing network. The solution to the first dilemma – motivation – was to heavily subsidize the knowledge-sharing network with tacit and valuable information and knowledge, that made suppliers realize that sharing knowledge instead of safeguarding it, contributed heavily to increased performance and new opportunities [40]. In addition, Toyota have managed to create a common understanding and goal for knowledge-sharing as a value enhancing effort, hence creating an internal motivation or "common purpose" for suppliers to share their tacit knowledge with the whole network.

The solution to the second dilemma with free riders was to create a set of rules or norms that network participants had to legally sign, stating that they was obliged to share its internal tacit knowledge in order to access Toyota's internal knowledge and the knowledge within the network [40]. These rules are taken seriously because Toyota can penalize free riders with economical sanctions if any of these rules are dishonored.

A solution to the third dilemma on creating mechanism and pathways for knowledge transfer among network partners is a bit more diverse. Toyota has taken several steps worth mentioning. Dyer and Nobeoka [40] found that creating a shared identity within a knowledge-sharing network would lower cost of coordination and transfer of knowledge. This is done through establishment of a common language, common understanding, trust, and shared goals. By enabling easy sharing of knowledge in a network a larger and more diverse set of knowledge can be accessed and contribute to creation of new knowledge and enhanced performance for network partners as a whole. Toyota have developed especially three network-level processes for acquisition, storing, and distributing of knowledge [40]: 1) a supplier association, 2) a consulting division, and 3) smaller thematic group learning teams.

The supplier association was established in 1943 and is an arena for knowledge transfer in a large scale, common training and education, and socializing events like conferences. Some of the events are arranged for transfer of explicit knowledge, e.g. future plans, while smaller events are arranged to allow for social interactions on a micro level for exchange of tacit knowledge.

Toyota's Operations Management Consulting Division is a set of problem solving teams or consultant teams that help Toyota's suppliers to implement the Toyota Production System and solve other operational challenges. This could be done in the oil and gas industry as well in dealing with operational or implementation issues for suppliers in implementing collaborative operating environments, and could be put together of early initiators within the operating company or other expert companies.

The third solution was to create smaller learning groups put together of small and large suppliers. Each group consisted of companies using many of the same production techniques, although none were direct competitors, and at least one of the group members had a long relationship history with Toyota. At the group meetings current challenges were discussed and solutions proposed by all the participating members in that group. After each meeting the group visited one of the member factories to propose improvement solutions to that plant for enhanced performance. Arranging these supplier groups can also benefit collaborative operating environments initiatives in the oil and gas industry, but in a smaller scale. A challenge in the oil and gas industry is to find enough suppliers that are not direct competitors and that are willing to share enough of its tacit knowledge for the greater good.

Chapter 4
Case study: ConocoPhillips and service companies

Figure 4-1 ConocoPhillips logo and the Ekofisk field center. Courtesy of ConocoPhillips.

This chapter contains the second part of this thesis – a case study of collaborative operating environments in drilling projects on the Ekofisk field. ConocoPhillips has been a pioneer in implementation of what they define as Integrated Operations, another name for collaborative operating environments. Ekofisk is the larges oil field on the Norwegian Continental Shelf, but is however a mature oilfield [2]. Increased oil recovery and lowering costs has highest priority for ConocoPhillips' operations in the North Sea. Because of the large scope of operations, increasing complexity and rising costs, functions and services have been outsourced to service companies, which is a good example of a collaborative network that has important effects on value creation. Service companies offer high quality value propositions in key areas of field operations, e.g. drilling and maintenance.

The aim of this case study is to identify where ConocoPhillips and some selected service companies are today in their implementation of collaborative operating environments, and identify improvement potential where further development can contribute positively to value creation in the business relationship between ConocoPhillips and service companies. In the next chapter proposed solutions to capitalize on these improvement solutions will be presented.

In addition to ConocoPhillips three (3) key service companies were interviewed and observed, from now on called Company A, Company B, and Company C. Company A was located at their own facilities as well as offshore. Company B was located in ConocoPhillips' offices and offshore, and Company C was located in ConocoPhillips' offices but all functions had been moved onshore. Company A provided a direct functional service, Company B provided a pure support function during operations, and Company C provided direct service in the planning phase and had a support role during operations. Information about the service companies is summarized in Table 4-1.

Table 4-1 General information on service companies

	Company A	Company B	Company C
Location	Own offices Offshore	ConocoPhillips offices Offshore	ConocoPhillips offices
Type of service	Functional	Simulation/support	Functional
Partnership length	Relatively short	Relatively short	Long term

4.1 Status quo: ConocoPhillips

Introduction

ConocoPhillips is the world's 25th largest oil company rated by total oil reserves[9] in 2010 [54]. On the NCS ConocoPhillips is one of the largest producers and Ekofisk is the third largest petroleum field found on the NCS, with over 700 million standard cubic meters of oil equivalents [55]. In 2012 ConocoPhillips repositioned its downstream business and formed Phillips 66. Hence, the exploration and production business – upstream – is formally ConocoPhillips.

Ekofisk is a mature – brown – field with aging assets, and suffers from heavy subsidence due to reservoir depletion. Subsidence has led to a nine-meter air gap reduction, and in 1987 Ekofisk was jacked up six meters to gain a satisfying air gap [56]. However, after water injection was initiated in the Ekofisk reservoir subsidence has decelerated and is now at a controllable level. Furthermore, as a consequence of

[9] A total petroleum reserve of 6.7 billion barrels of oil equivalents (boe) in 2010. 1 boe = 0.159 standard cubic meter (Sm^3). Includes gas, oil, and condensate.

subsidence and aging assets ConocoPhillips has initiated the largest construction project in the North Sea at the moment, to decommission and remove some of the old platforms and install new platforms away from the heavy subsidence areas.

The complexities of the Ekofisk field are large and lead to many challenges for professionals involved in working on this operation. Wells can collapse due to subsidence; aging platforms and wells are a risk for HSE and production; and the scope of operations are very large with drilling, maintenance, production optimization and logistics divided between offshore and onshore organizations. To get a picture of how large operations are at Ekofisk it is said that when the new Ekofisk hotel-platform is ready and installed it will be the third largest airport in Norway based on traffic. Over 250 wells have been drilled in the Ekofisk reservoir making well placements a challenge in order to avoid collisions. The Ekofisk reservoir is produced with pressure support from water injectors, and approximately 900,000 bbl of water are injected every day. Expected production rate from Ekofisk in 2011 was 161,000 bbl[10] of oil and 1.6 billion scf[11] of gas per day [55].

In 1999, an 1143-kilometer long fiber optic cable was installed from mainland Norway (Kårstø), through several platforms in the North Sea, including Ekofisk, to Lowestoft in the UK. This enabled a state of the art connection between the support facilities onshore and platforms offshore, which facilitates real-time data transfer, video conferencing, et cetera. ConocoPhillips has also installed in-field fiber optic cables between all platforms in the Ekofisk field center.

ConocoPhillips have during the last decade of implementation of collaborative operating environments transformed their onshore office facilities into a facility with various centers for different purposes with advanced collaboration, real-time monitoring, simulation, 3D visualization, and operational capabilities. The transformation has gone through several evolutionary stages, and is currently at stage five.

Network analysis

As indicated in the methodology, ConocoPhillips – the field operator – is the primary nodal company in this collaborative network. This statement can be justified by the following reasons:

1) ConocoPhillips is connected with the service companies with strong cohesive ties, while the cohesive ties between suppliers are weak. Intellectual property is guarded by service companies in ties between service companies, probably because of the competitive nature between them. However, service companies are connected, because they share information and data from drilling operations. Moreover, suppliers share of their intellectual property with the operator on a much broader base; even dimensions and equipment specifications are shared.

2) ConocoPhillips is the owner of these operations, and although the perception is moving from provider to partner perception, all the service companies still view themselves as providers and will sacrifice a lot to satisfy

[10] bbl = barrel
[11] scf = standard cubic feet

the customers needs and requests. Hence ConocoPhillips have a lot of power in the network.

3) On the other hand the contract strategy indicates that service companies provide functional services and thus shares risks, and create a win-win situation.

Collaborative drilling environment governance

Statement 2 above can further be used to determine the governance of ConocoPhillips' collaborative drilling environment, according to the governance model of Gereffi et al. [1] in Section 2.2.1 . Drilling projects inherits a form of modularity, which suggests a modular value chain governance model. For example well planning, geosteering, mud logging, drilling simulations, etc. can be modularized and several service companies have the capability to deliver each service module, and every module easily interfaces with other modules. All service companies are large multi-national corporations with experience and competence to be categorized has highly competent in their area. There is a high exchange of complex data between ConocoPhillips and service companies, as well as between service companies themselves.

A relational value chain could also be suggested as the correct governance model, but that would require power and influence to be more or less equally distributed between operator and service company, which is not the case in this case study. Moreover, decision authority during operations is mostly placed on ConocoPhillips' drilling engineers and drilling supervisors. Service companies can recommend a solution or to stop an operation, but cannot take the decision to abort a drilling operation; this is done by ConocoPhillips or the drilling contractor. However, during planning at least company C has full decision authority, and is even used in quality assurance of other service companies' work that is a real sign of mutual trust.

The conclusion is that the governance model of ConocoPhillips' collaborative drilling environment is a modular value chain with a power asymmetry, favoring ConocoPhillips.

Inter-inter-organizational ties in the collaborative drilling environment

Through interviews and observations it is possible to qualitatively see what type of inter-organizational ties are present in ConocoPhillips' collaborative drilling environment. Company B and C are located in house at ConocoPhillips' office facilities within their Onshore Drilling Center, and these companies have access to all of the physical facilities. This indicates strong inter-organizational ties between ConocoPhillips and Company B and C. Company A is located in their own offices where they have established their own drilling support center. However, Company C have to be present at morning meetings with ConocoPhillips every day either face-to-face or by video conferencing, which is also indicative of strong inter-organizational ties between ConocoPhillips and Company A. Information exchange between ConocoPhillips and all companies is large in scale, and complex information is exchanged among the collaborative drilling environment members at a high rate, which also suggests strong inter-organizational ties. During the interviews all service companies indicated that it was not difficult to reach a person needed within a satisfying time limit in case someone is needed.

All collaborative drilling environment members had full access to UHF radio (for offshore), internal telephone, VoIP, video conferencing and instant messaging, and these were in place at every office desk to orchestrate rich and effective communication. In high-risk operations like drilling projects it is from a safety perspective very positive to have strong inter-organizational ties.

ConocoPhillips is connected with strong cohesive ties with most of the service companies, while the service companies are connected with strong yet weaker ties with the other service companies. Strong and cohesive ties are preferable in stable operating environments, which fit drilling projects fairly well. However, without any weak bridging ties constraints are put on novel innovative solutions because there are not many new inputs from other companies than the collaborative drilling environment partners. In addition, companies in the collaborative drilling environment are dependent on each other to get new impulses and knowledge.

Network centrality

All of the collaborative drilling environment partners have a high degree centrality, because all of the partners are connected to each other.

ConocoPhillips' "betweenness" centrality is high, however the interviews and observations identified that Company A and Company C have relatively high "betweenness" centrality as well in relation to the other service companies. Company B has relatively low "betweenness" centrality.

Closeness centrality is high between ConocoPhillips and Company B, and ConocoPhillips and Company C. This can be justified by their location at ConocoPhillips' office building, and they are granted full access to facilities and have access to UHF radio, internal telephone, instant messaging, and video conferencing. Closeness centrality between ConocoPhillips and Company A is also relatively high because they run morning meetings every day and also have all the ICT capabilities as the companies sitting at ConocoPhillips' office building, and all companies share the same data from operations offshore.

Virtual team challenges

The knowledge integration challenges discussed in Section 2.3 have all been addressed by ConocoPhillips to some extent. Constraints on transactive memory have been resolved to a certain degree by having teams consisting of suppliers located in the ConocoPhillips office buildings, given them a face-to-face social arena to socialize, and most people are contracted to a position at one of the centers for at least 10-12 months. However, this is not the case for offshore members of teams, which do not have a social arena except from problem solving sessions to develop a transactive memory. Moreover, no social network profiles exist yet but ConocoPhillips is working on creating an avatar for everybody working in drilling projects that will be situated in a virtual reality environment. A solution like this will make it easier to find a person one needs for a particular problem; it is just to walk, virtually within the software application, over to the relevant center where a person with a certain expertise can be located. However, this solution is not expected to be available for some time still.

No large socializing events are held to compensate for lack of mutual understanding on group level. However, "Lunch and learn" events are held in smaller more specialized events where service companies and ConocoPhillips presents challenges, solutions, new tools, future plans, et cetera. Service company employees welcome these events:

"We become aware of what ConocoPhillips needs, who knows what, and what tools and solutions are available in the market".

Failure in sharing contextual knowledge has been resolved to some degree in the collaborative drilling environment. All tools necessary to share video, images, and audio from everywhere is available offshore and onshore at all times. But still there can be an issue to reach the same contextual knowledge between offshore and onshore personnel as indicated during interviews.

Inflexibility of inter-organizational ties might be a larger challenge, because has no tools for establishing weak ties except from personal relationships between professionals, which is very individual in size. Strong ties are present and is no large problem. A lot of information and communication technology applications accommodate for rich and effective communication and knowledge exchange to create strong inter-organizational ties.

Results from observations and interviews

Implementation of centers and facilities

Implementation of centers and facilities at ConocoPhillips has come a long way. The whole organizational layout have been redesigned from a traditional silo structure into a collaborative and integrated center structure with operational and support functions, illustrated in Figure 4-2. All centers are equipped with the latest communication equipment in order to integrate the offshore and onshore organization and remove the geographical distance between them. UHF radio is available at all desks in order to communicate with people walking around the platform offshore or ship traffic around the platform. All partners of ConocoPhillips involved in their operations can use the internal telephone to reach offshore personnel or someone onshore. Video conferencing is possible in all rooms and centers, and handheld cameras are available offshore to communicate contextual knowledge to support personnel onshore. Centers range from directly operational centers, like the onshore drilling center or the onshore operation center, to centers for planning,

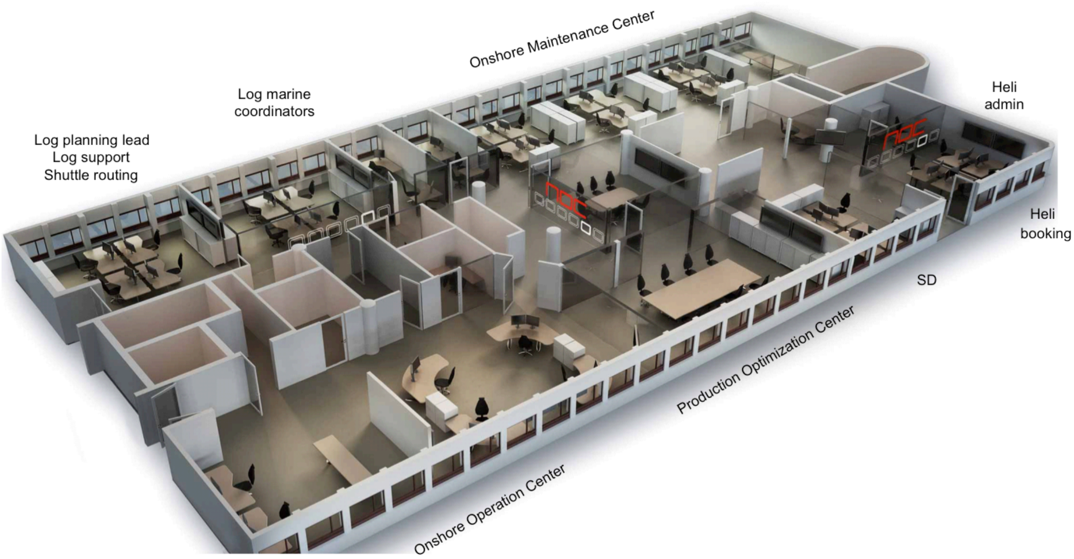

Figure 4-2 A small part of ConocoPhillips' Norway Operations Center. Courtesy of ConocoPhillips.

maintenance, modifications, and logistics. All the centers are located strategically to resemble the actual work process, as seen in Figure 4-2, hence one can start at one center and walk around with the clock and go through the whole work process from logistics, helicopter booking, maintenance, production optimization, and operation center. And everything is bound together with a sophisticated integrated work management system with integrated planning at the core.

Team structures

Team structures are integrated across functions and disciplines during drilling operations and integrated across onshore and offshore in ConocoPhillips. Teams consist of people from many service companies and are diverse groups. Teams are located onshore and offshore, in addition to the US at times. Through communication solutions mentioned above teams have the strong inter-organizational ties and communication pathways to collaborate across time and location.

Relationship perception

Changing perception of service companies is one of the important steps in developing collaborative operating environments and enhances value creation. This is because of benefits of increased trust, easier coordination, communication, and decentralization of decision authority. ConocoPhillips have done quite a good effort and has been able to convey the message to service companies that they are full partners. However, changing this perception also involves risks for ConocoPhillips because they transfer more decision authority and important operational functions over to their service partners. It was also said by one of the service companies that preferences exist some places in ConocoPhillips and some opposition was experienced at times toward the service company.

Integrated work practices

New work practices are also vital for successful implementation of collaborative operating environments. It is no use in developing tools, centers, and teams if the new changes are not embedded in how people do their work. ConocoPhillips now involve several disciplines integrated in cross-functional work practices. In addition, CODIO will provide integrated work practice compliance.

Knowledge integration

Some interesting work on knowledge integration is carried out in ConocoPhillips for knowledge integration in the whole collaborative drilling environment – a virtual Onshore Drilling Center. In this virtual drilling center an avatar[12] represents every person involved in drilling projects where one can access information about this person, like experiences and specialties. Other solutions for knowledge integration is small thematic events where service partners and ConocoPhillips themselves presents new knowledge, challenges, plans, etc. called "Lunch learning". These get positive feedback from service partners. However, there are no larger training events or socializing events involving all the collaborative drilling environment partners. Through the new development of CODIO social networks of experts are also created where collaboration is done through problem wall posts, sharing of multimedia, and instant messaging. This is a great arena for socialization

[12] An avatar is an icon or figure representing a particular person in computer games, Internet forums, etc.

and development of transactive memory, gaining mutual understanding, and share contextual knowledge.

Collaborative decision support tools

As mentioned above, one of ConocoPhillips' large sub-projects in their collaborative operating environments initiative is creating and implementing a *collaborative decision tool* for drilling projects – Collaborative Drilling in IO (CODIO). This tool will contribute towards reaching a transformational level of collaborative operating environment. As Vindasius [18] say visualization and data integration are two important elements to consider and master in order to realize more value, and these two elements are thoroughly addressed through CODIO. In addition, CODIO will also be able to propose a solution based on decision models, data, and knowledge.

4.2 Status quo: Collaborative partners

Service companies are an important part of ConocoPhillip's and any operators field operations in today's modern business and operational environment.

Results from observations and interviews

Implementation of centers and facilities

When service companies are considered implementation of centers and facilities is not developed as far in the service companies as ConocoPhillips have managed to accomplish. However, it might not be beneficial to develop stand-alone centers at the service companies' own office locations for all kinds of functions, because it could hinder business socialization and contribute negatively towards developing a partner perception. On the other hand, two of the service companies answered that working from their own centers worked fine by using collaboration rooms and video

Table 4-2 Summary of observation of and interviews with ConocoPhillips

Category	ConocoPhillips
Centers and facilities	Completely transformed organizational layout into centers.
Team structures	Virtual, cross functional and multi disciplinary
Relationship perception	All service companies are partners
Work practices	
Knowledge integration	Small thematic events – "Lunch learning" – arranged now and then. Cross-functional and organizational problem solving sessions and lessons learned sessions.
Decision support tools	Are about to implement CODIO
Employee satisfaction	View service company employees as ConocoPhillips employees
Belief in COE	This is definitely the future. A lot of management support and investments.

conferencing in business socialization and problem solving. But still, this can contributes towards an "us and they" mentality. It must be mentioned that one of the companies experienced both situations; first using a fully integrated center at their own location, then later moving into ConocoPhillips' locations in Tananger. Their remarks was that it worked perfectly in an operational setting to collaborate across large distances by means of ICT, but they felt more like a part of the core and got another relationship when they moved into ConocoPhillips' location.

Team structures

Team structures are virtual, multi-disciplinary, and cross-functional for all companies. All of the companies communicate and perform problem solving with personnel offshore and across other dispersed locations. However, interviews uncover that communication using video conferencing or other means presents some challenges between offshore and onshore. It was reported that mutual understanding and trust was a challenge. And onshore personnel was more aware of the benefits of using collaborative operating environments, while offshore personnel at times was more reserved to the solution. These are challenges that need to be addressed, and some similarities with the BP case in Chapter 3 can be seen. In order to get effective and productive virtual teams all have to share a belief that collaborative operating environments is the future and get an ownership to the new operational model. In addition, offshore personnel need to get the same mutual understanding of the benefits of collaborative operating environments, and understand the value of "virtuality" and support from onshore experts.

The decision environment was investigated in one of the questions in the case study, and showed some interesting findings. According to the literature review on virtual teams it was claimed that in order for virtual teams to become highly successful decisions had to become decentralized, and a collective leadership should replace single-leader command and control structure. Which would imply that service companies would be a part of the collective leadership. This is not the case most of the time in ConocoPhillips' drilling projects, where ConocoPhillips' drilling engineers and drilling supervisors have the main decision authority while the service companies only provide advise. For example, a well planner cannot abort a drilling operation, but can advise the drilling engineer to take the decision to abort.

Relationship perception

Relationship perception was one of the most valuable metrics in this case study and was a qualitative measure of integration and socialization in the collaborative drilling environment, as well as a measure of partnership health. And all interviews showed the same result; service companies felt more or less like partners rather than providers. This can also be put together with *employee satisfaction*, which was very high in all the companies in this case study. The professionals interviewed said the same; at ConocoPhillips everyone is welcomed as if they were ConocoPhillips employees. One of the persons interviewed said:

> *"Nobody at ConocoPhillips' offices, neither service company or operator, talk down to you because you are a service company employee. They don't give orders, they rather ask for help, discuss, and small talk."*

This is a very interesting and positive feedback, and is a proof that changing the relationship perception in this collaborative environment makes people more comfortable and prone to collaboration. On the other hand, a very small percentage of the people interviewed said that they still regarded themselves as providers or suppliers of a service, showing some "us and they" mentality. These were mainly senior employees. Another interesting observation was that service companies are taking over quality assurance tasks, controlling both ConocoPhillips and other service companies. Hence, this bare witness about a high level of trust in the service company from ConocoPhillips.

Integrated work processes and decision support tools

New work processes seem to be implemented in all of the companies, and work processes are multi-disciplinary and cross-functional. This introduces a high level of complexity and should be supported by advanced collaborative decision support tools, which can support work process compliance and decision coordination. Only one of the companies reported that they are working on a decision tool to support collaboration. However, this indicates that service companies see the potential in developing these tools. To cope with the increasing complexity of integrated work processes and virtual teams it is inevitable to develop and implement such solutions.

Integrated work processes are a part of the service companies today. But integrated work processes should be developed to foster more collaboration between the service companies, and tear down the wall between service companies and the reluctance to come to another service company and ask for help. This has been seen

Knowledge integration

During the interviews and observations no specific knowledge integration measures were seen at any of the service companies in terms of application solutions. However, all the companies are collaborating in problem solving which is an excellent arena for knowledge integration. Yet, these problem-solving sessions is only occurring when challenges arise and can at times be frequent and some times rather infrequent. As a consequence measures should be taken to create an application solution for socialization and knowledge integration where professionals can develop the necessary transactive memory.

Capability matching and objectives alignment

Two metrics can be used to measure an inter-organizational relationship: capability matching, and objectives alignment. Capability matching is how well company A's capabilities match company B's in terms of how well technologically and organizationally developed they are. Objectives alignment refers to how company A's objectives match the objectives of a focal company's or network's objectives. Three alternatives were available for these two metrics: complementary, competing, or indifferent.

When the service companies were asked to determine which one of these three characterized the collaborative drilling environment in terms of capability matching and objectives alignment, all said complementary. This implies that service companies are performing services that ConocoPhillips have completely outsourced, and do not perform themselves. If ConocoPhillips and a service company had a competing capability matching they would both perform a certain service. This can indicate that ConocoPhillips have come a long way in integrating service companies into their operations, and that these companies are granted a high level of trust.

Table 4-3 Summary of interviews and observations of collaborative partners

Category	Company A	Company B	Company C
Centers and facilities	Have set up their own onshore drilling center	Are located in ConocoPhillips' drilling center	Are located in ConocoPhillips' drilling center
Team structures	Virtual. Onshore and offshore personnel.		Virtual. Onshore and offshore personnel. Night shifts can be taken from the US.
Relationship perception	80/20 Partner/provider	70/30 Partner/provider	70/30 Partner/provider
Work practices	Integrated	Integrated	Integrated
Knowledge integration	No specific initiatives for knowledge integration. Developing a knowledge repository.	No specific initiatives for knowledge integration.	Small thematic events – "Lunch learning" – arranged now and then. Participate in problem solving.
Decision support tools	No specific tools available right now, but the knowledge repository will get a search function to look at previous experiences.	No specific tools.	Have some tools to optimize plans. New collaborative decision tool under development.
Employee satisfaction	Very satisfied with working with ConocoPhillips. Feel like ConocoPhillips employees. Are invited to large events.	Very satisfied with working with ConocoPhillips. Feel like ConocoPhillips employees. Are invited to large events. Have full access to all employee benefits.	Very satisfied with working with ConocoPhillips. Feel like ConocoPhillips employees. Are invited to large events. Have full access to all employee benefits.
Belief in COE	This is the future. Use the technologies a lot.	This is the future. COE defines the work function performed.	This is the future. Use the technologies a lot in monitor mode.
Access to facilities	Has full access to all facilities. Has all means of ConocoPhillips internal communication available.	Has full access to all facilities. Has all means of ConocoPhillips internal communication available.	Has full access to all facilities. Has all means of ConocoPhillips internal communication available. There exists a security level system to access project data.
Capability matching	Complementary	Complementary	Complementary
Objectives alignment	Complementary	Complementary	Complementary
Incentive systems	Day rates for a functional service	Day rates for 24/7 team	Day rates for team

The fact that objectives alignment was set to complementary indicates that ConocoPhillips has a large market power over the service companies, and that service companies would sacrifice a lot to have the same objectives as ConocoPhillips. As one of the interviewed persons said:

> *"If ConocoPhillips asked us to get them to the moon, we would do everything in our power to get them there. Of course we would sacrifice a lot to satisfy them, we want to "*

Incentive systems

In Section 2.2 it was indicated that to be able to develop a second generation and transformational collaborative operating environment, it is necessary to tailor a new incentive system that provides an equal sharing of risks and benefits. During the observations and interviews it was possible to determine what incentive system the service companies were hired on.

Two companies provide a functional service, and were performing a completely outsourced service for ConocoPhillips. Company A had bonus incentives for reaching the planned performance targets, and extra bonuses for exceeding the planned performance targets. Company B had a contract where they had to provide a team of professionals to be present at ConocoPhillips' onshore facilities. Company C's onshore tam was performing a support function, and only produced advice when negative situations developed. This company also had to provide a team of professionals with around the clock availability.

4.3 Level of collaborative operating environments

Based on interviews, observations, and papers the level of implementation of collaborative operating environments can be estimated. ConocoPhillips are providing much of the facilities for collaborative operating environments for Company B and Company C, while Company A provides much of the facilities themselves. First, if Vindasius' model is considered (ref. Section 2.1) all companies are definitely past the "Field of Dreams" scenario, proven by the shared belief that collaborative operating environments are the future operating model, and the new tools and work practices are used extensively in all companies. Actually Company B's function is a consequence of the change of operating model.

All service companies have implemented advanced communication capabilities to make coordination and communication between offshore and onshore easy and effective. Hence, a foundational level of implementation definitely exists. Information and data is widely integrated between all companies from the offshore installations and from different projects. However, there exists a security level system (level 1-10) to be able to access data and information on every drilling project, which is often relevant for exploration wells or tight wells. This is a constraint to move on to a transformational level of implementation. Nevertheless, access to information can be considered very open.

During the interviews and observations autonomous and smart alarm systems to filter invaluable and valuable information and data was not observed in a large scale. But visualization of information in 2D, 3D, and other formats had taken some important and valuable steps. During drilling projects numerous key performance indicators were observed on large projected screens and on personal computers, well paths were projected as well as observed in real time on large screens in 2D and 3D. This is a step towards a transformational level. Then, to reach a transformational level real time collaborative decision tools have to be implemented, and these are on their way as we speak both from one of the service companies and from ConocoPhillips (CODIO).

To conclude, Company A and B are now on a comprehensive implementation level and will have to work on collaborative decision tools and knowledge integration to take further steps toward a transformational level. Company C is also on a comprehensible level of implementation but is making some serious efforts in creating a collaborative decision support tool to make further steps, but will have to work on knowledge integration, as well as develop and integrate their own operational centers for drilling operations at ConocoPhillips. ConocoPhillips are beyond a comprehensible level of implementation and are heading in the correct direction by implementing the Collaborative Drilling in Integrated Operations (CODIO) tool and keep on developing their virtual reality tool used to locate experts and personnel when needed.

If the model from OLF is considered one can definitely say that ConocoPhillips' collaborative operating environment is moving towards generation 2. Integration between the onshore and offshore organization within ConocoPhillips has been ongoing for a long time and has been successful. Implementation of centers at service companies have started and integration of service companies into the operational organization is definitely ongoing and has come a long way, as can be justified by the transformation from a provider to a partner perspective on service companies and the level of trust some of the service companies have gained already. Some of the key operational processes has been outsourced to service companies, which involves a great deal of risk for ConocoPhillips, while at the same time the incentive scheme is moving to a functional service, where risks and opportunities are more equally shared and a win-win situation can be established.

4.4 Improvement potentials in ConocoPhillips' collaborative drilling environment

Implementation of centers

The difference in implementation level between operator and service companies is the most evident performance gap. However, this gap is not very large but is seen mainly in the implementation of centers and facilities, and development of strong inter-organizational ties with other collaborative drilling environment members than ConocoPhillips. With regards to development of company specific centers it might not be advisable to initiate a large-scale implementation and reengineering of centers at service company locations. A few factors affect this. First, service companies often are actively involved in operations with other operators. When a person from a service company sits at ConocoPhillips' center this person is less likely to engage in activities with other operators. If a service company has their own centers that serve more operators, it might impair the closeness and "betweenness" centrality of ConocoPhillips because it is easier to engage in activities with other operators and ConocoPhillips could easily be down prioritized.

Second, the scale of operations and type of service offered also affects if service companies should create centers. If the service company performs a large-scale functional service, e.g. drilling, it might be advisable to create their own drilling center to support their drilling operations. Then the drilling contractor can create their own support centers, e.g. maintenance and logistics, which can communicate with the relevant center at the operator. However, if the functional service is small or the service is purely a support function (e.g. simulation) service companies could preferably be situated in the operator's own centers.

However, as mentioned in Section 4.2 creation of company specific centers might hinder business socialization and create an "us and they" mentality.

Collaborative decision support tools

Development and implementation of collaborative decision support tools have come a long way in ConocoPhillips and Company C. The other companies have not developed any specific decision support tools. Decision support tools can take the collaborative drilling environment one step further to enhance decision quality and coordination, as well as enhance the knowledge integration. Thus, all companies should develop and implement a decision support tool. In order for decision support tools to be a success a suitable interface must be created between different decision support tools, or companies should share a decision support tool. ConocoPhillip's drilling decision support tools can integrate several companies at the same time, and is a very suitable tool to be shared between several companies.

However, the scope of involvement and services a company takes on could play an important role. For example, a drilling contractor is responsible for delivering a borehole for an operator, thus having the responsibility for maintenance and operations of the drilling rig. A service of this scope could justify that the drilling contractor develop its own decision support tool, to incorporate all of its own lessons learned and knowledge created and acquired during operations from different customers. On the other hand, a service company that has a support role could not justify developing a separate decision support tool. For example a company that monitors and simulates fluid properties in the borehole is not dependent on having a sophisticated decision support tool, but it could be valuable to be a part of an operator's decision support tool in order to comment on challenges and notify all participants about a negative trend.

Improvement potential in knowledge integration

To achieve value creation through collaborative operating environments it is important to achieve knowledge integration in the virtual teams. Everybody cannot know everything, but should know where to find the knowledge. And everybody should have a certain basic understanding of different disciplines. Problem solving is one great social arena where knowledge integration can occur, and problem solving involving many different experts and companies is an important part of ConocoPhillip's collaborative drilling environment. There does not seem to exist some kind of "yellow pages" or similar applications to locate experts with a specific knowledge or specialty in the companies, and locating an expert relies on personal relations or that an expert is located within the team.

Especially because several companies are involved in the collaborative drilling environment knowledge integration between companies, functions, and disciplines is very important to access and capitalize on the distributed knowledge available in a large network of experts within all companies involved. And there is a large potential in integrating knowledge and applying it in problem solving in ConocoPhillips' collaborative drilling environment.

A last more technical part of knowledge integration is to create a large and robust knowledge repository to access previous lessons learned. For example, if a situation is starting to develop it is valuable to be able to easily access what have been done in similar situations before and what the outcome was, for making the best decision now. One service company was working on such a knowledge repository to collect reports on incidents, lessons learned, project reports, and other valuable documentation. Such a solution can be integrated into decision support systems as a knowledge base. ConocoPhillips is also developing such a solution as a part of their Collaborative drilling in IO (CODIO) initiative. However, all companies should have such a user-friendly knowledge repository as a part of their knowledge integration strategy.

Potential in creating strong inter-organizational ties between service companies

Observations and interviews identified that service companies were collaborating together in the collaborative drilling environment without ConocoPhillips involved, in spite of being competitors. Still this collaboration was only in a small scale. However, when service companies collaborate it gives autonomy to the collaborative environment, and gives access to a larger base of distributed knowledge for the service companies involved.

In order to enhance collaboration between service companies stronger ties should be created between service companies, and service companies should be strongly encouraged to collaborate with other service companies. Some challenges are introduced when strong ties are created between service companies. Lowered "betweenness" centrality for ConocoPhillips can induce a power asymmetry in the collaborative drilling environment. Protecting intellectual property can also become an issue that needs to be resolved to make collaboration possible.

Virtual team challenges – building relationships

Teams are distributed between offshore and onshore locations, and communication between offshore and onshore occurs trough video conferencing quite often, or through phone calls. Someone that experienced performing a function from an offshore location first, but was later moved onshore, highlighted that communication between offshore and onshore personnel was at times a challenge. There can be several reasons for this. First is a lack of mutual understanding about the benefits of support from onshore experts. Offshore personnel might not see the benefit because they do not believe that someone sitting hundreds of kilometers away onshore can understand what is wrong offshore. Second is a difficulty in building relationships and trust. When the person moved onshore and into ConocoPhillips' locations it was much easier to build stronger relationships between professionals and get that mutual understanding and high level of trust needed to perform well in a team.

Partner perception

Changing partner perception has come a long way in the collaborative drilling environment at ConocoPhillips. Service company employees feel as a part of ConocoPhillips' own staff. Communication is information based and informal, and everybody has access to data, information, and facilities. However, this perception change has to take place in all parts of the collaborative operating environment, and a high level of trust should be established. None of the service companies asked indicated a full partner perception, which is also indicated through a power asymmetry and a relatively centralized decision authority. Nonetheless, ConocoPhillips have through interviews indicated a higher level of partner perception than the service companies, and it is actually the service providers that have to further work on changing the relationship perception from provider to partner. Creating a stronger ownership to ConocoPhillips' operations to become even more integrated might be the key to be able to move into ConocoPhillips' drilling environment to grow into a higher level of collaborative operating environment.

Chapter 5
Recommendations for future development

5.1 Change perception

The importance of changing perception from provider to partner has been elaborated in this thesis. It was also one of the areas of investigation during the case study of ConocoPhillips and its collaborative drilling environment, giving some valuable information on how service partners are perceived by ConocoPhillips and how service partners perceive themselves in the collaborative drilling environment. As a consequence an improvement potential was identified showing a need for increased awareness and future effort in fueling the change of perception from service company to service partner.

One of the proposals for changing the perception within the collaborative drilling environment is to increase socialization efforts among service partners and operator. To do this common goals and ownership has to be created towards the collaborative drilling environment, for example through awareness campaigns and joint social and training events. Especially socialization between the onshore and offshore workers should have high priority. Such social and training events could be done through virtual solutions for video conferencing to include both offshore and onshore. For example, the "Lunch learning" events should be broadcasted on the platforms as well as in the premises onshore. Another proposal is to foster the traditional "coffee corner chat", and also include the offshore coffee corner. A video screen and a camera should be put up in a coffee corner at the onshore facility in Tananger and the same in the offshore coffee corner that broadcasts all the time. This might invoke social interactions between the offshore and onshore facilities and personnel in an informal setting, and bring the two organizations together not only in problem solving and during operations but also in a pure social context.

5.2 Create a framework for generating personal collaborative relationships

In the previous chapter it was identified that it was difficult to establish valuable relationships between onshore and offshore personnel in virtual settings, for example in a videoconference meeting. In order to accomplish valuable collaboration between functions, disciplines, and locations trust and good relationships need to be developed. As identified in the example from the oil and gas industry in Chapter 3, coaching and virtual meeting training should be carried out across all collaborative partners from time to time to create a solid foundation for collaboration and an understanding of the benefits of virtual collaboration. Maybe creating a coaching team as suggested by Mueller et al. [13] that can organize and follow up virtual teams can be one good solution to close the gap between traditional face-to-face and virtual interactions.

Another solution can be to have a sort of rotation of personnel, so that onshore support personnel can get the possibility to create a mutual understanding and contextual knowledge, as well as closer relationships with offshore personnel. Lastly, Toyota has managed to create an exceptional supplier network, where small and large events are held to foster experience transfer between suppliers and a chance to socialize and create personal relationships across disciplines, functions and organizations. Organizing such events for all collaborative partners, both onshore and offshore, should be initiated. Today there exist "lunch and learn" events at ConocoPhillips' onshore offices, which can be a good starting point for expanding to include offshore and other distributed locations as well.

5.3 Develop and integrate innovative collaborative applications

It has been discussed in several sections the importance of developing collaborative decision support tools and integrated work processes in order to evolve into a transformational second generation collaborative operating environment, and realize the potential of enhanced value creation.

Collaborative applications can be a solution to several of the identified challenges. First, a collaborative application can provide work process compliance by integrating roles, responsibilities, and processes in an ICT system that supports coordination and communication between different participants in a certain process. And this system has to be accessible by all partners of the collaborative operating environment to provide transparency and make it easy to follow the workflow at all times. Hence, it makes it easy for partners to know what to do next and who is responsible for doing it. When collaborative environments get large and complex, like ConocoPhillips' drilling environment, integration of disciplines and functional areas are key for success, and an application solution that provides coordination of large work processes has a large value creating potential. For example, when planning a well several functions and disciplines are involved. Well planners are responsible for making the well trajectory and plan, but need support from reservoir engineers responsible for production to optimize well location. Directional drillers might have some comments to optimize the well trajectory, and the drilling contractor knows about the limitations of their equipment. In other words, an integrated work process is extremely complex. Because experts and professionals are dispersed, an effective social network communication solution should be in place to make it easy to include the right people at the right time without delays.

Second, a collaborative application should include a decision support tool or an expert system that can give advise on best solutions, in a combination between existing explicit knowledge from a knowledge repository, and tacit knowledge from experts. A collaborative application like this will need to have a smooth interface between the different modules.

If a drilling team comes to a situation where fluid properties are developing in the wrong direction, they should be able to access previous events with similar characteristics and see what solution was selected then and what the outcome of that decision was. And the team should be able to do problem solving in the application by communicating and sharing pictures, videos, audio, and other contextual knowledge. During the problem solving, team members should be able to plot different solutions into a decision model to get a recommended solution to implement.

Third, it should be able to simulate and visualize the different solutions in real time as the problem solving session goes on.

Such a collaborative application is under development in ConocoPhillips – called CODIO or collaborative drilling in integrated operations – that incorporates all these functions more or less [43, 45].

5.4 Develop stronger ties between service companies

Collaboration between ConocoPhillips and service companies in the collaborative drilling environment is a frequent activity. However, collaboration between service companies happens much more infrequent. This represents a value creating potential. If service providers would collaborate and access a wider network of distributed knowledge, value creating would positively benefit from it.

Service companies are often strong competitors and is reluctant to help or collaborative with other service providers. Again the Toyota Case in Section 3.4 give a good example on how to overcome the challenge of making competing suppliers collaborate to enhance value creation.

First, to motivate service companies to share tacit knowledge and collaborate more in problem solving on their own initiative, one needs to create a common goal and a common purpose behind collaboration. Maybe ConocoPhillips have to force or strongly encourage service companies to collaborate in the start to make them realize there are more benefits to be realized from sharing tacit knowledge and collaborate in problem solving, than safeguard their knowledge and keep it only to themselves.

Second, to make sure no “blind passengers” are getting the benefits in being a part of such a collaborative partnership with other service companies without contributing anything, a legally binding contract could be signed giving ConocoPhillips the right to punish service companies that only exploits the collaborative partnership. Service companies would probably not share their product specifications, but can share of their experiences and tacit knowledge.

5.5 Enhance knowledge integration between collaborative partners

Knowledge integration has been identified as a key element in knowledge application in collaborative operating environments (ref. Section 2.3). In Section 4.4 it was identified that there existed an improvement potential for knowledge integration in ConocoPhillips’ collaborative drilling environment. Knowledge integration was the synthesis of distributed experts’ tacit knowledge into a situation specific knowledge for the challenge at hand. But an important element of knowledge integration was to know who knows what – transactive memory – which relies on personal relationships and socialization. Another element was mutual understanding, or sharing the same language, terms, and having an idea about several disciplines without being a specialist.

Training and learning events between organizations should be encouraged to create a common socializing arena where professionals can meet from all partner organizations to share experiences, challenges, plans, and knowledge. It has been mentioned earlier as a recommendation for further development to create such socializing arenas.

Another suggestion to enhance the transactive memory of ConocoPhillips’ collaborative drilling environment is to create a ConocoPhillips Operational “Facebook” to establish weak inter-organizational ties, and where it is easy to search for a specific specialty or competence and get a list of names within the collaborative partners that can be included in a virtual team to support problem solving. Applications like this already exist in many companies without being used actively, for example in Microsoft Share Point Server.

Chapter 6
Discussion

Not a lot has been done in the past looking at what is decisive for value creation in collaborative operating environments as a whole. Many subjects have been researched for decades and good theories exist, but collaborative operating environments is a compound topic involving all these subjects. However, this thesis have highlighted some of the important performance drivers from theory on inter-organizational relationships, organizational teams, distributed knowledge management, decision support in complex operating environments, and integrated work processes.

The case study is only a qualitative study of an existing collaborative operating environment, and should be put more emphasis on in further studies and quantitative results should be produced. The group interview method used worked unexpectedly well, and can be recommended for later studies and interviews. It was easier to get access to the employees' real feelings and opinions when two to four persons were discussing in a group, and the group showed more enthusiasm than when a single person was interviewed. On the other hand, if the group was large some of the interview subjects got excluded and just sat down in a corner to observe.

Objectives alignment was improperly measured in the case study and gave no significant results. In further research it is recommended to investigate the metric objectives alignments more thoroughly for it to make a valuable contribution. When considering a customer – supplier relationship as in this thesis it is evident that the supplier in this case aligns their objectives with the customer to receive these extremely valuable contracts.

Lastly, incentive systems was a part of the case study, but was however difficult to identify. The interviewed personnel from two of the service companies did not have detailed knowledge of contract strategy and incentive systems in the inter-organizational relationship with ConocoPhillips.

Recommendations for future work

The subject of value creation in collaborative operating environments is a large subject with many interesting areas of research. However, this thesis has only been able to investigate a small section of the complete subject. Especially the case study has only investigated the operator-service partner relationship from the perspective of the onshore personnel. A future research proposal was to conduct a large-scale case study including both the onshore and offshore environments with interviews and observations would grant valuable knowledge on how the relationship between operator and service partner affects value creation in collaborative operating environments.

Another subject of interest could be to investigate the conditions for when a service company should create their own onshore support centers and when they should locate themselves at the operators own centers. For example how does scale of service and function affect whether a service company should create their own center.

One of the most interesting subjects to research would be to look at value creation in collaborative operating environments form a service company to service company point of view. During the case study it was discovered that service companies was moving in the direction of putting competition with other service companies aside, and replace it with collaboration instead. This could possibly be the next novel solution to realizing more value potentials from collaborative operating environments.

In future research on the area of collaborative operating environments, one should look into the incentive systems used to enhance value creation, motivate service companies to share tacit knowledge, and create more collaboration and strong ties between service companies.

Chapter 7
Conclusion

The aim of this thesis was to identify drivers of value creation in collaborative operating environments, identify existing gaps and improvement potentials in the business relationship between operator and service companies in collaborative operating environments, and propose solutions to close these gaps.

Learning from available literature, lessons learned and experiences from different industry examples completed objective one. In Chapter 2 possible drivers of value creation in collaborative operating environments were identified and investigated through literature: business-to-business networks, virtual teams, distributed knowledge management systems, integrated work processes, and collaborative decision support. In addition, a review of best practices and lessons learned in Chapter 3 gave many good examples of collaborative operating environments in other industries, and recommended solutions to solve different challenges was presented. Industries selected was military, space, oil and gas, and automotive. The learning from industry examples and literature, and case study showed that knowledge integration in virtual teams and collaborative decision support tools can make large contributions to realizing value potentials. It is also shown that collaborative operating environments is a value creating effort that enhances HSE, lowers costs, and optimizes operations through better decisions.

To look at a real collaborative operating environment a case study was conducted in Chapter 4. This case study looked on the relationship between ConocoPhillips – a major operator – and their collaborative partners in drilling projects. The case study concluded that ConocoPhillips were the primary node of their collaborative drilling environment, and the form of network governance was a modular value chain, possibly a relational value chain (ref. Gereffi's governance model in Section 2.2.1). In addition, most of the inter-organizational ties between ConocoPhillips and the three service partners investigated consisted of strong cohesive ties.

It was also discovered through the case study that one of the drivers of value creation in these drilling projects was the level of trust between service companies, and between service companies and ConocoPhillips. There existed different levels of trust, and one of the service companies (with longest partnership history) even got the task to perform quality assurance of work done by ConocoPhillips and other service companies, which is a sign of great trust. Another interesting observation was that even though most service companies were competitors, they collaborated in problem solving as partners. It was said by one of the interview subjects from one of the service companies:

> *"We are very glad when other service companies get their jobs done successfully, and ConocoPhillips don't loose money"*

It shows that integration has come a long way in ConocoPhillips' collaborative drilling environment, and the level of implementation is moving towards generation two and transformational (ref. OLF's and Vindasius' model in Section 2.1). Other indications of this transition are that operations from the onshore centers are now on a 24/7 basis, and centers are becoming highly integrated across functions, disciplines, and organizations.

Difference in partner versus provider point of view and the importance of changing from a provider to a partner point of view was also stressed early on. The case study concluded that also this indicator of changed operational model showed that ConocoPhillips have come a long way in their implementation and reengineering. All service companies felt like one of ConocoPhillips' own employees, and the "us and they" perception was not very present. A high level of job satisfaction by all twelve-interview subjects also confirmed this.

Maybe one can say that today companies compete on having the best possible product and service solution, but in the future softer characteristics are valued more; like trust, partnership history, quality, complementary capabilities, common values and goals, etc.

The decision environment was investigated in one of the questions in the case study, and showed some interesting findings. According to the literature review on virtual teams it was claimed that in order for virtual teams to become highly successful decisions had to become decentralized, and a collective leadership should take the place of single-leader command and control structure. Which would imply that service companies would be a part of the collective leadership. Here lies an improvement potential in ConocoPhillips' drilling projects, where ConocoPhillips' drilling engineers and drilling supervisors have the main decision authority while the service companies only provide advise in most cases.

Several recommendations for future development were proposed, and event though addressing multiple issues, the most important recommendation is to create arenas for business socialization among partners of the collaborative drilling environment. Another recommendation was to develop and implement collaborative operations applications for decision support and work process compliance.

Bibliography

1. Gereffi, G., J. Humphrey, and T. Sturgeon, *The governance of global value chains.* Review of International Political Economy, 2005. **12**(1): p. 27.
2. Oljedirektoratet, *Petroleumsressursene på norsk kontinentalsokkel 2011*, Oljedirektoratet, Editor 2011, Oljedirektoratet: Stavanger.
3. Oljemuseum, N. *Kulturminne Ekofisk*. Kulturminne Ekofisk [cited 2012 6 June 2012]; Available from: http://www.kulturminne-ekofisk.no/.
4. Oljeindustriens Landsforening (OLF), *eDrift - det tredje effektiviseringsspranget*, 2003, Oljeindustriens Landsforening.
5. The Norwegian Oil and Energy Ministry, *White Paper No. 38 On Petroleum Activity*, D.K. Olje-og-Energidepartement, Editor 2003-2004: Oslo.
6. Liyanage, J.P., M. Herbert, and J. Harestad, *Smart Integrated eOperations for High-Risk and Technologically Complex Assets: Operational Networks and Collaborative Partnerships in the Digital Environment*, in *Supply Chain Management: Issues in the New Era of Collaboration and Competition*, W.Y.C. Wang, M.S.H. Heng, and P.Y.K. Chau, Editors. 2007, Idea Group Inc. p. 387-414.
7. Oljeindustriens Landsforening (OLF), *Verdipotensialet for Integrerte Operasjoner på Norsk Sokkel*, 2006, Oljeindustriens Landsforening (OLF): Stavanger.
8. Oljeindustriens Landsforening (OLF), *Oppdatert verdipotensiale for integrerte operasjoner på norsk sokkel*, 2007, Oljeindustriens Landsforening (OLF): Stavanger.
9. National Aeronautics and Space Administration (NASA). *NASA Images.* [cited 2012 26th of February]; Available from: http://www.nasaimages.org/.
10. Bughin, J. and M. Chui *The rise of the networked enterprise: Web 2.0 finds its payday* McKinsey Quarterly, 2010.
11. Meinich, B.H., *BP's Field of the Future in Norway*, B. Petroleum, Editor, British Petroleum.
12. Tyberø, P., B. Allen, and J.T. Helgesen, *Controlling Cement Operations from an Onshore Operation Center SPE/IADC 92344*, in *SPE/IADC Drilling Conference*2005, SPE/IADC: Amsterdam, The Netherlands. p. 6.
13. Mueller, K., C. McClelland, and A. Anvar, *The Role of Human Factors Integration and Change Management Coaching in Integrating Multidisciplinary Teams Working in Collaborative Work Environments SPE 128616*, in *SPE Intelligent Energy Conference*

*and Exhibition*2010, Society of Petroleum Engineers: Utrecht, The Netherlands. p. 5.

14. Aspaas, K., *Dear Lady Algorithm (Kjære frøken algoritme)*, in *Aftenposten (web edition)*2012, Aftenposten.
15. Liyanage, J.P. and E. Bjerkebaek, *Use of advanced technologies and information solutions for North Sea offshore assets: Ambitious changes and Socio-technical dimensions.* International Journal of International Technology and Information Management, 2007. **15**(4): p. 1-10.
16. Liyanage, J.P., *Rapid Virtual Enterprising to Manage Complex and High-Risk Assets*, in *Encyclopedia of Networked and Virtual Organizations*, G.D. Putnik and M.M. Cruz-Cunha, Editors. 2008, Business Science Review: Hayden, PA, USA. p. 697-704.
17. Oljeindustriens Landsforening (OLF), *Integrated Work Processes: Future work processes on the Norwegian Continental Shelf*, S.G.I. Operations, Editor 2005, Oljeindustriens Landsforening (OLF): Stavanger. p. 29.
18. Vindasius, J., *The Integrated Collaboration Environment as a Platform for New Ways of Working: Lesson Learned from Recent Projects*, in *SPE Intelligent Energy Conference and Exhibition*2008, Society of Petroleum Engineers (SPE): Amsterdam, The Netherlands. p. 10.
19. Mundim, A.P.R., A. Rossi, and A. Stocchetti, *SMEs in Global Market: Challenges, Opportunities and Threats.* Brazilian Electronic Journal of Economics, 2000. **3**(1).
20. Siebel, P., *Virtuelle Unternehmen: Eine Zusammenfassung*, in *Workshop Virtualitt als Wettbewerbsfaktor,*1997, Universität Bern: Bern.
21. Innovation Norway. *An ambitious programme.* [cited 2012 02.03.2012]; Available from: http://www.nce.no.
22. Vik, A., *NODE: Unity through collaboration*, in *Petronews*2011, Petro Media AS: Stavanger, Norway.
23. Kongsberg, N.S.E., *Annual Report*, 2011, NCE Systems Engineering Kongsberg: Kongsberg.
24. Ale Ebrahim, N., S. Ahmed, and Z. Taha, *Virtual Teams: a Literature Review.* Australian Journal of Basic and Applied Sciences, 2009. **3**(3): p. 16.
25. Thompson, K., *The Networked Enterprise: Competing for the Future Through Virtual Network Enterprises.* 1st ed. ed2008, Tampa, FL, USA: Meghan-Kiffer Press.
26. McGuinness, T., *Markets and Managerial Hierarchies*, in *Markets, Hierarchies, and Networks*, G. Thompson, et al., Editors. 1994, SAGE Publications Ltd: London.
27. Gulati, R., D.A. Dialdin, and L. Wang, *Organizational Networks*, in *The Blackwell companion to organizations*, J.A.C. Baum, Editor 2002, Blackwell Business: Malden, Mass. p. XXXI, 957 s.
28. Newman, M.E.J., *A measure of betweenness centrality based on random walks*, 2003, University of Michigan: Ann Arbor, MI 48109–1120.
29. Hansen, M., *The search-transfer problem: The role of weak ties in sharing knowledge across organization subunits.* Administrative Science Quarterly, 1999. **44**: p. 83–111.
30. Jones, C., W.S. Hesterly, and S.P. Borgatti, *A General Theory of Network Governance: Exchange Conditions and Social Mechanisms.* Academy of Management Review, 1997. **22**(4).

31. Thompson, K., *Bioteams: How to create high performance terams and virtual groups based on nature's most successful designs*. 1st ed2008, Tampa, FL, USA: Meghan-Kiffer Press.
32. Ahuja, M.K. and J.E. Galvin, *Socialization in virtual groups*. Journal of Management, 2001. **29**(2): p. 1-25.
33. Bergiel, B.J., E.B. Bergiel, and P.W. Balsmeier, *Nature of virtual teams: a summary of their advantages and disadvantages*. Management Research News, 2008. **31**(2): p. 99-110.
34. Katzy, B.R. and G. Schuh, *The Virtual Enterprise*, in *Handbook of Life Cycle Engineering: Concepts, Methods and Tools*, A. Molina, J.M. Sanchez, and A. Kusiak, Editors. 1997, Chapman & Hall: New York.
35. Queen's University *Life-size, 3D hologram-like telepods may revolutionize videoconferencing*. 2012.
36. Broder, J.M. *BP Shortcuts Led to Gulf Oil Spill, Report Says*. New York Times, 2011.
37. Washington Post, *BP oil spill cleanup and containment*, 2011.
38. Alavi, M. and A. Tiwana, *Knowledge Integration in Virtual Teams: The Potential Role of KMS*. Journal of the American Society for Information Science and Technology, 2002. **53**(12): p. 1029-37.
39. Dwyer, J.P., et al., *Real-Time Connectivity and the Potential Benefits to Appalachian Operations*, in *SPE Eastern Regional/AAPG Eastern Section Joint Meeting*2008, Society of Petroleum Engineers (SPE): Pittsburgh, Pennsylvania, USA. p. 9.
40. Dyer, J.H. and K. Nobeoka, *Creating and Manageing a High-Performance Knowledge-Sharing Network: The Toyota Case*. Strategic Management Journal, 2000. **21**: p. 345-367.
41. Liyanage, J.P., *Hybrid Intelligence through Business Socialization and Networking: Managing Complexities in the Digital Era*, in *Handbook of Research on Business Social Networking: Organizational, Managerial, and Technological Dimensions*, E. Carter, Editor 2012, Business Science Reference: Hershey, PA, USA. p. 567-582.
42. Huang, J.C. and S. Newell, *Knowledge integration processes and dynamics within the context of cross-functional projects*. International Journal of Project Management, 2003. **21**(2003): p. 167-176.
43. Fjellheim, R.A., R.B. Bratvold, and M. Herbert, *CODIO - Collaborative Decisionmaking in Integrated Operations*, in *SPE Intelligent Energy Conference and Exhibition*2008, Society of Petroleum Engineers (SPE): Amsterdam, The Netherlands.
44. Schick, A.G., L.A. Gordon, and S. Haka, *Information overload: A temporal approach*. Accounting, Organizations and Society, 1990. **15**(3): p. 199-220.
45. Fjellheim, R.A., *CODIO - Decision and Planning System for Drilling*, Computas, Editor 2011: Stavanger.
46. Aven, T., *Risk analysis: assessing uncertainties beyond expected values and probabilities*2008, Chichester, England: Wiley. x, 194 s.
47. Bai, Y. and J.P. Liyanage, *Framework and systematic functional criteria for integrated work processes in complex assets: a case study on integrated planning in offshore oil and gas production industry*. International Journal of Strategic Engineering Asset Management, 2012. **1**(1): p. 49-68.
48. Howley, T.J., *Collaborative Operations*, 2001, The MITRE Corporation: Bedford, Massachusetts.

49. Cohen, D., *Knowing the drill: Virtual teamwork at BP*, in *Perspectives in Business Innovation*1998. p. 14-19.
50. SustainValue. *Sustainable Value Creation in Manufacturing Networks*. 2011 [cited 2012 17.03]; Available from: http://www.sustainvalue.eu/index.htm.
51. Downie, R.D., *Defining Integrated Operations*. Joint Force Quarterly, 2005. **38**(3rd Quarter 2005): p. 10-13.
52. Keller, R.M., et al. *Collaborative systems for NASA science, engineering, and mission operations*. in *Collaboration Technologies and Systems (CTS), 2011 International Conference on*. 2011.
53. Gilstrap, R., *Lessons Learned: Science & Exploration Activities in Remote Field Locations*, 2010, National Aeroneutical and Space Agency (NASA).
54. Petro Strategies, I. *World's Largest Oil and Gas Companies*. 2010 14.5.2012 [cited 2012 25.5]; Available from: http://www.petrostrategies.org/Links/worlds_largest_oil_and_gas_companies.htm.
55. Oljedirektoratet, *Fakta 2011*, J. Ødegård Hansen, S. Berg Verlo, and E. Zenker, Editors. 2011, Oljedirektoratet
Det Kongelige Norske Olje- og Energi departement: Stavanger.
56. Oljemuseum, N. *Oppjekking er et faktum*. Kulturminne Ekofisk [cited 2012 6 June 2012]; Available from: http://www.kulturminne-ekofisk.no/modules/module_123/templates/ekofisk_publisher_template_category_2.asp?strParams=8%233%23788l773l748%23864&iCategoryId=463&iInfoId=454&iContentMenuRootId=1445&strMenuRootName=&iSelectedMenuItemId=1445&iMin=719&iMax=764.

Appendix A Interview guidelines

Investigate level of integration between service company and operator
• Access to facilities • Access to information and data • Team structures • Roles and responsibilities
Investigate how the decision environment and work practices are
• Authority • Autonomy • Decision support • Integration Work Practices
Investigate relationship characteristics
• Partners vs. providers perception • Employee satisfaction • Capability matching (complementary, equal, independent) • Objectives matching (complementary, competing, independent) • Partnership health (inter-partner learning, trust, partnership history)