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MASTER'S THESIS

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Preface (i)

This master thesis reviews today’s ROV technology and operational ROV setup. Through future scenario theory an operational scenario with the new empowered ROV (eROV) has been imagined. This includes a seabed structure of hubs/charging stations to accommodate such operational model. The eROV is controlled from an onshore and perform all ROV tasks within its geographical area. Towing the eROV from one location to a new worksite has been used to demonstrate a future operation with the eROV working independently without a supporting vessel at all times.

The thesis started to unfold several weeks after a technical meeting with supervisor Trond Eriksen at the Company (Statoil) in September 2016 regarding “Future ROV Operations”. After a face-to-face meeting and one phone meeting a “mind map” was made to structure ideas and to focus on being creative moving the thesis forward. The starting point was to investigate different technologies searching and reading ROV related scientific articles, relating this to a personal view on what is needed and will be demanded in the future. A draft of the Project Description was sent through for pre-acceptance to the University of Stavanger on the 31st of January 2016.

On the 2nd of February 2017 the annual FFU (Forening For Undervannsteknologi) Conference at Clarion Hotel Air, Sola was attended. The topic was Subsea Evolution, focusing on the changes in the market and the technological evolution. Part of the program was ROV Remote Piloting and the introduction to the prototype of the “Eelume – can it change the ROV industry?”. This seminar was interesting and relevant for this thesis. The FFU seminar was attended once again on the 25th of January 2018. This year’s topic was sustainability, i.e. sustainable ROV inspections and digitalizing ROV operations. Oceaneering’s Onshore Control Center (OCC) and the Total Martin Linge Central Control Room (CCR) were visited, in addition to a breakfast seminar for the eROV at Oceaneering on the 9th of November 2017.

It has been very interesting and educational to research what is ahead of the oil and gas industry when it comes to ROV technology.

A special thanks to Supervisor Trond Eriksen (Company), Ole Steinar Andersen (Company), and Professor Jayantha P. Liyanage at the University of Stavanger who have been very supportive during the research period.

In addition, I would like to thank all other personnel and colleagues working within the subsea industry who have provided the author with useful and relevant information.

Stavanger, February 2018

Erik Bråten

Abstract (ii)

The oil and gas industry is rapidly changing. The oil price is fluctuating and there has currently been an excess of personnel. Today's Remote Operated Vehicle (ROV) operations are demanding and costly, requiring a support vessel at all times. As subsea assets are aging, the need for inspection and new technology at a lower cost is increasing.

The specific problem for this thesis was to:

- Challenge today’s operations setup and mindset of ROV operation and look into future Resident ROV (RROV) / Autonomous Underwater Vehicle (AUV) and Empowered ROV (eROV) operations.
- Demonstrate possible economic benefit by adapting to new concepts and new technologies (business driven innovation).

New technologies such as Resident ROV (RROV) and Empowered ROV (eROV) are currently introduced and under development. The main feature of this technology is that it allows for remote piloting from an Onshore Control Center (OCC). There appears to be a paradigm change in which the ROV and the industry is becoming more and more electrified and autonomous. Comparison is made to other industries such as the aviation and automobile industry. In the latter, there is a powertrain shift moving to hybrids and electric vehicles. Key words in this new paradigm are “autonomous”, “resident” and “electric” (ref. FFU conference 2017).

This master thesis investigates ROV operations and the state of the art technology that is currently available. It outlines how the Company’s operations are planned and executed today and details new ROV technology under development. The thesis also reviews the Company’s resources available and estimates cost of establishing and running an Onshore Control Center (OCC).

As a theoretical basis, the master thesis uses Integrated (remote) Operations, Digitalization trends, Sharing Economy and Cost Effectiveness, Scenario Thinking and Dynamic resources and capabilities.

Today’s operations are planned manually. It requires a surface support vessel at all times due to the umbilical connected to the ROV. The ROV is controlled locally from the vessel. These operations are costly and gives limited flexibility.

An incentive for removing the umbilical - ROV working independently - has been going on for decades.

New developing technology allows signals to be transferred via fiber or using telecommunications, which opens up for controlling the ROV from an OCC. An OCC will give more flexibility because one ROV crew can control several ROVs at different locations subsea. This gives operational benefits.

Until ROVs in the future are fully autonomous (long term future scenario), a supporting vessel is required to move the eROV from one location to the other. The thesis uses towing as a concept to put the new eROV technology into an “operational context” in order to maximize use of the eROV concept.

Future operations also require a subsea infrastructure with hubs/docking stations to recharge the eROV and gain access to tooling etc. Until an infrastructure is fully established, relocation of the eROV from one location to another should be looked into in more detail - to optimize operations. Better planning and sharing of resources could lead to a more sustainable business model. This thesis shows that it is feasible to use towing as a method to relocate the ROV if the eROV concept is fully introduced and developed.

During the study the importance of people, processes and governance appeared - rather than just focusing on new technology. In order to succeed implementing new technology it is important that man, technology and organisation are connected and that collaboration is recognized.

If the cost assumptions in this thesis are correct, and if sharing of other support vessels/optimized operations is viable, the eROV concept could be a more sustainable business model. A certain number of ROV hours are needed to get the hourly ROV rate down as it is very costly to run an OCC around the clock (24 hours a day, 7 days a week).

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Abbreviations

Abbreviation	Description
AHTS	Anchor Handling Tug Supply (vessel)
AHV	Anchor Handling Vessel
AML	Arbeidsmiljøloven (Working Environment Act)
BEV	Battery Electric Vehicle
BGO	Bergen
CAPEX	Capital Expenditure
CCR Technician	Central Control Room Technician (Total)
Company	The organization (oil company) studied in this thesis
Contractor	IMR vessel supplier/ ROV supplier such as Subsea 7, Technip, Deep Ocean
Co2	Carbon Dioxide
CP readings	Cathodic Potential readings
DCC	Document Control Center
DNV GL	Det Norske Veritas Germanischer Lloyd
DMA	Dead Man Anchor
EJR	End Job Reports
eROV	Empowered ROV (Remote Operated underwater Vehicle)
FE	Field Engineer
FFU	Forening For Undervannsteknologi
FTP server	File Transfer Protocol Server
GR	General Requirement
HPU	Hydraulic Power Unit
HSE	Health Safety Environment
IMR	Inspection Maintenance and Repair
IO	Integrated Operations
IOC	Integrated Operational Center
ITS	Intelligent Transportation System
Kwh	KiloWatt Hours
LARS	Launch and recovery System
LCI	Life Cycle Information
MaaS	Mobility as a Service
NCS	Norwegian Continental Shelf
NG	Next Generation
OBS-ROV	Observation ROV
OCC	Onshore/Operational Control Center
OCV	Offshore Construction Vessel
OFI	Opportunities for Improvement
OIM	Offshore Installation Manager
OLF	Norsk Olje og Gass (earlier Oljeindustriens LandsForening
OM	Offshore Manager (same as Offshore Installation Manager and vice versa
OPEX	Operational Expenditure
PE	Project Engineer

PIMS	Project Interface Management System (Omega AS)
PSV	Platform Support Vessel
Remote Piloting	ROV pilot located in a typical onshore Operational Control Center, controlling ROV remotely and Subsea at any location by use of data and video transfer
ROV	Remote Operated Underwater Vehicle
RROV	Resident Remote Operated Underwater Vehicle
RTD	Research Technology and Development
SR	Specific Requirement
STID	The Company Technical Information Database
SS	Shift Supervisor
SURF	Subsea Installations, Umbilical, Riser and Flowline
TaaS	Transportation as a Service
Te	Metric Ton
TRL	Technology Readiness Level
UID	Underwater Intervention Drone
VTMIS	Vessel Transport Management Information System
WI	Work Instruction
WP	Work Package
WP	Work Process
WROV	Work Class Remote Operated Underwater Vehicle
4G LTE	Fourth-generation Long Term Evolution

Terminology

Value network consists of organizations (companies) cooperating with each other to benefit all network members. In manufacturing industries lead producer and its suppliers and customers form a typical value network. Values are principles or standards of behavior. (Sustainvalue.eu, 2013)

Subsea USB - The company Blue Logic has named the product “Subsea USB”, which, according to the company, should not be mistaken with a conventional USB interface that you have on your PC. Both interfaces transfers electrical power and data communication simultaneously in the same socket. One of the major benefits of the Blue Logic Inductive Subsea USB Connector system is the ability to also transform voltage through the interface allowing for many different types of sensors or consumers to be connected subsea regardless of voltage requirements. (subseaworldnews.com, 2018) / (bluelogic.no, 2017)

1. INTRODUCTION

1.1. Thesis Background

The petroleum industry is the largest industry in Norway. Norway is the 8th largest producer of oil and the 3rd largest producer of gas in the world (norskpetroleum.no, 2018). The second largest industry in Norway is the supplier and service industry with over 1100 companies involved, measured in turnover (norskpetroleum.no, 2018).

The industry started in the early 1960's with Phillips Petroleum (snl.no, 2018). With over 50 years of operations Norway has gained international acknowledgement for its expertise and technological development in the industry.

In the early days large platforms were built. In order to be more cost efficient, more and more fields have been developed as subsea infrastructures. Subsea assets are tied-in to existing fields. In general, the different assets are categorized and referred to as topside or subsea assets.

The subsea cost challenge is that profitability has been under pressure. One of the initiatives taken to ease this pressure is standardization of building blocks. A concept called the "Subsea Factory" has been introduced by the Company such as Asgard Subsea Compression Project. This project is based on standardizing building blocks to lower costs.

All ROV operations subsea requires a vessel, if the ROV is not controlled from topside (platform). This means that all offshore operations subsea require a vessel and an ROV spread onboard. The large oil operators typically have an IMR vessel frame agreement to perform ROV work on asset 24/7.

Today most industrial ROV operations are manually controlled with little and almost no control functions and autonomy. Some small inspection ROVs have been manufactured with limited autonomy. A typical ROV setup is a rig or vessel with an ROV spread onboard, including control container/control room and ROV crew (operators) onboard vessel/rig.

1.2. Problem / Challenge

The major problem in the subsea industry is the general increase in subsea costs (Sintef.no, 2017). A part of this is the cost of ROV operations. The number of subsea fields increases and gets older. The outlook is that the subsea cost is increasing globally. In general, there is a subsea cost challenge. Summary of global E&P expenditure for 2014 was $ 50 billions and are estimated to be $ 100 billions in 2019. (Sum of Subsea Services (IMR), SURF and Subsea Equipment (manifolds, XT, Valves etc.) (Sintef.no, 2014)

With respect to current conditions, some of the major questions related to developing ROV concepts for the future are:

- Can we challenge the way we are thinking about ROV operations combined with new technology?
- Can today's ROV operations be more efficient and predictable/optimized by use of common control room onshore (remote piloting) combined with new ROV technology?
- What is required to make these new technology concepts operational and is it possible to demonstrate economical benefit introducing new technology?
- Can the technology driven innovation lead us to think differently of how we run our business today?
- What if we use the resources and technology differently; can we utilize the ROVs better, at a lower cost and at the same time reduce the environmental impact?

The new technology does not have any value if it is not put in a value network and can be utilized operationally.

The above issues were very central in exploring suitable concepts related to future of ROVs. They provided a practical basis in defining the Thesis project.

1.3. Objective

The objective of this thesis is to explore the future of ROV operations and to investigate if such future ROV operations, using remote operations, can be more cost efficient than today's operations. Through identifying Company's currently available resources and future required resources the objective has been to evaluate the Company's capability to adapt to new operational solutions and new technology.

The specific objective for this master thesis is to:

- Challenge today's operations setup and mindset of ROV operation and look into future RROV/AUV/eROV operations.
- Demonstrate possible economic benefit by adapting to new concepts and new technologies (business driven innovation).

Based on the above the specific project tasks are described as:

- Subtask 1: Review todays ROV technology and technology under development.
- Subtask 2: Develop/Elaborate on possible ROV of the future concepts based on current conditions and trends

1.4. Methodology

To structure all thoughts and ideas a literature review has been performed for this study. The literature review consists of two parts. Firstly, to find relevant theory basis and secondly, to identify and review the Company's resources (capabilities), state of the art technology and developing technology.

Information has been gathered through literature studies. Relevant information has been structured after discussions with industry personnel, and meetings with personnel involved in today’s planning of the IMR operations have been undertaken. An industry conference and a breakfast seminar was attended, but the main information has been gathered through informal meetings/emails and peer reviews with industry personnel/colleagues. Information, knowledge and competence (experience) has also been gained from working in the subsea industry over the 10 last years.

Company has provided the planned number of annual subsea asset ROV inspection hours and this has been used as the basis for ROV hours in the feasibility section.

1.5. Assumptions

For the business case/feasibility study a few assumptions have been made:

- A “Subsea USB” will be available in the future subsea infrastructure. This is an interchangeable connector which transfers electric and hydraulic power. This assumption was agreed with Company in the start of the project. Associated with assumption is a standardization of “Subsea USB” connectors for the future when connecting auxiliary assets to existing subsea assets.
- The eROV concept will be available. This is based on that in the future ROV will work more independently without the umbilical. Trends such as push from the industry and technology move in this direction.
- Infrastructure, i.e. electrical power, to support charging stations will be available as nodes in a subsea pattern, especially in areas with high ROV activity. As the eROV concept above is based on battery technology it is essential for a solid operational model to have a well planned and built infrastructure subsea. For example, the Company could use its size and influence to establish a network of subsea charging stations similar to the automobile industry’s charging infrastructure for electric cars.

1.6. Limitations

The following section describes the limitations and identifies areas not completed in the study:

- The first limitation is related to simulation of the (PSV) vessels in a fixed pattern. In the section for optimization and calculations for towing of the eROV, the original plan was to use historical data for these simulations and get more exact data simulations. Access to real time data for Company vessels on charter (access to VTMIS) was requested but data was evaluated to be too sensitive by the Company. For the vessel path optimization section the closest field or known location is used for setting up the business case and estimating towing distances and time.

- The second limitation is related to operational costs of the vessels and the Onshore Control Center. Access to the Company’s contracts for the vessels and the ROV services was never requested. Therefore cost figures in this thesis are based on best guess estimates.
- The third limitation listed is related to estimated number of ROV hours for the Company that can be performed with an eROV, meaning no support required from a vessel for lifting/tooling operations. With this data available a more exact cost picture could have been estimated. Expected or estimated total number of hours including other ROV operations that do not require lift operations or support vessels was requested, but remains unknown. Calculation in the business case is therefore based on the known hours for planned work given by the Company. Calculations with additional “ad-hoc hours” are therefore based on simple figures of additional hours in order to demonstrate and drive the hourly operating cost down for the remote piloting and the eROV concept. More information on this is found in Appendix III and in the discussion in chapter 5.

1.7. Structure of Thesis

The main content of this thesis consists of 12 chapters, including the appendices and this introductory chapter.

The introduction chapter outlines the thesis background and the main challenge. The thesis is structured according to its two main challenges:

- Challenge today’s operations setup and mindset of ROV operation and look into future RROV/AUV/eROV operations.
- Demonstrate possible economic benefit by adapting to new concepts and new technologies (business driven innovation).

The theory review aims to cover relevant theories, including technology. It was also seen as highly relevant to look into currently available resources within the Company in order to work smarter and to better utilize resources internally.

Chapter 2 contains the literature study performed in this thesis. It covers relevant theory and provides an introduction to the Company. Also included in this section are the resources supporting the overall offshore operations such as Company Marine & Logistic and the Company Subsea Tool Pool (sharing of tooling among different subsea fields).

State of the art technology and current operational setup for the Company is detailed, including the IMR operational work processes. The chapter ends with details of the IMR operations and offshore vessel organizations during execution of IMR operations.

Chapter 3 presents next generation technology, operations and future scenarios.

The RROV, Remote Piloting and the eROV concept is outlined. Brief details on test trials performed are included including the Technology Readiness Level (TRL).

Next generation operations details ideas for digitalization of planning and future improvements for better workflows through digitalization. It also contains an introduction to the “ROV Planner”, a cloud based ROV Planning Management tool used to optimize planning and execution of IMR (ROV) operations.

Path planning and optimisation ideas for towing are elaborated on. The chapter details support functions and the possibility to optimize PSV and other vessels to relocate the eROV from one location to another.

Concepts of required subsea infrastructure (areas) with battery pack for storage of energy and relocation of the eROV thru either subsea towing or recovery by liftline to vessel deck are also covered.

Multiple options to make a vessel suitable for towing of the eROV is detailed before the chapter moves into future scenarios for operations.

Three different future scenarios are described. The thesis selects scenario II as relevant case and expands on this in the feasibility analysis section.

Chapter 4 includes a cost feasibility study by using the 2017 planned Subsea Assets ROV inspection hours as a basis for an operations model with a setup of an OCC.

Chapter 5 evaluates system capabilities and recommendations.

It details why there will be a change to electric ROVs and identifies the constraints. The environmental aspect and the resource capabilities are detailed.

A new business model and the need for digitalization is discussed. A new business model canvas details a new business model running operations from an Onshore Control Center. The layers in a Capability Stack is presented together with the evaluation and definition of the resources needed for a new operation context. A cloud based ROV planning tool is proposed to optimize operations.

Chapter 6 gives a brief reflection of own work and recommendations for further work.

Chapter 7 contains the overall conclusion. The chapter presents the cost of annual inspection with an IMR vessel compared with cost using new business model (future scenario II). The calculation shows that an increase of the number of ROV hours significantly impacts the total cost picture.

Appendix I: Subsea Asset Annual ROV inspection estimates 2017. Includes the inspection estimates given by Company per geographical area.

Appendix II: Information workflow diagrams, current and future. Describes the current workflow for planning and execution of IMR operations and an optimized future workflow diagram using a cloud-based planning tool (ROV Planner).

Appendix III: ROV cost estimates for area 5, including towing cost. The appendix contains cost estimate sheets where the inspection of area 5 have been looked into in detail, including towing of the eROV from one location to recharge station (hub) to simulate a operational scenario using the eROV.

Appendix IV: Extracts and screenshots from ROV Planner Tool. Appendix IV presents some ideas and screenshots for what the ROV planning tool could look like and its functions, for illustration purposes only.

Appendix V: A list of all currently available vessels supporting marine operations, as provided by the Company.

2. LITERATURE AND THEORY REVIEW

2.1. Background

For the past three years the oil and gas industry in Norway has experienced an extremely challenging time and laid off thousands of people. Figures given in the media estimate that over 25 000 jobs have been lost. From 2010 to 2014 oil prices were stable at just above $100 per barrel. At the time of writing, a barrel of oil has a value of approximately $60.

The recent decline in the oil price has been driven by multiple factors: several years of upward surprises in the production of unconventional oil; weakening global demand; a significant shift in OPEC policy; unwinding of some geopolitical risks; and an appreciation of the U.S. dollar (Baffes, John, et al, 2015).

Low oil prices and estimated increase in subsea costs in combination with new technology provides the background to improve or change today's operational setup for IMR operations.

Time was spent to find the most relevant topics leading to a holistic theory review. Future operations include the digitalization trends (IoT) that are happening in society combined with the sharing and cost-effective view of operations/business models. As the new ROV technology involves remote operations, Integrated Operations (IO) theory was studied. Scenario thinking theory was chosen to learn more about how to better prepare for the future and look from the outside and in. This was combined with studying the importance of resources and capabilities available for the Company and those required for future operations.

2.2. Chapter Overview

The reason for this literature review is to place the theory and the overall available technology, resources and organization including the operations in a larger picture.

This chapter is divided into two parts. The first part describes the theoretical basis and the second subchapter describes the Company's available resources and the state of the art technology including IMR operations.

2.3. Theoretical Basis

2.3.1. Integrated (Remote) Operations

Within the oil and gas industry the term Integrated Operations (IO) are mostly thought of as onshore control centers to support offshore operations. The operational center allows offshore and onshore staff to work closer together, sharing screens and data through collaboration with multidisciplinary teams and no geographical limitations.

OLF has defined the term IO as "real time data onshore from offshore fields and new integrated work processes". (OLF, 2007).

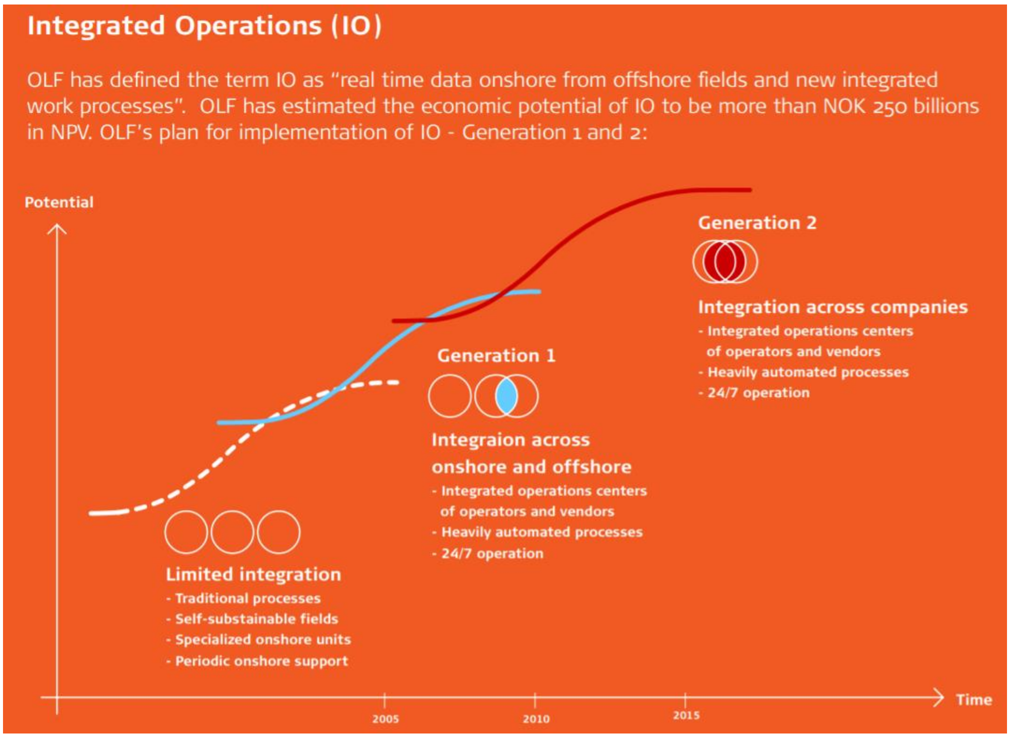


Figure 1 – OLF Integrated Operations - existing and future practices (Source; https://www.norskoljeogass.no/PageFiles/14295/070919%20IO%20and%20Ontology%20-%20Brosjyre.pdf?epslanguage=no)

Integrated Operations will most likely dominate more and more in the future as part of a new way of doing business. Note from the figure above the Generation 2 is described an "integration across companies". Having the right people at the right time available for 24/7 operations becomes more important as technology allows to do so. For the oil and gas industry this means having a team onshore team supporting offshore operations. Technology advancement makes it possible to use, transfer and analyse data to increase efficiency, to be more competitive and to increase profits. Theory also argues that it improves HSE and reduces risk.

Times are changing, new terms such as Internet of Things (IoT) and Digitalization becomes part of any business. The terms are technology related, but Integrated Operations are not only about technology. It has other dimensions, and these are; people, processes, technology and governance, according to Rosendahl T. & Hepsø V. (2013 preface p. xxi).

The introduction of IO has impacted organizational conditions through localization of more workplaces onshore, workplace design, guiding documentation, and human factors such as workload, stress, teamwork and choice of working methods. (Stene, Trine M. 2016 p.20)

In the book “Integrated Operations in the Oil and Gas industry, Sustainability and Capability Development” (Rosendahl T. & Hepsø V., 2013 p. 1) the authors argue that that the development of the capabilities is something that happens inside an “ecology”. The authors (ibid. preface p. xx) describe “capability” as the “combined capacity and ability to plan and execute in accordance with business objectives through a designed combination of human skills, work processes, organizational change and technology”. They also address the importance of a capability approach for Integrated Operations and how it can improve our understanding of how people, process, technology and governance issues are connected and managed to create scalable and sustainable practices (ibid preface p. xxii). Technology in a capability platform is an enabling device for people, process and governance. On its own, technology seldom drives value (ibid, p.5).

There are two approaches towards optimizing operations to improve learning and performance. Over the years, different views have been shared that technology is more important than people and processes and vice versa. In order to improve Integrated Operations and to make the all the dimensions work better together there are two main methodologies:

1. “The Process approach” focuses on the work-flows. This means a more traditional process approach based on “as is”, thinking from the inside to the outside.

2. “The Capability approach” is a “to be” approach, starting from the outside moving towards the inside, based on the thought that innovation and change normally starts from the outside and in.

A capability platform consists of 5 basic layers (ibid, p.9). It represents a system of complexity and can be used for large organisations to gain a holistic approach:

1. Technology resource layer
2. An intelligent infrastructure
3. Information and collaboration layer
4. Knowledge sharing and analytic layer
5. A business operations layer

All these layers are seen as an ecology. Different companies play different roles, and as the market changes some companies are more dominant than others. If the integrated operations are to work optimally these layers need to work together.

Another theory that supports focus on human factors when implementing the IO is a method called “Integrated Operations Man – Technology – Organisation” (IO MTO). This is a tool for changing an organisational model. It is based on three steps with a clear vision, strategy and goal as part of the initial strategy. The steps are:

- Data gathering and categorization of functions
- Function allocation and Work Process modeling
- Consequence analysis

The first step is identification of possibilities, i.e. identification of existing functions and work activities. The organisational model is laid out through function allocation and work process modelling (job categories and design of new work processes). In the final step, the consequence analysis, consequences are identified and evaluated through third-party verification ensuring that work process models and HSE are accounted for. Working through these steps will be helpful to the management decision and implementation itself. In this process the change management is ongoing at all times.

The main intention behind the method “has been to gradually cover all aspects involved in systematic change of an MTO system along with its sub-systems and processes (including work processes intensively involving human and organization factors), so that the new organization of the system is prepared for IO. The IO MTO method has already proven to be very powerful in detailed function analysis (including data gathering and categorization of functions) and function (re)allocation, as it has been employed in a considerable number of projects within the petroleum industry”. (Thunem Atoosa P-J, et al. , 2009 p. 2/5)

2.3.2. Digitalization Trends

Digitalization is a megatrend. Most companies worldwide are affected in one way or another, and it involves investments that require tradeoffs to limit spendings and still achieve growth.

Digitalization is “the use of digital technologies to change a business model and provide new revenue and value-producing opportunities; it is the process of moving to a digital business” (Gartner, 2018). Digitalization allows us to work smarter and more efficiently. It could provide a safer work environment and a greener workplace. Sensors can give input to systems to improve maintenance, and cloud solutions can give easy access to documents and sharing of documents/data. As an example, better decisions can be made by an engineering team by using real time video signals transferred from an ROV for immediate analysis. This could also mean improved outcomes for subsea operations as a whole.

The author Jan Eivind Danielsen argues that though digitalization it is possible to reduce accidents, simplify management and compliance. Data can be used smart and shared via databases. Cost of storing data has become inexpensive. He also argues that business models could be challenged through digitalisation (Danielsen, Jan E., 2017)

The digital change can be found everywhere and revolutionizes the entire value creation chain. New innovative products and business models are being developed. Companies are forced to think over their strategies completely (Valentina Ignat, 2017).

It is also debated how this digitalization makes the supply chain more agile and efficient. Today supply chains tend to work in silos; digitalization makes all processes more transparent.

According to the Norwegian business newspaper Dagens Næringsliv, Statoil will spend between one and two billion NOK on digitalization projects by 2020. A new data center will save 10 billion NOK for the company through eliminating platform production issues, help to remove bottlenecks thereby increasing the theoretical production capacity, and strengthen the company's preventive maintenance by earlier identification of potential failures on critical in equipment to avoid production interruptions and stop of production (Ånestad, M., 2017). The approach is not to only use external IT resources but to use internal resources through interdisciplinary collaboration and integrated teams.

It is therefore important to have a clear digital strategy that outlines how new technology should be considered, planned and developed.

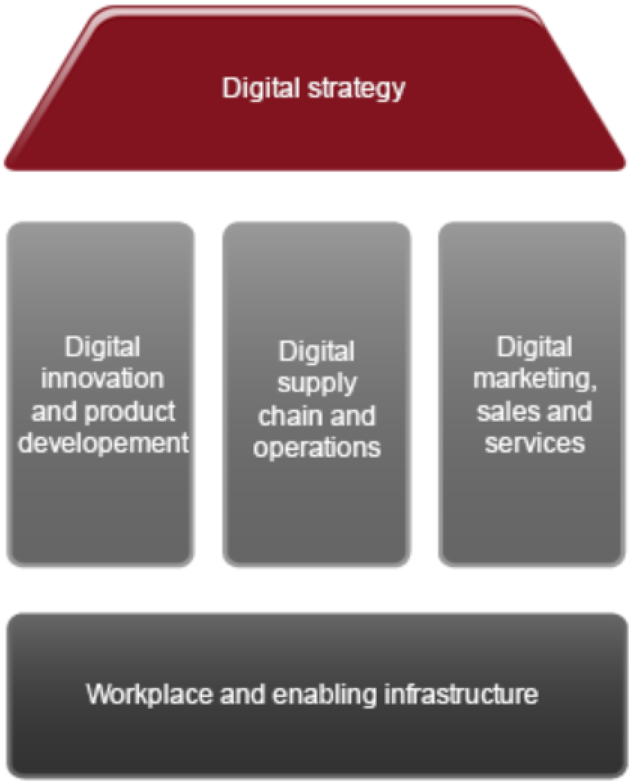


Figure 2 – Digital Strategy (pwc.com, 2017) (Source; https://www.strategyand.pwc.com/global/home/what-we-think/digitization/digital-strategy-capabilities)

2.3.3. Sharing Economy and Cost Effectiveness

The sharing economy is currently widely debated in the media. The most known sharing economy companies are Airbnb and Uber. Both companies challenge traditional business models through new IT platforms, which results in more efficient ways of working and easy access for clients to their services. Airbnb provides accommodation through a new online business model. Uber has challenged the traditional taxi services. The company also develops autonomous systems for automobiles and has recently signed a contract with Volvo cars.

Behind new sharing experiences such as Uber and Airbnb, data centers and network infrastructure is making business possible through online transactions. Information technology is affecting old traditional business models and IT becomes the important basic platform for the business. Resources are used on-demand avoiding models set up for handling peak situations, enabling sharing of resources and cost reduction. Theoretically both OPEX and CAPEX should be lower. In addition, it allows for a scalable “on demand use” of staff and equipment involved in the operations.

Uber’s Transportational Business Model is shown below:

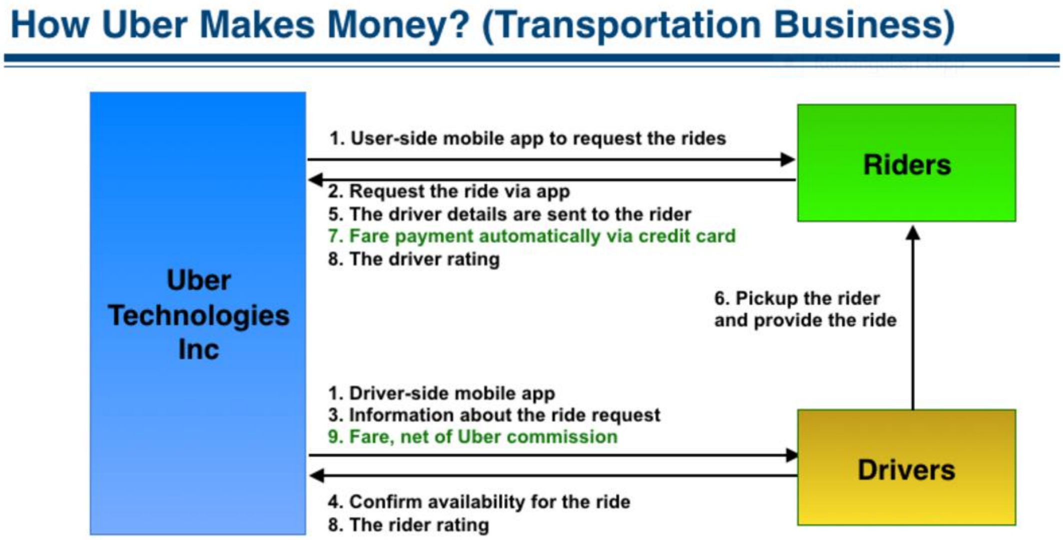


Figure 3 – Uber Business Model Schematic (revenueandprofits.com, 2017) (Source; https://revenuesandprofits.com/how-uber-makes-money-understanding-uber-business-model/)

Other concepts such as Maas and TaaS (Mobility as a Service and Transportation as a Service) describe the shift away from personally owned models over to more sustainable mobility solutions. These concepts are based on consumers needs (on demand) rather than owning and having an individual solution at all times.

The downturn in the oil and gas industry has led all levels of the value chain to focus on cost effectiveness. New technical concepts are being developed, and companies are constantly trying to cut cost and work smarter. Alliances are being developed to work smarter together. “The Subsea Alliance” (AkerBP, AkerSolutions and Subsea 7) is one example, where companies work closely together, using online collaboration tools and shared IT platforms.

2.3.4. Scenario Thinking Theory

Scenario thinking theory can be used to best estimate what the Company’s future will look like. Traditional thinking is that the future will be similar to recent past. In the short picture this is likely to be true, but most likely not in the long run.

Scenario Planning is a strategic tool – to identify critical future uncertainties and to investigate blind spots in the organization (Kahane, 1999). The oil and gas company

Shell has had a Scenario Team since 1970 and uses it to prepare for multiple futures and to make better decisions. In an analysis and planning definitions and outcome variables, Chermack and Lyhham, (2002, p. 343) defined scenario planning as “a process of positing several informed, plausible and imagined alternative future environments in which decisions about the future may be played out, for the purpose changing current thinking, improving decision making enhancing human and organizational learning and improving performance”.

Over a longer period, current trends will not hold due to unforeseen events or step changes in technologies or regulations are changed. Michael Porter defines scenario planning as an internally consistent view of what the future might turn out to be (Michael Porter, 1985). It is important to understand that scenario thinking should not be mixed with forecasting a single future; the point is rather to encourage divergent thinking about what could plausibly be the future to achieve a better outcome for the business.

Multiple scenarios are laid out for the organization to better prepare for the future. Identifying what is needed today to prepare for the future for the future is vital. An organisation that is better prepared for the future will most likely handle the future better and make decisions with a better outcome. Another aspect of scenario planning is that it can challenge more analytical calculations, which could be positive (Erik F. Øverland, Erik Larsen, 2014).

Scenario planning is not only a planning instrument, but also a learning tool. Industry, technology or consumer scenarios can guide R&D, business or product development. Scenarios may function both as inspiration for generating idea and as filters through which new ideas and projects can be passed (Lindgren M. and Banhold H., 2009) Development of paradigm-challenging strategies requires the integration of high-level strategic thinking and a strong emphasis on futures thinking (Lindgren M. and Banhold H., 2009).

One of the basic principles in scenario thinking is to think in terms of futures (scenarios). Theory argues that is is more creative to use the approach “from future to present” vs. the “from present to future” approach. Scenario planning can be used to prepare for the future of ROV operations. Currently in the ROV and subsea industry there is uncertainty in the future powertrain of ROVs, and the extent of autonomous technology. It can therefore be used a part of the strategic thinking and planning for the future. This is elaborated on in Chapter 3 of this thesis which looks into several future scenarios for ROV operations.

2.3.5. Dynamic Resources and Capabilities

The concept of of dynamic resources and capabilities was founded by Jay Barney, professor at the Ohio State University. Resource Based View (RBV) of a company focuses on how an organization can combine its resources to gain a competitive advantage (Barney, 1991). The theory argues that dynamic resources and capabilities are key drivers for competitive advantage and profitability. The main objective of Barner’s strategy is to create a sustainable competitive advantage. He argues that there are four main characteristics (VRIO) that need to be in place in order to obtain this advantage:

- Value, the resource must add value
- Rare, the resources are for others hard to adopt (doing business differently, differentiation)
- Imitable (hard/costly to copy). Could also be patented.
- Organizational (organized/exploited)

In short, the theory is that with valuable and rare resources and capabilities, companies have a competitive advantage. In addition, internal resources need to be exploited in a smart and efficient way.

The VRIO is a framework to assess strengths and can be helpful identifying areas that need to be improved (Barney, J., 1991). These strengths will define the core competencies in the company and should be included in the strategy moving forward.

2.4. Status Quo: Introduction to Company and available resources, State of the Art ROV Technology & IMR operations

2.4.1. Introduction to Company and Available Resources

The Company is a large energy-based company called Statoil ASA. Its headquarter is in Stavanger, Norway. It is represented in approximately 36 countries and has produced oil and gas in the Norwegian continental shelf (NCS) since 1972. The Norwegian state owns 67 per cent of the Company and it is rated one of the 50 most valuable companies in the world. From the 1990s it has built a global business located in Europe, Africa, North America and Brazil. It has over 29 000 employees.

In the next section some of the highly relevant resources (vessels, bases, subsea fields, etc) are reviewed with a view to improve and optimize ROV operations. The highly skilled and experienced people within the organization are also part of the capabilities needed when introducing new technology such as the eROV concept.

The Company was chosen because it has many subsea fields and has the highest ROV and marine activity in the NCS. The challenge is therefore of major relevance for the Company. Due to the high volume of ROV activity it makes the challenge even more relevant for the Company.

2.4.1.1. The Company’s Subsea fields

The overview over the Company’s resources in form of subsea fields are found in the infographic below. The Company is the operator of 552 wells and the service provider of 7 fields:

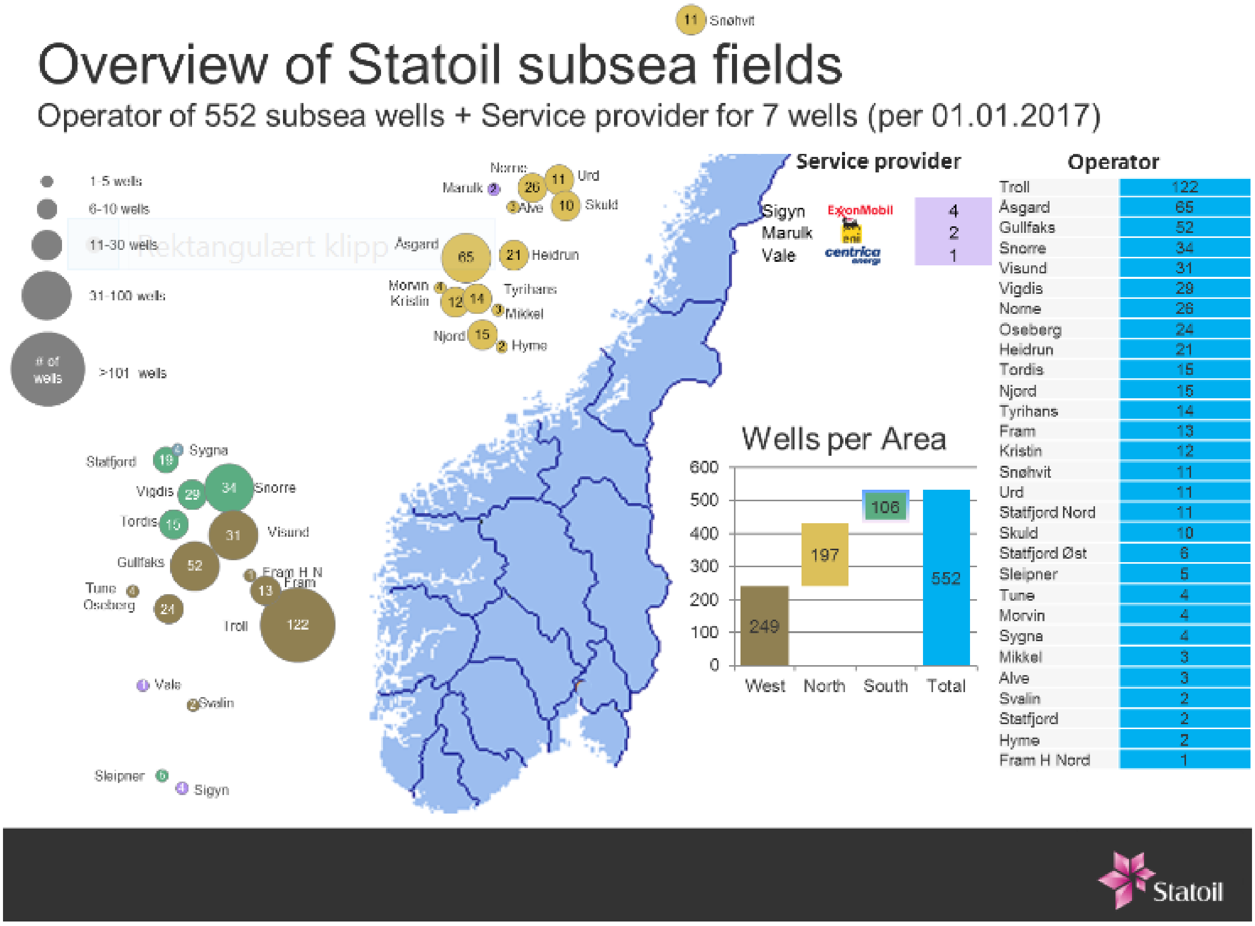


Figure 4 – Overview over subsea field and wells (Eriksen, Trond 2017) (Source; MTOM - ROV Operations - Masteroppgave (Overview over subsea field and wells) (email 19.05.17))

2.4.1.2. The Company's Marine and Logistics Department

The Marine and Logistics department is responsible for all vessels to and from the Company's offshore assets. This department is separate from the IMR department. Staff and office is in Bergen, Norway.

Figure 5 – Company Marine and logistics onshore including vessels (Monstad, Frida Eklof 2016) (Source; http://transportlogistikk.norskindustri.no/siteassets/dokumenter/foredrag-2016/17.okt.-q1-kl.-11.40-eklof-monstad.pdf?id=72115)

Through this department the Company runs all the logistics and marine operations involved with the operations offshore. It also handles logistics onshore as seen in figure 5 above. The department has frame agreements with a large number of vessels; PSV, OCV and AHV which support all marine operations, except frame agreements for IMR operations. On an ad hoc basis the department handles the charter of an IMR vessel if needed for a limited time of operations.

2.4.1.3. The Company's support bases

The Company has the base structure visualised below which supports and handles equipment during mobilisation/demobilisation, light maintenance and general logistics:

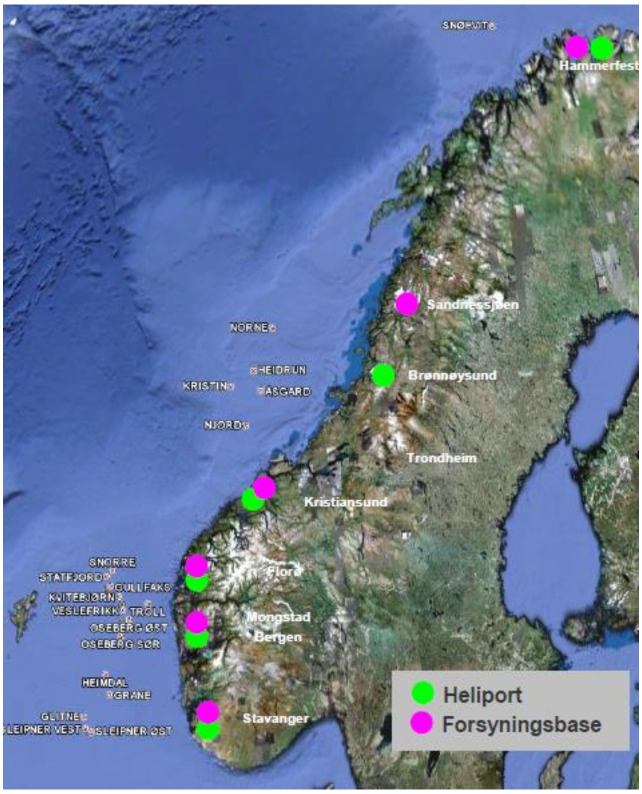


Figure 6 – Support bases for Company (Monstad, Frida Eklof 2016) (Source; http://transportlogistikk.norskindustri.no/siteassets/dokumenter/foredrag-2016/17.okt.-q1-kl.-11.40-eklof-monstad.pdf?id=72115)

2.4.1.4. The Company's supply vessels

The Company currently has eight vessels from Mongstad and Florø and four vessels from Dusavik on a frame agreement, running three times a week to support marine operations. Details are found in Appendix V.

During the study, the Company Marine and Logistics department provided feedback saying that ROV is required for all Company anchor handling operations during prelay and rig move operations. More vessels with heave compensated crane installed would be added value and lead to a more flexible use of the vessels.

An anchor handling vessel has a typical day rate in today's market between NOK 250 000,- and NOK 350 000,-. These vessels complete with a heave compensated crane would lead to operational flexibility and could be used as IMR/Project vessels (Andersen, Ole Steinar, 2017).

All the above-mentioned vessels are in this thesis considered as Company resources.

2.4.1.5. The Company's Subsea Tool Pool

The Company Tool Pool is an example of the term "Sharing Economy". The Company Tool Pool was established in 1992. The objective is to obtain operational and emergency readiness, cost sharing and to give synergy effects through joint use, maintenance and storage. A Steering Committee is responsible for managing the Subsea Pool.

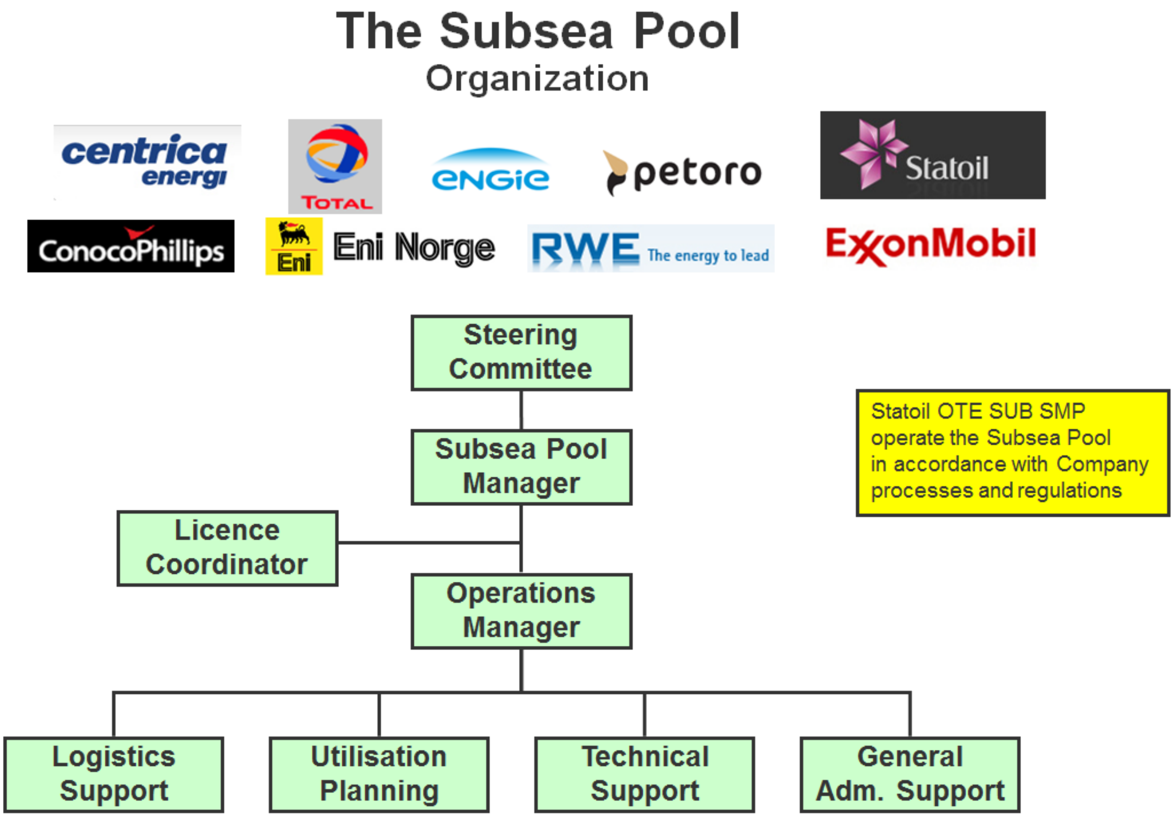


Figure 7 – Extract from PPT Presentation of Subsea Pool (Juvik, Frode, 2017) (Source; Juvik Frode, Statoil (2017) RE: MTOM - - - Subsea Pool (email 20.01.2017), extract from Powerpoint presentation).

The Tool Pool coordinates administration, logistics, maintenance and emergency preparedness through agreed priority rules. It also coordinates hiring out tools and handles distribution of revenues.

The Tool Pool uses the “Right to use of tools principle”: Legal ownership is kept by the original buyer of the tools. Legal ownership does not give priority to the owner if other Licenses have been allowed to buy into the right to use of the tools. To become a member of existing common Tool Groups, Licenses must buy rights to use the tools. Nonmembers of a Tool Group can rent tools from any Tool Group. This gives low priority. ROV tools are currently part of the tools in the tool pool portfolio.

New investments are shared based on number of «compatible wells» in each new tool group. Administration, storage and operational cost such as maintenance and recertification cost is shared based on total number of subsea wells.

The Company’s Tool Pool scheme is in this thesis considered as a resource.

2.4.2. State of the Art ROV technology and IMR operations

Det Norske Veritas (DNV GL) defines marine operations as a special planned, non-routine operation of limited duration at sea. Marine operations are normally related to temporary phases such as load transfer, transportation and installation (DNV, 2011b).

This thesis will mainly focus on IMR operations and the way this service is setup internally in the Company. Other operators would have similar contractual structure, but the internal work flows would differ.

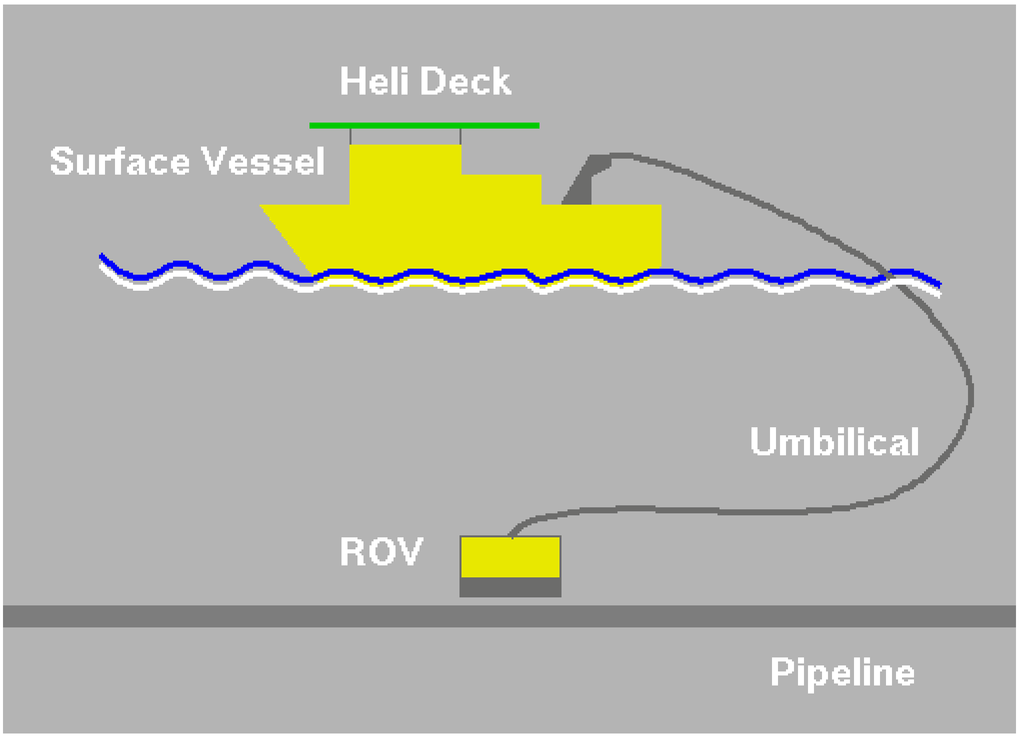


Figure 8 – Simplified System Overview showing surface vessel with ROV connected to vessel via Umbilical. (neo.no, 2017) (Source; neo.no (2017), neo.no Official website (online) Available at: http://www.neo.no/img/x4_overvw.gif (Accessed 29.09.2017).

For IMR operations a dedicated IMR vessel is normally used. The vessel would typically be customized to accommodate a wide arrangement of IMR task. These tasks consist of inspection, maintenance and repair of subsea assets and installations. Some vessels have a scale treatment system built into the vessel in accordance with the Company's specifications. Most often these vessels have a moon pool for handling of modules and tooling.

A typical IMR vessel or Offshore Construction Vessel has two WROV onboard and are manned up with ROV Crew that minimum are three staff on dayshift and three staff on night shift per ROV. In addition, there is a Shift Supervisor (SS) on day and night-shift. The Offshore Installation Manager (OIM) is typically floating (12 hrs shift) and overall responsible for the Offshore operation. In addition, there will be a marine crew on board the vessel.

The remotely operated underwater vehicle (ROV) is a tethered underwater unit. It is normally controlled from a vessel by the ROV crew onboard. On newer vessels the ROV is placed in a hangar. Deployed and recovered of the ROV is via an A-frame/LARS through splash zone. When working in harsh conditions a load-carrying umbilical cable is used along with a tether management system. The purpose of the TMS is to shorten the tether to minimize drag where there are underwater currents.

The umbilical transfers electrical power, video and data signals between the topside crew and the ROV. Electric power is used to run an electric motor to run a hydraulic pump to power tools (torque tools, hyd cutter etc) and the ROVs throughsters.

System overview:

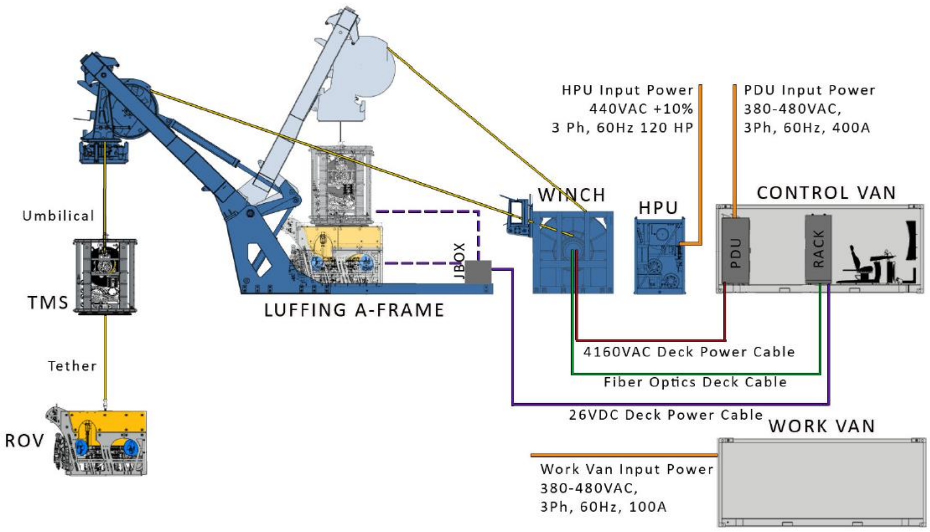


Figure 9 – ROV system overview (FMC Technologies, 2012) (Source; FMC Technologies (2012), Schilling Robotics HD ROV System, Operations, Maintenance & Repair, Training Course Student Guide, 2012).

Above is a schematic of a full ROV spread. Both the ROV and the TMS are deployed and recovered into the sea. The rest stays onboard the vessel. The system comprises of building blocks and stand-alone units. A full ROV spread could therefore be fitted on the aft deck on any (offshore construction) vessel as the Control Van/Work Van are normal ISO Containers. In a newer purpose built IMR vessel these control functions are built into the vessel.

The two most known ROVs are described as:

- **Work Class ROV (WROV):** WROV are built to perform construction work subsea and has two advances manipulators (arms). It is normally built on a large flotation frame were tooling skids can be fitted.
- **Observation ROV (OBS ROV):** An observation ROV is smaller in size and lighter than the WROV. It does not have any manipulators and are mainly used for inspection use or to assist other operations.

2.4.3. IMR Operations

Today almost all ROV operations performed in the NCS require a support vessel with a WROV to perform operations on the seabed. Larger rigs will have their own ROVs with limited reach due to the umbilical supplying electric and hydraulic power to the ROV.

Typical operations are General Subsea Inspections of any Subsea Asset, Pipeline Inspections, Subsea Construction work, Intervention work including valve operations, Tie-In Operations, hatch operations on Subsea Protection Structures, CP readings, Hydraulic and Electrical Flying Lead or jumper installation/fault finding, Leak detection and Cutting Operation. Many operations in the future will still require support from the vessel and an offshore crane or a moonpool/cursor system to deploy and recover subsea assets, tooling, hatch operations on templates subsea, etc.

These jobs require engineering and are described as IMR offshore campaigns. Today the operators/large oil companies do not own their own IMR vessel or OCV. These vessels are hired at a daily rate from Service Companies such as Subsea 7, Technip, Deep Ocean and Oceaneering.

The annual ROV subsea asset inspection does normally not require a vessel and could be performed using the ROV only. If a lifting operation is required in this setting it would typically be a manifold hatch operation to get ROV access to the work site/inspection site.

There are more than 5 000 subsea wells in the NCS and with aging equipment it is expected that the need for inspection and repair operations will increase significantly in the next years (Schjølberg, Ingrid, et al, 2016)

2.4.3.1. Company Work processes: Planning and executing IMR operations

The Company uses a Sharepoint system where a request for new IMR work is identified and logged from the license/field.

The “customer” (licensee at field) will identify a new Work Instruction by giving inputs such as; Project name, Field and Service Description. A request for vessel and resources is then completed, as seen in the figure below:

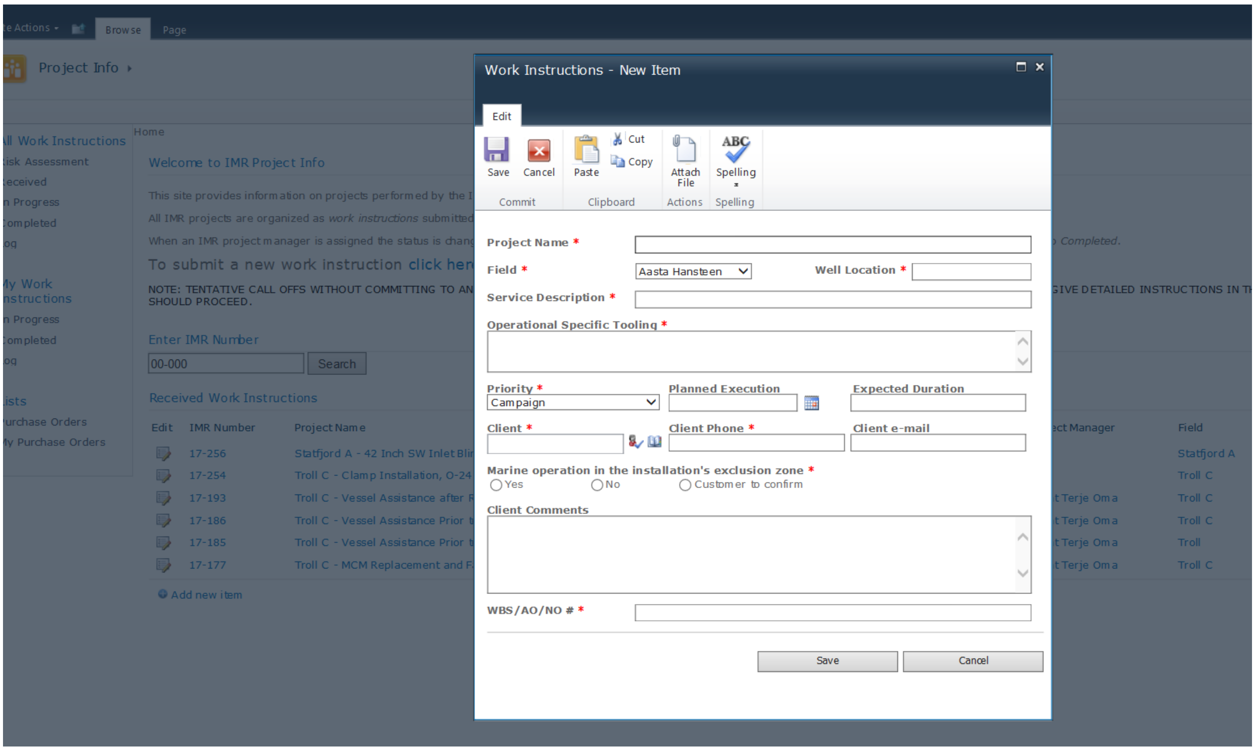
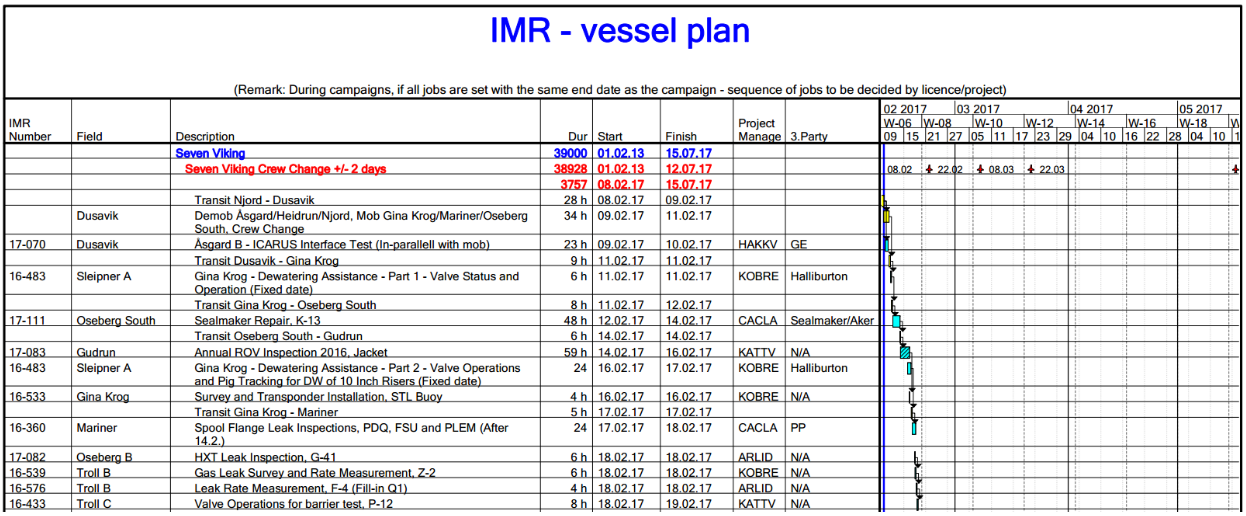


Figure 10 – Company IMR Work Instruction GUI from Project Info (Tennøy, Torodd 2017) (Source; Tennøy, Torodd, 2017, Snap (Project Info) (email 05.05.2017))

An IMR number is logged (ex.17-106) with a complete Project Name/description (Troll C – Vessel Assistance).

The next step for the IMR department is to manually transfer this data into an overall offshore resource plan (currently software in use is Safran Software Solutions).



IMR - vessel plan

(Remark: During campaigns, if all jobs are set with the same end date as the campaign - sequence of jobs to be decided by licence/project)

IMR Number	Field	Description	Dur	Start	Finish	Project Manage	3.Party
		Seven Viking	39000	01.02.13	15.07.17		
		Seven Viking Crew Change +/- 2 days	38928	01.02.13	12.07.17		
			3757	08.02.17	15.07.17		
		Transit Njord - Dusavik	28 h	08.02.17	09.02.17		
	Dusavik	Demob Åsgard/Heidrun/Njord, Mob Gina Krog/Mariner/Oseberg South, Crew Change	34 h	09.02.17	11.02.17		
17-070	Dusavik	Åsgard B - ICARUS Interface Test (In-parallell with mob)	23 h	09.02.17	10.02.17	HAKKV	GE
		Transit Dusavik - Gina Krog	9 h	11.02.17	11.02.17		
16-483	Sleipner A	Gina Krog - Dewatering Assistance - Part 1 - Valve Status and Operation (Fixed date)	6 h	11.02.17	11.02.17	KOBRE	Halliburton
		Transit Gina Krog - Oseberg South	8 h	11.02.17	12.02.17		
17-111	Oseberg South	Sealmaker Repair, K-13	48 h	12.02.17	14.02.17	CACLA	Sealmaker/Aker
		Transit Oseberg South - Gudrun	6 h	14.02.17	14.02.17		
17-083	Gudrun	Annual ROV Inspection 2016, Jacket	59 h	14.02.17	16.02.17	KATTV	N/A
16-483	Sleipner A	Gina Krog - Dewatering Assistance - Part 2 - Valve Operations and Pig Tracking for DW of 10 Inch Risers (Fixed date)	24	16.02.17	17.02.17	KOBRE	Halliburton
16-533	Gina Krog	Survey and Transponder Installation, STL Buoy	4 h	16.02.17	16.02.17	KOBRE	N/A
		Transit Gina Krog - Mariner	5 h	17.02.17	17.02.17		
16-360	Mariner	Spool Flange Leak Inspections, PDQ, FSU and PLEM (After 14.2.)	24	17.02.17	18.02.17	CACLA	PP
17-082	Oseberg B	HXT Leak Inspection, G-41	6 h	18.02.17	18.02.17	ARLID	N/A
16-539	Troll B	Gas Leak Survey and Rate Measurement, Z-2	6 h	18.02.17	18.02.17	KOBRE	N/A
16-576	Troll B	Leak Rate Measurement, F-4 (Fill-in Q1)	4 h	18.02.17	18.02.17	ARLID	N/A
16-433	Troll C	Valve Operations for barrier test, P-12	8 h	18.02.17	19.02.17	KATTV	N/A

Figure 11 – Vessel Plan 2017-06 (Tennøy, Torodd, 2017) (Source; Tennøy, Torodd (2017)MTOM - ROV Operations - - - Annual Inspection timer fordelt på felt (email 13.06.2017))

Once all the details are identified, a summary is made in a Work Instruction (WI) and Work program. All these work processes are manual processes where emails are sent between the involved parties attaching files, uploading files to each company's local drive.

The next step in the work process is for the Company to assign the task to one of the IMR contractors. An email request/instruction is then sent to the assigned Frame Agreement IMR vessel operators. The service and vessel operator will then issue a budget based on operational time, number of estimated hours of engineering, and identified tooling rental, 3rd party involvement, etc.

Before commencing any further work, the budget is to be approved by the Company. An Engineer from both parties are assigned the job as "Responsible Engineer".

A high-level information flow chart is found in the figure below:

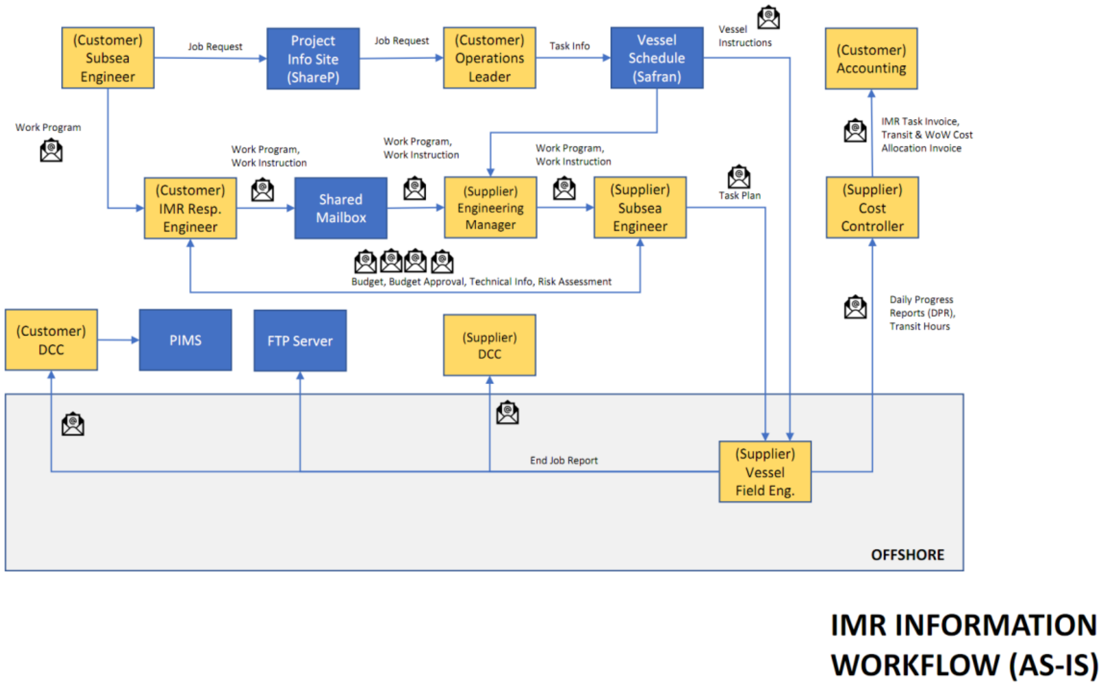


Figure 12 – Company IMR information flowchart, planning and executing an IMR job (as-is) (Bråten Erik., 2017)

Effective hours on job according to day-rate is added to the actual MGO (Marine Fuel) cost according to contract. WOW and transit and other common cost is added to job based on cost allocation rules ("brønnfordelingsnøkkel") using Company internal routines.

The Company's IMR department runs weekly status meetings and the responsible engineers for the IMR jobs follow up their project through email and correspondence. One task is to find and make available relevant information to complete the engineering. The process is dynamic, involving many manual actions.

Annual ROV inspections also fall into the IMR department and the vessel schedule i.e information is identified in the Project Info. In addition, SAP is also used to manually update and plan ROV inspections.

The “Project Info” system is also used as a “Project Library” (experience database), but its main function remains as a planning tool.

End Jobs Reports (EJR) are currently placed in Project Interface Management System (PIMS). ROV videos/pictures from operations are saved on a memory stick, placed in an envelope and sent from vessel to the DCC to be filed manually. Other contractors have FTP server access and can upload to a common server, still requiring manual tasks for filing.

General as-built documentation is archived in STID.

Challenges and Opportunities for Improvement (OFI):

- All the manual handling of data
- Limited vessel availability (currently three vessels), creating additional work due to changes in vessel schedule
- Vessel schedule not automatically updated from Project Info
- As the IMR department is often used to source experience from operations, it important to have a solid and good experience database to easily pull data from.

The Subcontractor’s onshore Engineering team is responsible for the engineering, preparing procedures and task plans for the offshore execution team. Task Plans and Procedures are issued and checked onshore and sent offshore before execution.

2.4.3.2. Offshore vessel organisation and responsibilities during IMR operations

The organisation and responsibilities onboard the IMR vessel is normally defined in the contract between the Company and Subcontractor for the marine organisation or in a Mobilisation Procedure. Typically, the organisation has the following setup:

Overall responsible of the IMR vessel is the Vessel Master.

In control of the offshore operation is the Offshore Manager (OM). The OM will liaise with the Company representative onboard during execution of operations.

In charge of and controlling the IMR activities during operations is the Shift Supervisor (SS). He adheres to procedures, task plans and instructions given by the Offshore Manager or the Captain. The shift supervisor will also lead the ROV operations and work closely with the Field Engineer/Project Engineer onboard vessel.

The Subsea Field Engineer / Project Engineer (FE/PE) is responsible for the planning of the operation by preparing operational procedures and task plans, based on information fed from the IMR Engineer, the Work Program and the Work instruction given by the Company.

The Company Representative signs task plans, isolations and completion certificates, interface Permits to Work (PTW) and handles all technical matters during the offshore operations.

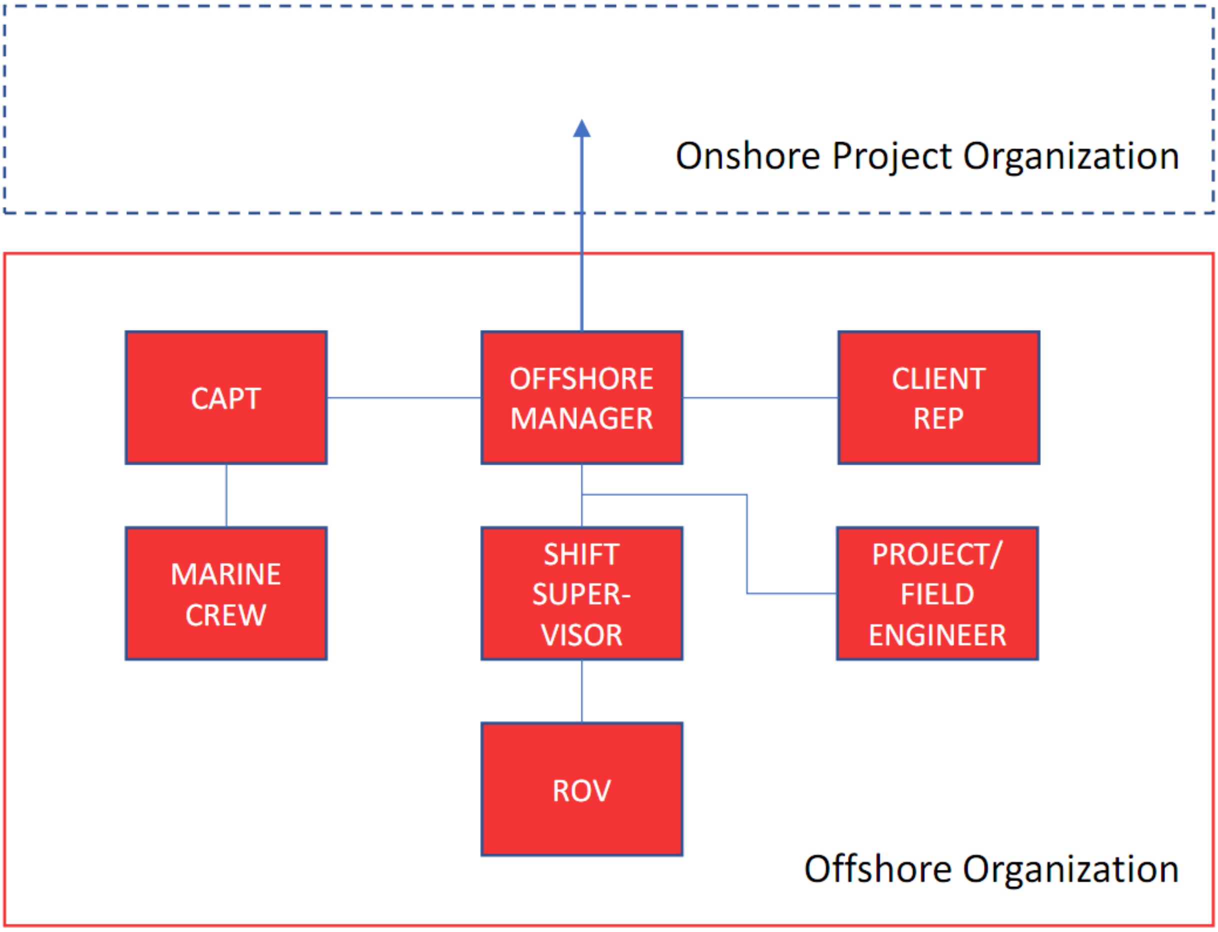


Figure 13 – Typical Organisation Chart onboard an IMR offshore vessel (Bråten, Erik, 2017)

3. NEXT GENERATION (NG) TECHNOLOGY, OPERATIONS AND FUTURE SCENARIOS

3.1. Next generation technology concepts

The Company has several future ROV related ongoing projects. These projects represent radical innovations rather than incremental improvements, and are pushing the limits we have had until now with regards to general ROV operations:

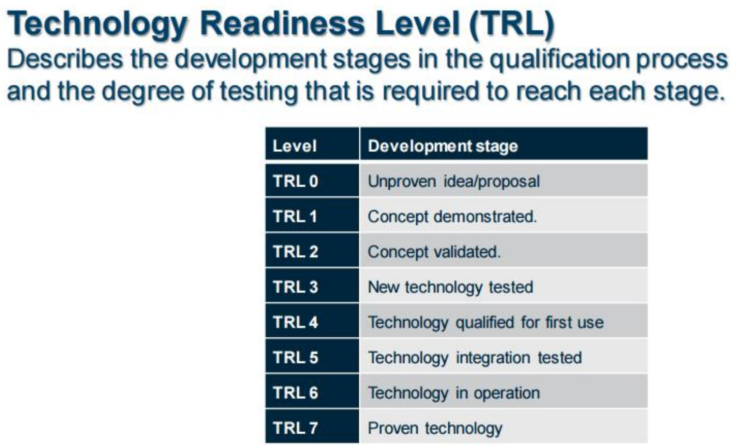
- **Remote piloting**: General concept for controlling an ROV from a remote location.
- **RROV**: Resident Remotely Operated Vehicle.
- **eROV**: Empowered ROV with electric pack including 4G Buoy for transfer of signals

The main differences between the RROV and the eROV concept is the that the eROV has its own battery pack and signals are transferred via a buoy and not through fixed and pre-installed fiber optics routes. The eROV can be used in any location with 4G LTE coverage whilst the RROV is limited to its installation position. The eROV can therefore be taken onboard a vessel and positioned at the worksite, whilst the RROV is limited to its position (typically adjacent to rig location). Both concepts allow for remote piloting controlling the ROV. The RROV can still be controlled from the Rig if control systems and personnel is available at site.

This thesis focuses mainly on the eROV concept because this is a WROV system, considered a very flexible ROV system. The eROV concept is capable of doing general subsea construction work, not just inspection and limited valve operations.

Both “Eelume” and “Hugin” are ongoing innovative ROV projects, but without manipulator arms, limiting the capability of completing subsea construction work.

Technology Readiness Level (TRL) is a measure of the maturity of a given technology.


Technology Readiness Level (TRL)

Describes the development stages in the qualification process and the degree of testing that is required to reach each stage.

Level	Development stage
TRL 0	Unproven idea/proposal
TRL 1	Concept demonstrated.
TRL 2	Concept validated.
TRL 3	New technology tested
TRL 4	Technology qualified for first use
TRL 5	Technology integration tested
TRL 6	Technology in operation
TRL 7	Proven technology

Figure 14 – Company TRL level overview (Eriksen, Trond, et. al., 2017) (Source; Eriksen, Trond et al (2017), Iversen Arve, Bernt Fanghol, Remote-piloting-connecting-what-s-needed-with-what-s-next-iversen-oceaneering-fanghol-telenor-maritime-eriksen-Company-asa, Presentation FFU-seminar, Sola Clarion Airport Hotel, Sola 01.02.2017) Available at: https://d26pw6xcesd4up.cloudfront.net/1493969933/remote-piloting-connecting-what-s-needed-with-what-s-next-iversen-oceaneering-fanghol-telenor-maritime-erikesn-statoil-asa.pdf (Accessed 10.05 2017))

The TRL for the Company's new technology projects is shown in the table below.

Table 1 - TRL level overview for new technology

System	TRL	Comments
Remote Piloting Concept	5	assumed TRL maturity
RROV Concept	5	assumed TRL maturity
eROV Concept	4	assumed TRL maturity

3.1.1. The Remote Piloting Concept

The Remote Piloting Concept combines telecommunications technology and ROV technology. The Onshore Control Center control facility enables full functionality and control of the ROV with associated tooling from the remote location. Real time communication systems, low latency and high-speed broadband data communication from offshore makes subsea operations possible from an onshore location.

A successful test was performed on Dec 6th 2016 from Songa Endurance. ROV tasks performed were:

- Stab HP-Cap High Pressure seal test line with dummy stab.
- Lay down and raise riser El. Connector support frame.
- Clean a section of template hatch structure.

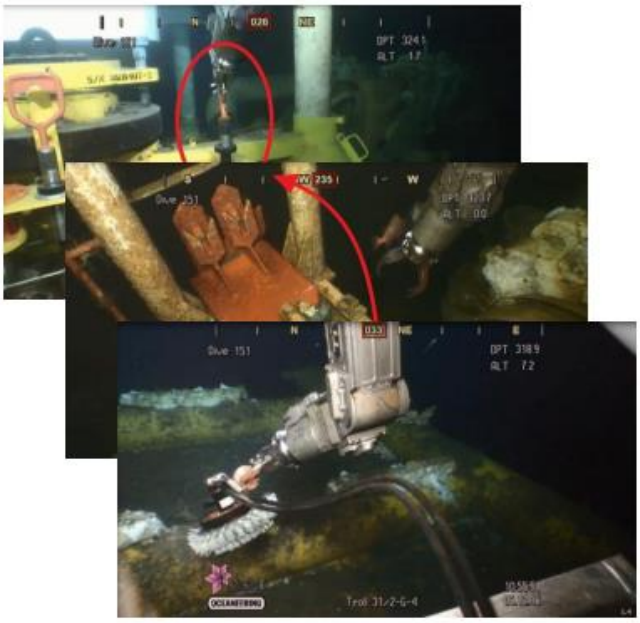


Figure 15 – Pictures taken during test trail May 6th for the above described tasks (Eriksen, Trond, et. al., 2017) (Source; Eriksen, Trond et al (2017), Iversen Arve, Bernt Fanghol, Remote-piloting-connecting-what-s-needed-with-what-s-next-iversen-oceaneering-fanghol-telenor-maritime-eriksen-Company-asa, Presentation FFU-seminar, Sola Clarion Airport Hotel, Sola 01.02.2017) Available at: https://d26pw6xcesd4up.cloudfront.net/1493969933/remote-piloting-connecting-what-s-needed-with-what-s-next-iversen-oceaneering-fanghol-telenor-maritime-erikesn-statoil-asa.pdf (Accessed 10.05 2017))

Figure 16 – Picture from onshore control room during test trial May 6th (Eriksen, Trond et al 2017) (Source; Eriksen, Trond et al (2017), Iversen Arve, Bernt Fanghol, Remote-piloting-connecting-what-s-needed-with-what-s-next-iversen-oceaneering-fanghol-telenor-maritime-eriksen-Company-asa, Presentation FFU-seminar, Sola Clarion Airport Hotel, Sola 01.02.2017) Available at: https://d26pw6xcesd4up.cloudfront.net/1493969933/remote-piloting-connecting-what-s-needed-with-what-s-next-iversen-oceaneering-fanghol-telenor-maritime-erikesn-statoil-asa.pdf (Accessed 10.05 2017))

3.1.2. The RROV Concept

The Resident Remotely Operated Vehicle (RROV) is a “permanent” ROV system installed on the seabed. This is different from an ROV that is deployed and recovered before every dive. The aim is to have the ROV subsea for extended periods time of up to three months. The RROV system allows control the ROV from either the rig directly, but also from an OCC via Tampnet, a dedicated fiber-based network for platforms. The system is also designed to operate on the 4G mobile broadband.

The RROV system has been installed at Visund and Snorre B fields. This system is permanently installed at location. The main new functionality for Visund and Snorre B is therefore the option of remote piloting the RROV.

3.1.3. The eROV Concept

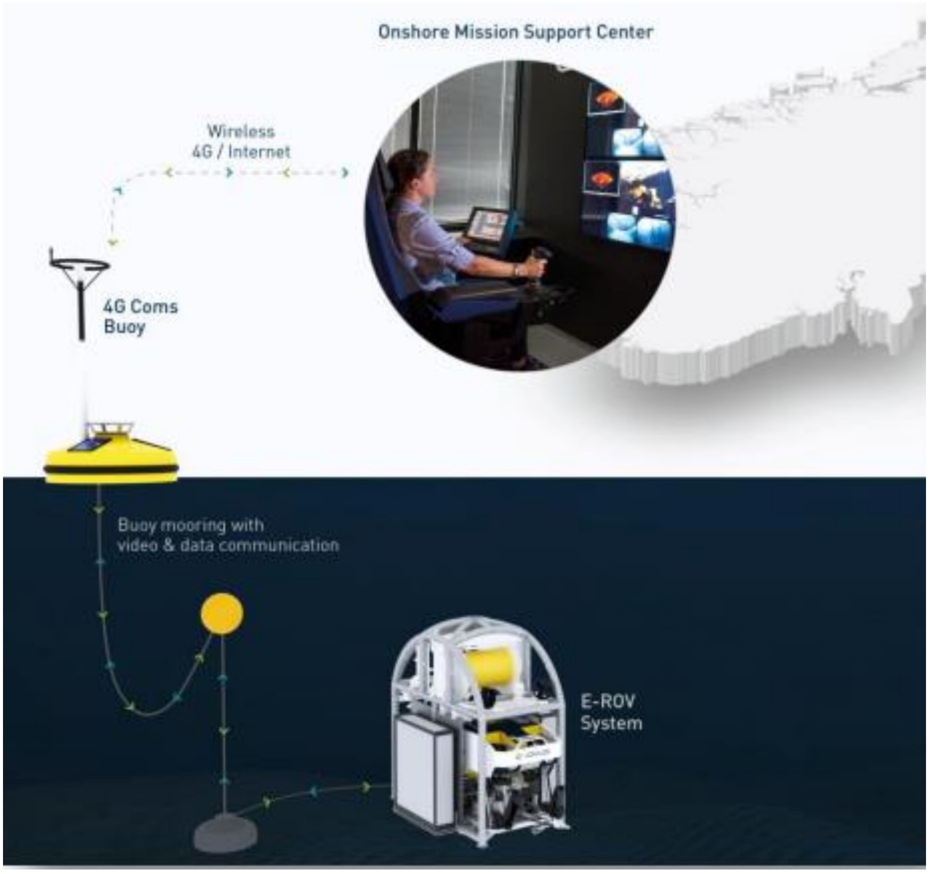


Figure 17 – Company eROV concept (Eriksen, Trond et al 2017) (Source; Eriksen, Trond et al (2017), Iversen Arve, Bernt Fanghol, Remote-piloting-connecting-what-s-needed-with-what-s-next-iversen-oceaneering-fanghol-telenor-maritime-eriksen-Company-asa, Presentation FFU-seminar, Sola Clarion Airport Hotel, Sola 01.02.2017) Available at: https://d26pw6xcesd4up.cloudfront.net/1493969933/remote-piloting-connecting-what-s-needed-with-what-s-next-iversen-oceaneering-fanghol-telenor-maritime-erikesn-statoil-asa.pdf (Accessed 10.05 2017))

This concept is a battery powered electric WROV complete with 4G LTE data buoy. The eROV is controlled from the Onshore Control Center. A successful trial was performed in June 2017 (3 weeks at 330m below sea level at Troll).

In May 2017, Oceaneering's eROV was under construction and the ENOVUS ROV was used as the the ROV technology. The prototype eROV has two batteries each of

10 Kwh and the ROV frame has been modified to contain battery packs of 100 Kwh. The building blocks have been the standard, and the current plan is to use Fuego buoy during testing with lazy S configuration for the umbilical.

The estimated capacity for the eROV doing standard valve operations is that the battery will last approximately 24 hrs. The eROV has a HPU that currently requires 5 Kw and drains the battery fast.

According to Oceaneering one of the main challenges has been the communications time delay seen on the screen controlling the ROV from an OCC. Available technology now allows for real time monitoring of inputs given by ROV pilot.

The eNovous ROV is approximately 3.400 kg and dimensions are: 2.7m x 1.6m x 1.8m (LxWxH).

The deployment frame including battery pack has the following weight and dimensions: 344m x 2.82m x 3.81m (LxWxH) and weight is 3 700 kg + battery pack of 6 000 kg = total weight of ROV cage to 9 700 kg (Complete with ROV 14.1 Te).

Figure 18 – Oceaneering eROV manufacturing plant Stavanger, Norway. eROV under construction. The ROV cage is seen on the left in the picture with large battery packs to be installed on the sidewalls of the ROV cage. (picture Bråten, Erik, 18.05.2017)

3.1.4. Communications technology

4G Comms Buoy and coverage in the NCS: Tampnet 4G LTE is a high capacity, low latency wireless network consisting of LTE base stations strategically placed in the North Sea and Gulf of Mexico on key offshore installations.

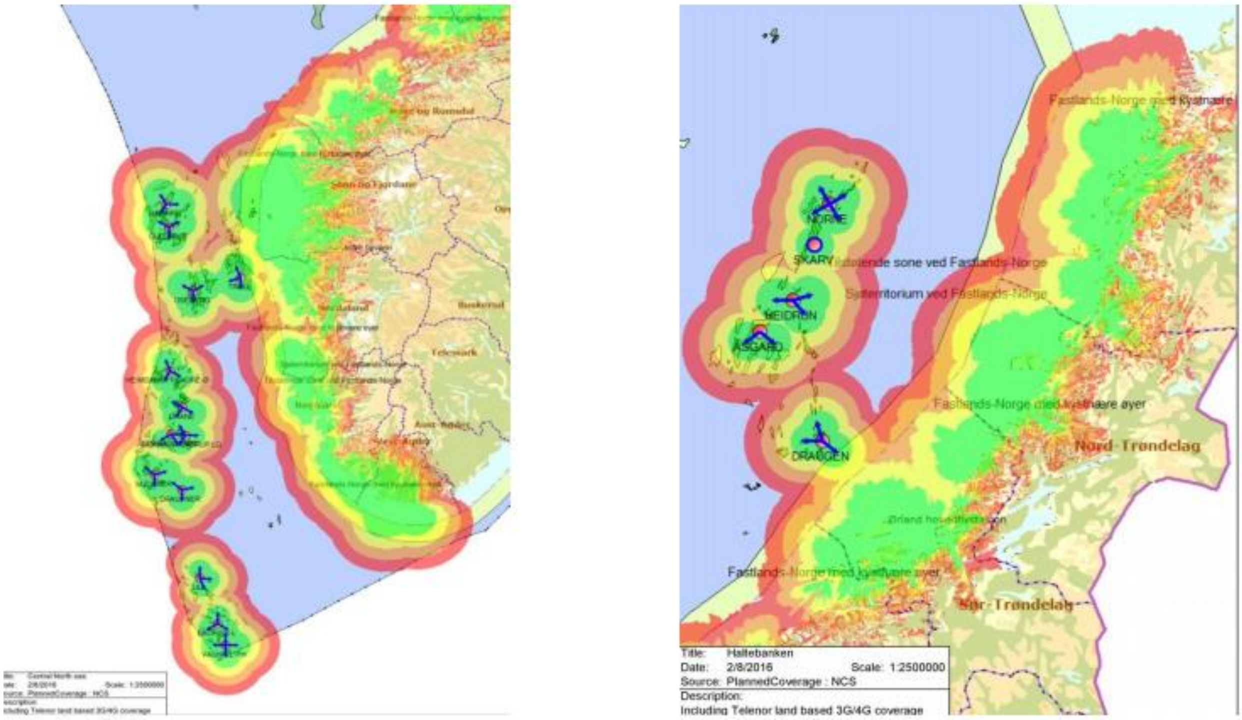


Figure 19 – Combined coverage on NCS and shore based mobile broadband (Eriksen, Trond et al 2017) (Source; Eriksen, Trond et al (2017), Iversen Arve, Bernt Fanghol, Remote-piloting-connecting-what-s-needed-with-what-s-next-iversen-oceaneering-fanghol-telenor-maritime-eriksen-Company-asa, Presentation FFU-seminar, Sola Clarion Airport Hotel, Sola 01.02.2017) Available at: https://d26pw6xcesd4up.cloudfront.net/1493969933/remote-piloting-connecting-what-s-needed-with-what-s-next-iversen-oceaneering-fanghol-telenor-maritime-erikesn-statoil-asa.pdf (Accessed 10.05 2017))

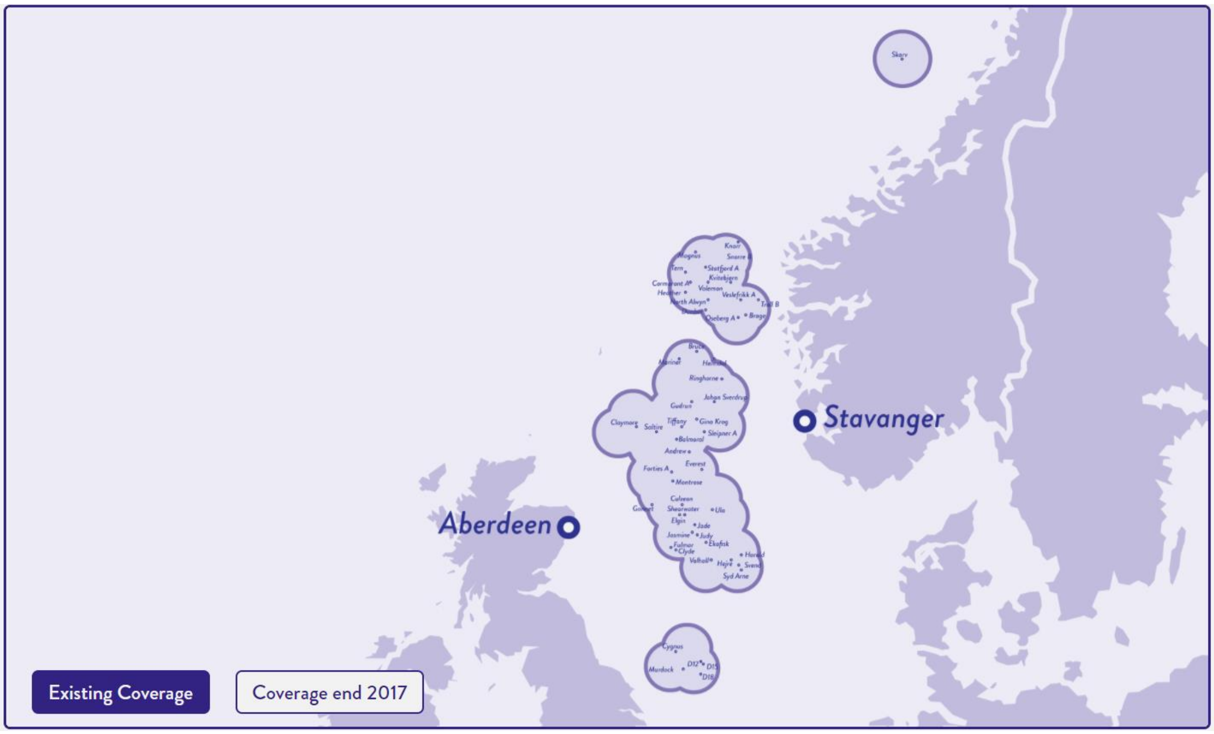


Figure 20 - Existing 4G LTE coverage (Tampnet.com, 2017) (Source; Tampnet.com (2017). Official website (online). Available at:http://www.tampnet.com/north-sea/#4G LTE Coverage)

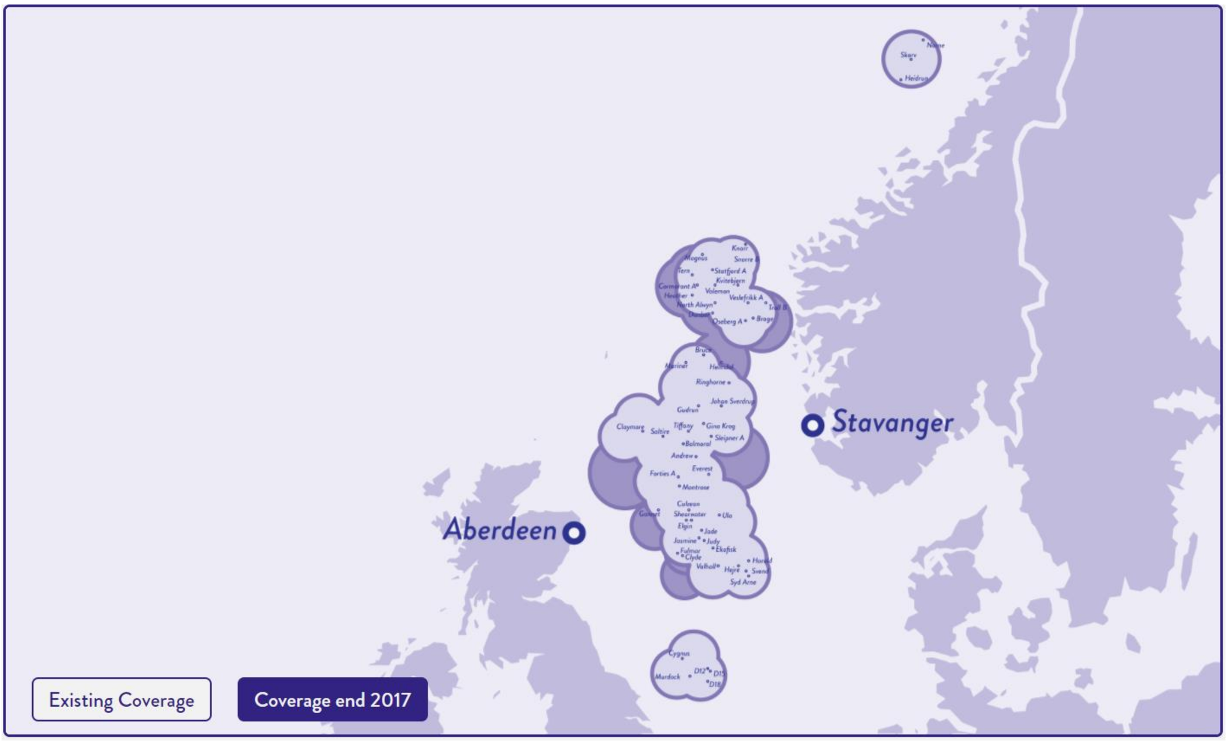


Figure 21 - 4G LTE coverage by end of 2017 (Tampnet.com, 2017) (Source; Tampnet.com (2017). Official website (online). Available at:http://www.tampnet.com/north-sea/#4G LTE Coverage)

3.2. Next Generation (NG) Operations

This section expands on next generation operations and the resources required to prepare for the future scenarios described in section 3.3.

As outlined in the literature review, scenario planning is about preparing for the future. The better prepared the Company is, the better decisions can be taken, which again could lead to better outcomes, giving a competitive advantage.

As a large oil and gas company the Company is in a unique situation and has many resources available. These resources are financial assets, frame agreements for vessels, staff with high competence, and the Company Tool Pool for sharing of tooling.

The eROV technology is innovative, smart and environmentally friendly, but the question is: How can you improve operations using this new technology? Once the battery is drained after 24 hours of operations, what happens then? Is it possible to set up and align all resources, and think differently with new technology available?

3.2.1. Digitalize ROV planning: ROV management tool for IMR operations

As seen in chapter 2 (figure 12), the planning and execution process contains multiple manual steps and an excessive amount of emails with attachments. This could be improved by smart sharing of data to improve work processes, also supported from theory in chapter 2.3.2 (Danielsen, Jan E., 2017)

This section outlines a future ROV management system that could help optimize operations and sharing of information and data.

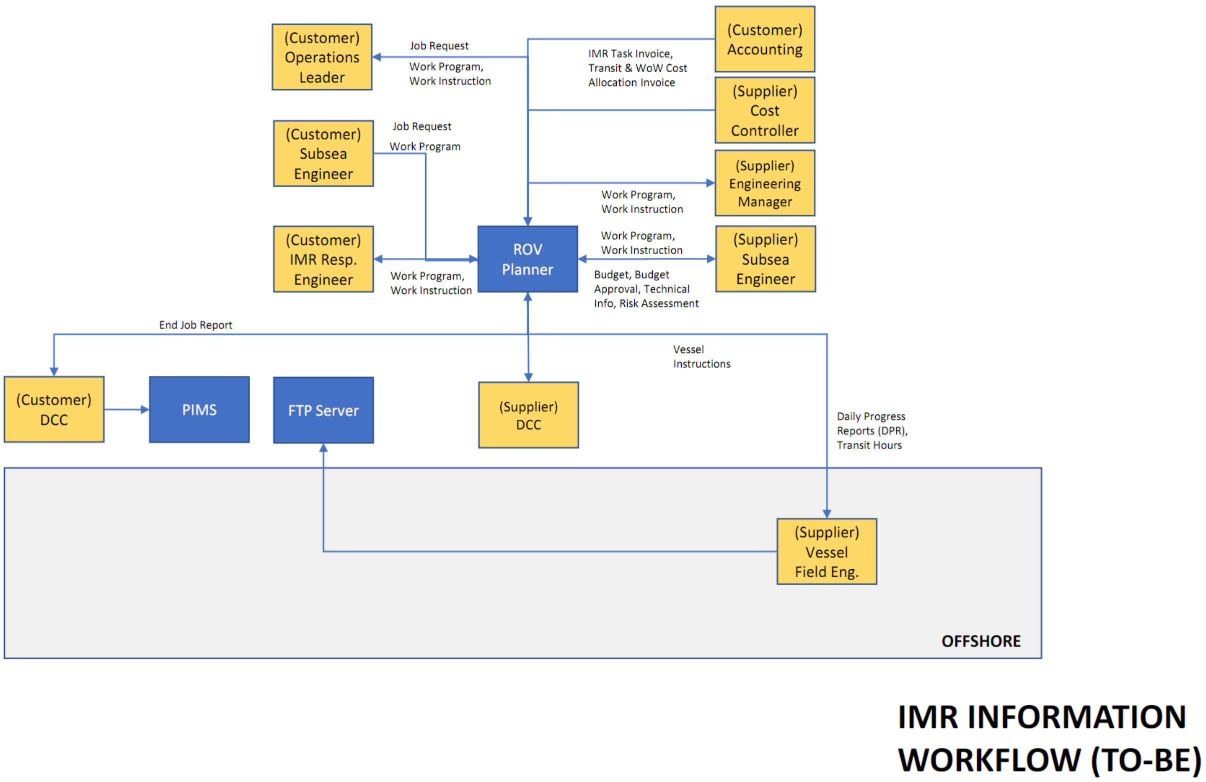


Figure 22 – IMR Information Workflow (to-be) (Bråten, Erik, 2017)

In figure 22, the ROV planning tool is imagined as the management system and a digitalization of the ROV operations. This IT tool is suggested to be used for initiating operations, planning and execution including as-built documentation (LCI), and cost control and invoicing. The tool should digitize and support all workflows involved in the operations. The planner also has a vessel path optimizer planning tool. All information is stored in one location and shared among involved personnel involved in the operations.

Eldar Sætre, President and CEO in the Company, describes the LEAN concept thus: *"Simplification is a vital part of our agenda. It is not about cutting costs by doing less. It means getting to the core and doing more with less. LEAN is a concept and a way of working that more at Company are getting to know. It is a philosophy of continuous improvement, through involvement and collaboration. And it applies to all of us*". (Eriksen, Trond et al, 2017 p. 2)

Ideas for a leaner approach for ROV operations using the ROV Planner tool:

- Planning Tool, planning of ROV operations
- Booking of ROV and reuse of staff
- Cost Calculator: comparing use of traditional IMR vessel vs eROV, find most

cost-efficient solution for task to be performed
- Logistics and tooling: have all logistics and tooling in one system (cost savings)
- Invoicing Tool: avoid email attachments and manual follow up
- Vessel Management: full access and overview of available vessels and technical capabilities/limitations
- Daily Progress Report (DPR): reported in database format and searchable
- Documentation and LCI: experience database, reuse of data
- Future functionality: Sales Pipe (online market site, available ROVs shown marked as green on screen). The Company to be the Principal for smaller stakeholders and partners.
- Cloud-based. Available from anywhere, any time. Documentation shared in one location, avoiding excessive amount of emails with attachments and manual processes.

3.2.2. Path Planning and Optimization

Is it possible to optimize current available resources, and use already existing vessels in the Company's portfolio in a smarter way?

Cars drive on roads, trains on tracks and airplanes fly in airways. The Company's chartered vessels have optimized sailing routes. Why can't ROVs have an optimized pattern for planned inspection work to optimize operations?

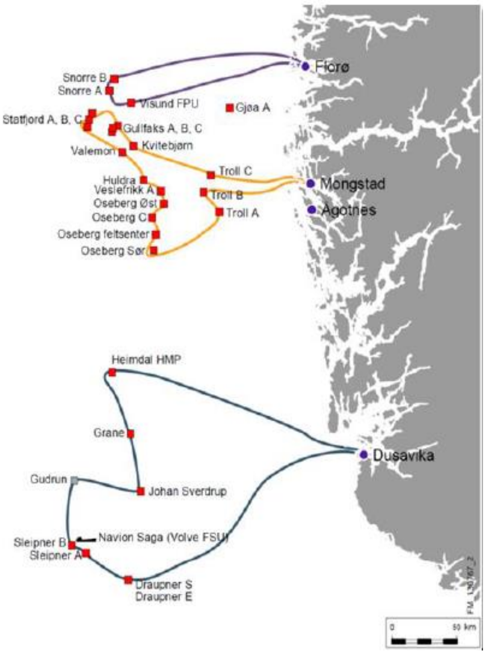


Figure 23 – Optimized path planning for OSV (Monstad, Frida Eklof, 2016) (Source; http://transportlogistikk.norskindustri.no/siteassets/dokumenter/foredrag-2016/17.okt.-q1-kl.-11.40-eklof-monstad.pdf?id=72115)

According to the Company's Marine and Logistics department, the Company has vessels which do a round trip every other day, three times a week. For a round trip a PSV typically carries cargo of 1 000 m2 (Andersen, Ole Steinar, 2017).

Many IMR operations do not require a large IMR vessel such as Seven Viking or North Sea Giant. ROV Inspection work is one example. ROV Inspection operations do normally not require an offshore crane or any kind of additional tooling for the ROV to complete the operation. Another type of vessel (PSV/AHTS) can therefore be used to tow the eROV to and from the work site. Once the eROV is on its own on the seabed, the PSV can continue in the optimized path planning that originally existed.

Why are ROV operations not put into a structured path planning system? Imagine in the future the ROVs in the NCS navigating in “ROV seaways”. Improved path planning, having the eROV more available offshore at all times at locations/hubs subsea, versus today’s planning, mobilizing, transiting every time a request is made for an ROV.

The umbilical until now has been the main constraint, but with the new technology available, controlling ROV from a remote location. With new technology available, could the eROV be put into a more structured system to increase utilization?

3.2.3. Infrastructure: Subsea Charging/Docking Stations (Battery Packs)

For the ROV to become more independent and self sufficient, a subsea infrastructure is required offshore. Hubs are therefore needed in places with high IMR activity. The general status for brownfield sites (old existing infrastructure) is that there is no or limited electrical capacity available. This is like what we are experiencing in the household grid. In the future we will heat our water during night hours and recharge electric cars during morning hours to even out electrical consumption peaks.

The incentives to do so will be through pricing models in which electricity will be cheaper at certain times to avoid all electric car owner plugging in and charging their cars in the afternoon arriving home from work. But this issue could be solved by charging and storing in battery packs when there is overcapacity of power available. The same principle could be used subsea at the charging/docking stations for the ROVs.

A suggested technical setup would be to use a “Temporarily Retrofit Subsea USB” (Blue Logic). This can be connected to the subsea Template spare tronic receptacle. There is a need to add a Safety Box to accommodate for SIL (Safety Integrity Level) which are company/system specific (Aker/GE/FMC). Together with a battery pack power can be stored and the eROV could be recharged at a location in the nodes as indicated in the above schematic.

Figure 24 – Blue Logic retrofit Subsea USB (Eide, Helge Sverre, 2017) (Source; Eide, Helge Sverre (2017),PPT (email 29.09.17))

The “Subsea USB” is an inductive connector, a product from Blue Logic. The connector is 100 % sealed from seawater avoiding a short circuit. No pins are required to be mated and there are no pin configuration issues. Galvanically sealing of male and female makes the system "optical" connected (Blue Logic, 2017).

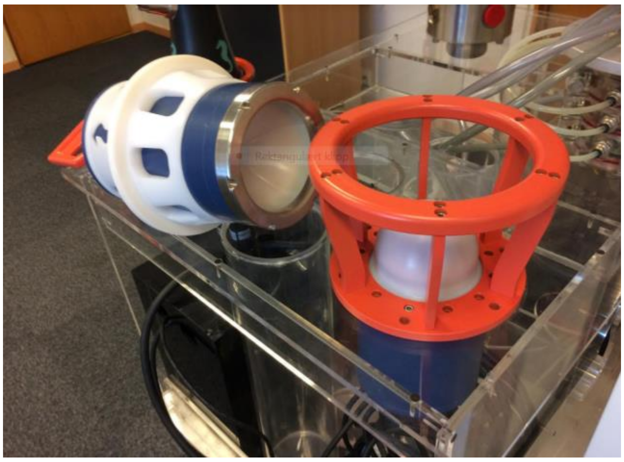


Figure 25 – Blue Logic Subsea USB receptacle from visit 29.09.17 (Photo, Bråten, Erik 2017)

3.2.4. Relocation of eROV when electrically discharged

When the battery is fully drained the eROV needs to be recharged. Relocation or recovery of ROV is required if the ROV is not located close to a hub or charging point. With current technology this means support from a vessel with a liftline:

3.2.4.1. Recovery to vessel deck via Crane or vessel moonpool

One option for an IMR vessel is to recover to surface by use of crane or via moon pool. With the buoy attached this is time consuming vs. a normal recovery of an ROV via an A-frame. The company has indicated that its goal is to perform an eROV spread deployment/recovery in four hours total with an IMR vessel.

3.2.4.2. Towing operations

Another option is moving the eROV from one location by simply towing it. The buoy attached also makes the move complicated and time consuming and limits the towing speed. If the eROV is towed together with the buoy, the buoy would be the limiting factor for the towing speed. The issue towing the buoy according to the company Fugro is that it is dragged under water, but it is possible to have an optimized rigging setup that limits the extension of how much the buoy is pulled under water.

Another option would be to to have several buoys at each hub/node, for example 2-3 buoys per eROV. The buoy is relatively cheap compared to the ROV system itself.

Fugro has good experience with towing speed of 5 kts for the Wavescan buoy.

Different vessel needs to be set up with minimum required equipment to perform the tow. As a minimum a winch and sheave arrangement are needed. An AHV would have all this equipment available, for the PSV or other vessels winches and sheaves would be needed.

There are several options for a towing setup. One option is to connect into the ROV cage and leave the buoy floating aft. Another option is to pick up and secure the buoy in an A-frame or Davit system, similar to a lifeboat crane-like device.

If buoyancy was added to ROV cage, or battery weight reduced, this would ease handling and towing operations and should be investigated in detail. The size of the winches could be reduced as result of an improvement like this.

3.2.5. eROV buoy and rigging arrangments

Fugro has two types of buoys that could be used.

Seawatch Wavescan Buoy: The largest buoy is the Wavescan buoy. This is designed for harsh conditions and are large and heavy. This buoy is 2.8 m in diameter and the weight is 1 Te. The tripod for the antenna is 4 meters over sea level which will give better COMM signals in large waves. It can lose its signal if waves are too large avoiding signals to transmit. The solar system for charging is 4 x 40 w.

Seawatch Midi 185: The other buoy offered by Fugro is the Midi buoy. This is designed for less harsh environment, but have according to Fugro (Arve Berg, 02.10.17) been used in Shetland and the Barents Sea successfully. It is manufactured in one piece of polyethylene, weighs 600 kg and has a diameter of 1.85 m. Due to its physical size and weight, it is easier to handle offshore.

Both buoys have a disc shaped form which makes it better suitable for towing. Also, these buoys tend to be pulled less under water according to Fugro.

Figure 26 – Fugro Seawatch Midi 185 buoy (Fugro.com, 2017) (Source; Fugro.com (2017) Official website (online) Available at: https://www.fugro.com/about-fugro/our-expertise/technology/seawatch-metocean-buoys-and-sensors (Accessed 29.09.2017))

Mooring and umbilical attachments: The ideal mooring for the buoy is a one piece or piggyback solution for mooring and signal transfer. Two independent products is according to Fugro challenging as these product will tend to twist.

An optimized armored cable or piggyback solution and cost must be investigated in detail and has therefore been moved to the section for recommended future work.

3.2.6. Optimizing Currently Available Vessels

To work smart and use available resources it is suggested to use more inexpensive vessels (compared to an IMR vessel) during the relocation of the eROV. This could also give some operational flexibility.

As a minimum for the towing scenario most of these vessels need to undertake an upgrade to lift the eROV of seabed and tow the eROV from location A to B.

Below are several alternatives listed starting with the most inexpensive and simple solution:

3.2.6.1. Winch and sheave setup

A vessel without a crane can be fitted with a winch and sheave arrangement. This will make it possible to tow the eROV from location A to B.

With a small crane on the aft deck smaller tooling could also be deployed to the eROV performing a load transfer. Tooling could be deployed and recovered in big bags to the subsea work site.

Figure 27 – Typical winch (Ace-winches.com, 2017) Source; Ace-winches.com, (2017) Ace Winches Official Website (online). Available at :http://www.ace-winches.com/products/drum-winches/hydraulic-drum-winches/10-20-tonne-wll/ (Accessed 30.09.2017))

Cost Purchase: NOK 6,1 mill (15 Te) (Sepro) (Abram, Martin, 2017).

If the battery pack of the eROV is reduced in weight, this will impact the winch required meaning a smaller winch can be used and this will be less expensive.

3.2.6.2. Offshore davit system

A very simple offshore davit system for recovery and hang of of the buoy (during transit) is estimated to NOK 100 000,-

Cost Purchase: NOK 100 000,- (estimated cost for a simple model).

3.2.6.3. A-frame/LARS system

A-frames are typically used for ROVs on aft deck of a vessel or more permanent into the ROV hangar on board the vessel.

The project cost received from Sepro for A-frame suitable for the eROV of 15 Te is given below:

Cost Purchase: NOK 5.2 MILL (Sepro)

3.2.6.4. 25t Light Module Handling System (Side Cursor arrangement)

The LMHS is specially designed to deploy and recover subsea modules in a safe and efficient operation.

The system is designed as a stand-alone tower with a single interface to the deck of the vessel. The design allows for installation on a variety of vessels such as PSVs, AHTS and more traditional IMR vessels with and without cargo rails.

Maximum cargo rail size is 3,0m x 1,5m (H x W).

As an alternative the system may also be installed to operate through a moon pool.

By utilizing a slewing structure, the system can land and pick up modules from multiple slots on the deck and does not require use of deck transport systems.

Different shaped modules are easily handled by adjustable prongs and are safely handled through the splash zone by a cursor guide frame with adjustable down force towards the module.

Safe subsea landing and lift-off are ensured by AHC&ART winches for the module and guidewires. This concept could be used if the eROV with cage needs to be recovered to deck or shore. The system requires 450 kVA electric power supply from vessel, alternatively diesel generator on deck.

Figure 28 – Axtech 25 Te Light Module Handling System (Axtech.no, 2017) (Source; Axtech.no (2017) Axtech.no Official Website (online) Available at:http://axtech.no/index.php/system-solutions/25t-light-module-handling-system (Accessed 30.09.2017))

Cost Purchase: 26-30 MNOK

Rental cost/day rate: 20 000 NOK

Installation cost: 600-700 000 NOK (incl. shoreside crane 120 Te for installation)

(Ødegård, Kjell, 2017)

3.2.7. High level cost comparison of towing vs IMR vessel transfer

The example below is for towing the eROV complete with the buoy arrangement from Troll A to Veslefrikk a 2 hrs tow with a transit speed of 13.5 kt. All amounts in NOK.

Table 2 - High level cost comparison of towing vs IMR vessel transfer

Vessel Type	Transit Speed	Cost	Total Cost	Day Rate
IMR vessel	13,5 kt	2 x 33 333	67 000	800 000
PSV vessel	7 kt*	4 x 8 333	33 000	200 000

* Buoy limiting factor for speed

The examples show that if towing transits doubles in time, cost is still half of an IMR vessel.

Even if towing speed is 3 times higher (15 kt vs 5 kt) it is still approximately 35 % cheaper to tow this short distance with a less expensive vessel (Path/transit optimization not included).

3.2.8. Onshore Control Center: Setup and Operations

The concept for RROV and eROV is to control the ROV from a remote location. Onshore Control Centers for remote ROV have already been established and tested by Oceaneering and IKM Subsea. Subsea 7 is planning to establish a center in their main office at Forus.

On Thursday 9th of November 2017 the Company opened the first IOC for Valemon located in Bergen, Norway. This was Norway’s first platform to be remotely controlled from land. The company is planning to open several IOCs in 2018 (Statoil, 2017).

The Martin Linge CCR is also located in Stavanger. This is a Center Control Room for the platform Martin Linge. This project is executed by Total. The operations have not started yet due to a delayed project, but some information has been gathered from Total to learn more from their operational philosophy and setup of the OCC.

From this we see that, ref. the OLF infographic in figure 1:

- The remote operations for platforms are in accordance with Generation 1 (integration across onshore and offshore), and
- The remote operations for ROVs are setup in accordance with Generation 2 (integration across companies).

Looking at the infographic for Martin Linge in figure 29, the remote ROV operations from an OCC have many similarities to Total’s CCR:

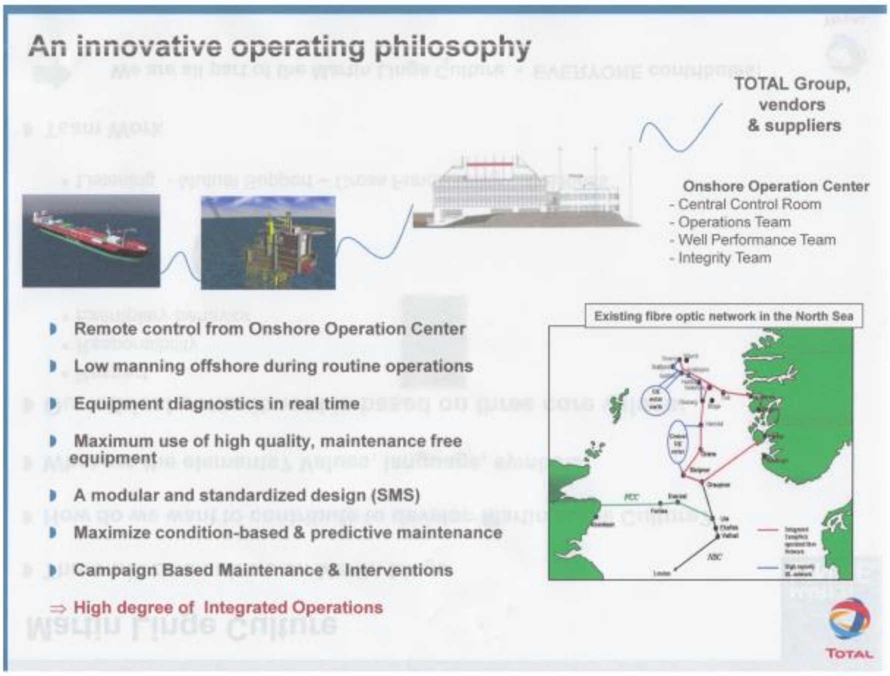


Figure 29 – Martin Linge Operations Philosophy Schematic overview (Sandland, Ellen 2013) (Source; Sandland, Ellen, (2013). Master Thesis - Kontraktsformens utvikling i olje og gassindustrien mellom operatør (Total) og kontraktør, Universitetet i Stavanger Institutt for industriell økonomi,risikostyring og planlegging 11.06.2013)

In discussions with Total, access to a Company presentation was made available by Total. The main objective from this project is to reduce OPEX and increase safety by reducing 60-70 personnel on the platform offshore to a staff of approximately 18 located onshore.

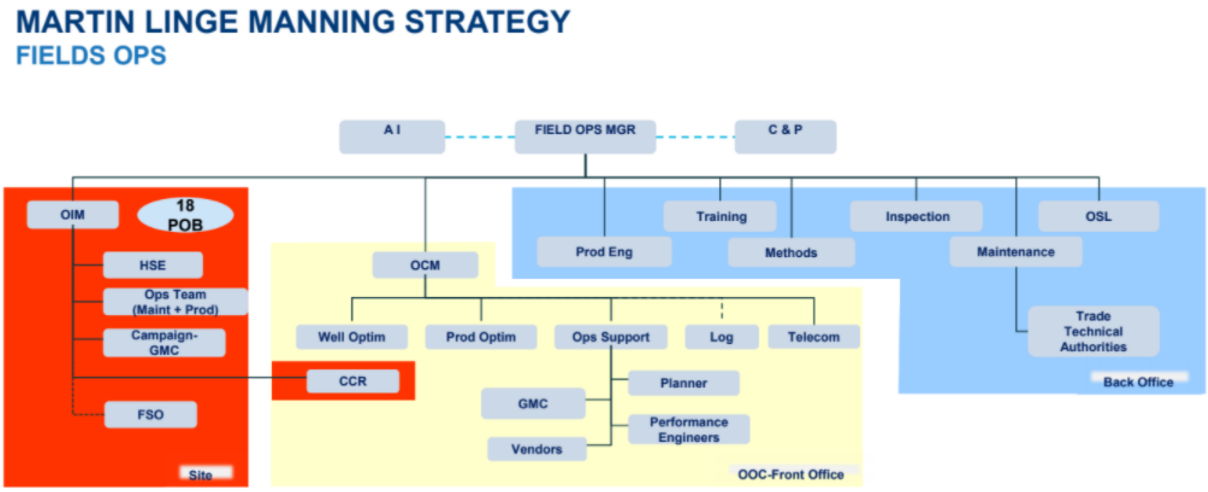


Figure 30 – Martin Linge Manning Strategy (Kvinnsland Steinar, 2017) (Source; Kvinnsland, Steinar, (2017). Re: ML Op. Philosophy (email 25.10.2017, Extract from PPT, Martin Linge Project, Total)

According to figure 30, the onshore Center Control Room (operated 24/7) has a front office (yellow) and a back office (blue) support team for the operations (daytime only).

The two technicians in the CCR belongs to the Offshore organization (red).

The CCR is located in Dusavik, Stavanger, Norway. The facilities were visited 03.11.17 and the introduction to the CCR was given by Steinar Kvinnsland, Total.

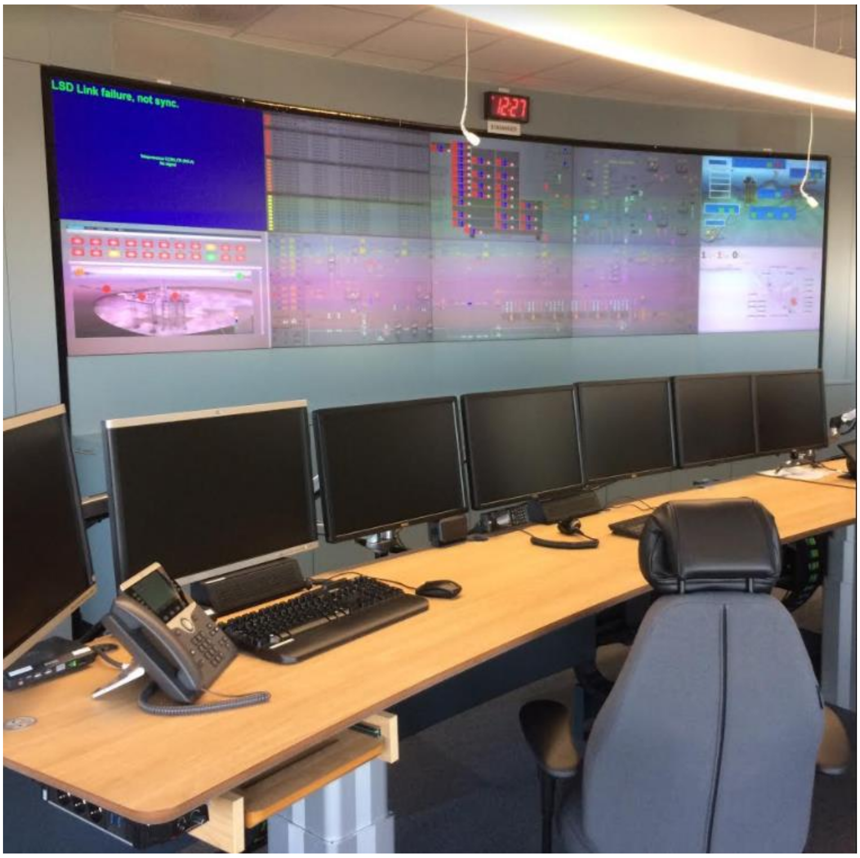


Figure 31 – Martin Linge Onshore Central Control Room (Photo, Bråten, Erik from visit at Total November 2017)

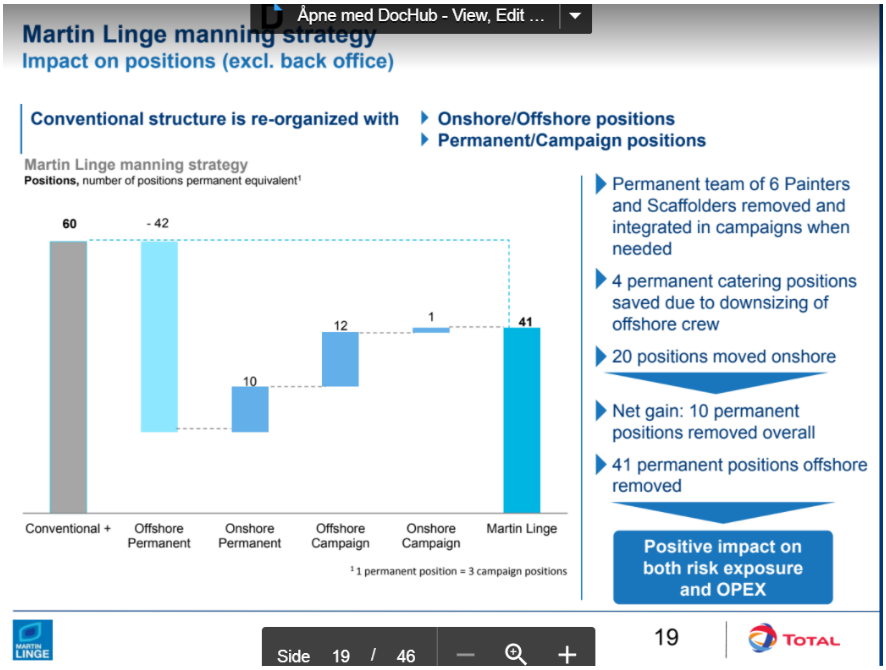


Figure 32 – Martin Linge Manning Strategy (Kvinnsland, Steinar, 2017) (Source; Kvinnsland, Steinar, (2017). Re: ML Op. Philosophy (email 25.10.2017, Extract from PPT, Martin Linge Project, Total)

Current IMR operations using an IMR vessel have functions as Offshore resources/project staff onboard the vessel. Some of these functions/responsibilities will have to be replaced by personnel onshore in a new OCC environment. As a minimum the OM and the SS onboard, the vessel need to be replaced to be part of the day-to-day operations in the OCC.

The Company's internal resources can be more involved in the offshore operations compared to what we see today. For example, the Subsea Engineer/IMR Engineer could follow the job from planning through the offshore operations in such way that the licenses/IMR department could replace the PE/FE in the "day-to-day operations" onboard the IMR vessel.

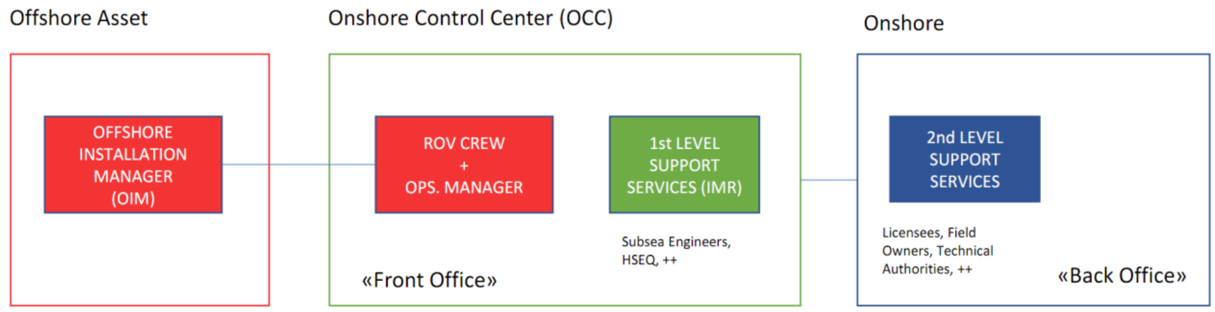


Figure 33 – Organisation Chart Next Generation Operations from an OCC (Bråten, Erik 2018)

3.2.9. Martin Linge: Onshore Rotation

In figure 34 below is the agreed onshore shift rotation from the Martin Linge Project provided by Total. All Process Technicians will rotate functioning as Field Technicians (8 months offshore) 2/4 rotation, and CCR Technicians (8 months onshore). Onshore shifts are 12,5 hrs (day and night - 0.5 hours handover).

According to Total the shift plan below is a result of a complex picture including multiple tariff agreements, AML (Arbeidsmiljøloven) and special/exclusive agreements.

Total is planning to have accommodation available for technicians working on the onshore shift rotation. This accommodation is provided to make the work environment like the work environment offshore. According to Total, this only applies for onshore personnel commuting.

Total also emphasizes that for "hands on" experience it is important to maintain the field competence for all technicians, ref. onshore and offshore rotation periods for 8 months.

Normal plan Onshore

- Nightshift dark blue 18:45 - 07:15 (0,5 hours handover)
- Dayshift in yellow 06:45 - 19:15 (0,5 hours handover)

Plan enighet 13.7.2016

Normal plan

Week/Day	Mon	Tue	Wed	Thu	Fri	Sat	Sun	Hours
1	x	x	x	x	12,5	12,5	12,5	37,5
2	12,5	x	x	x	x	x	x	12,5
3	x	x	x	12,5	12,5	12,5	12,5	50
4	12,5	12,5	12,5	x	x	x	x	37,5
5	x	12,5	12,5	12,5	x	x	x	37,5
6	x	x	x	x	x	x	x	0
							Total	**175**
							Average/we	**29,16666667**

Ferieplan

Week/Day	Mon	Tue	Wed	Thu	Fri	Sat	Sun	Hours
1	x	x	x	x	x	x	x	0
2	x	x	x	x	x	x	x	0
3	x	x	x	12,5	12,5	12,5	12,5	50
4	12,5	12,5	12,5	x	x	x	x	37,5
5	x	x	x	12,5	12,5	12,5	12,5	50
6	12,5	12,5	12,5	x	x	x	x	37,5
							Total	**175**
							Average/we	**29,16666667**

Figure 34 – Martin Linge Operations Planned Onshore shift rotation (Yellow = Dayshift, Blue= Night shift) (Gundersen Frank Indreland 2017) (Source; Gundersen, Frank Indreland, Div. ML OP. Phil (email, 12.10.17))

3.3. Future Scenarios

To elaborate on future technology and operational setup, scenario thinking theory is used. Three phases have been identified; the short-term scenario, the middle term scenario and the "almost impossible" long-term future scenario.

Three different dominant concepts are outlined below. Common for all of them is that they focus on technology. The ROV and Subsea industry appears to be in a paradigm change and the future technology for the powertrains and autonomy is uncertain, but some trends are seen.

ROV systems tend to become more electrified. The words "electric" and "autonomous" are often found in literature about ROV technology.

Wireless transfer of signals underwater is still a challenge. This will most likely be available in the future, but until then the signals can be sent via a 4G buoy as seen in the eROV concept presented earlier.

In general, the need for ROV technology for the Company is high as the number of subsea wells and fields are increasing and aging. There are already 522 wells owned by the Company. A key question is how humans use ROVs in the future and how the operations can be as sustainable as possible.

3.3.1. Scenario I: Probable - Trend Scenario

Continuation of today's ROV operations with limited use of AUVs/eROVs.

This scenario is basically a continuation of today's operations. The trend is that there are more and more autonomous functions built into ROVs.

This scenario uses the eROV when suitable whereas the eROV is deployed and recovered to deck of a vessel using crane or moonpool arrangements. The IMR vessel can leave worksite while the eROV works independently and are controlled from an OCC. When the task is completed the IMR vessel picks up the eROV for recharge, or replaces the eROV, if the Company has multiple eROVs available for operations to continue.

Technical requirements and support for scenario I:

- IMR vessel
- eROVs (AUVs)
- Onshore Control Center with remote piloting for on demand operations

3.3.2. Scenario II: Desired – Normative Scenario

This scenario requires a subsea infrastructure supporting the eROV with a hub/charging station. The eROV belongs to its area/hub and are towed from one location to another location. The eROV could also be supported by large vessel with moon pool/crane for recovery and deployment of the eROV (IMR vessel).

The eROVs is working in its dedicated areas as seen in figure 35 below. The eROV has limited vessel support and one docking station within its area. As an example, area 5 has Sleipner A as the main hub.

The eROV can operate independently until the battery is drained. The eROV then needs support from a vessel (IMR or modified PSV) for towing or relocation to the charging station (hub) for battery recharge. The most inexpensive and cost-efficient vessel should be chosen for the towing operation to cut costs.

All eROV operations are controlled from the OCC.

This scenario also expects more use of tooling skid packages for the eROV and more and more components are electric - meaning less and less hydraulic systems on the ROV.

The docking/charging stations ROV in the subsea infrastructure will in the future be used for the AUVs maneuvering from one area to another independently. Towing from one location to another will be less required because AUVs technology replaces this support function over time. In addition, battery capacity is believed to improve soon.

3.3.2.1. ROV Clusters: Example of workable areas

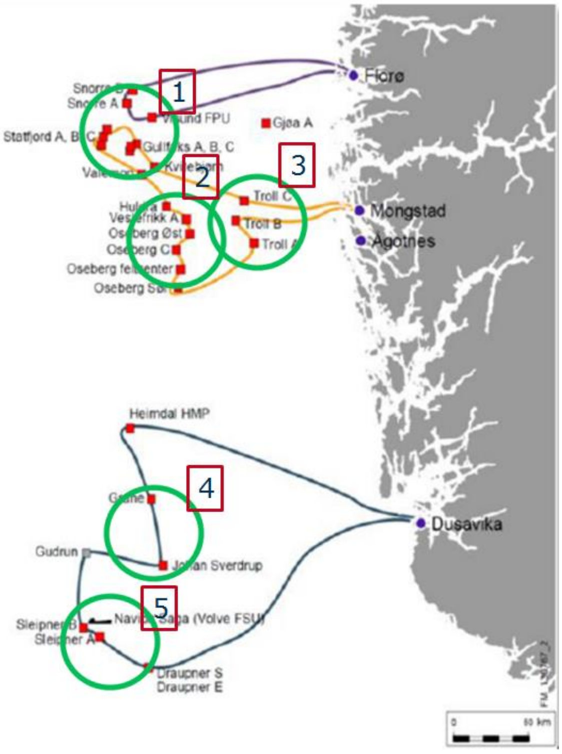


Figure 35 – Example of Cluster/area with high ROV activity. Troll/Oseberg, Tampen, Frigg-Heimdal and Sleipner area (Amended - Source; http://transportlogistikk.norskindustri.no/siteassets/dokumenter/foredrag-2016/17.okt.-q1-kl.-11.40-eklof-monstad.pdf?id=72115)

Imagine that the areas with high IMR activity is divided into areas hosting one or several ROVs. In figure 35 above, areas have been identified to illustrate a concept of infrastructure with charging/docking stations to support the eROV.

In this scenario the eROV operates for 2 months, which is extended time of operations from what we see today and is replaced on Hard Time maintenance philosophy every second month. When operational experience is gained this maintenance philosophy t interval can be changed accordingly to optimize operations.

Technical requirements and support for scenario II:

- IMR vessel (for recovery and deployment complete with crane)
- PSV (support, relocation/towing of ROV)
- eROVs (AUVs)
- ROV Planner Management tool - for planning and executing ROV operations
- Subsea infrastructure hubs/charging stations (Subsea USB connector)
- Onshore Control Center (remote piloting) (24/7 operations)

The feasibility analysis section describes in detail the scenario for completing an ROV inspection using scenario II, ref. chapter 4.

3.3.3. Scenario III: Possible – Contrasted Scenario

Scenario III is a continuation of alternative II and the subsea infrastructure (hub/charging stations).

Scenario III has limited or nearly no use of IMR vessels for routine and inspection work. All systems and components are electrified. eROVs and AUV/UIDs have multiple docking stations, adding more flexibility to operations.

The request for an unmanned autonomous surface vessel (ASV) to support the operations with crane (lift line) or tooling are made automatically based on input given from the Subsea Engineer planning the job. Use of a manned support vessel for towing the eROV from one location to another location is phased out. The autonomous (unmanned) surface vessels are taking over these tasks until technology and infrastructure allows for full autonomy from location A to B. In the long perspective the AUV can navigate independently from one location to another. All operations are controlled from the OCC.

“On-demand mobility” is shared as a commodity among several operators (different business model than we see today) via an online marketplace, sharing ROVs and services. Other industries such as fish farming and offshore wind mills will also use this market place to get access to ROVs and services.

3.3.3.1. Autonomous Surface Vehicle (ASV)

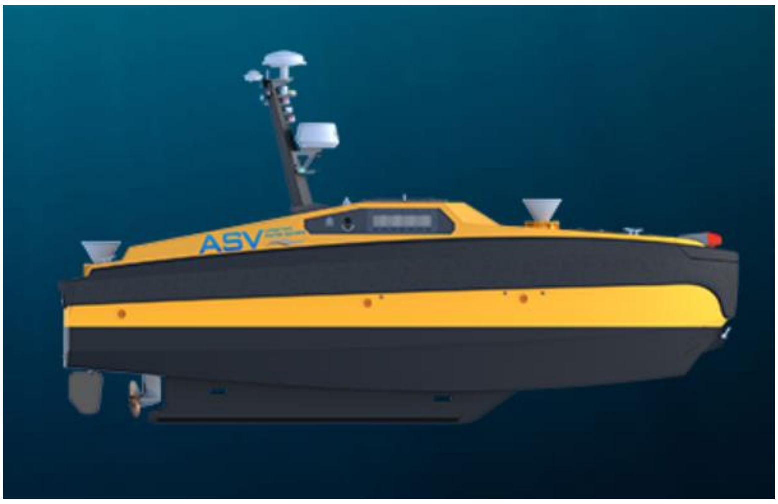


Figure 36 - Autonomous Surface vessel (ASV). (Asvglobal.com, 2017) (Source; Asvglobal.com (2017), Official Website (online). Available at: https://www.asvglobal.com/products/ (Accessed 29.09.2017))

The vessel in figure 36 above is an Autonomous Surface Vessel (ASV) called C-Worker 8, a multi-role work class ASV. This technology is currently available. In the future it is imagined that the ASV has a crane for subsea lifting and supports the ROV for hatch operations, etc.

Technical requirements and support for scenario III:

- Limited/no use of IMR vessel for routine/inspection tasks
- eROV/AUV
- ROV Planner Management tool - for planning and executing ROV operations
- Subsea infrastructure hubs/charging stations (subsea USB connector - multiple stations in one dedicated area)
- Onshore Control Center (remote piloting) (24/7 operations)
- Enhanced Autonomous Surface vessel with crane or lifting arrangements
- Online Business Model (online marketplace - also available for other industries)

3.3.4. Chosen Scenario

This master thesis will mainly cover scenario II because this technology is under development and the at the same time the operational context is not given yet. The fact that the operational model supporting this technology remains unknown makes it even more interesting to choose this scenario. In addition, the eROV concept is electric and a game changer if technology and operational model can be implemented successfully.

Scenario I is less interesting because it is a continuation of today’s practices, and scenario III contains too many unknowns to perform a more detailed analysis.

4. FEASIBILITY ANALYSIS: FUTURE SCENARIO II

This feasibility analysis chapter focuses on scenario II outlined previously and focuses mainly on the cost and the Company's capabilities using existing resources, which in short are:

- Modified PSVs to support relocation/towing of eROV
- eROVs
- ROV Planner Management tool - for planning and executing ROV operations
- Future Subsea infrastructure hubs/charging stations (Subsea USB connector)
- Onshore Control Center (remote piloting) (24/7 operations)

4.1. Cost Feasibility Study

To understand the overall cost for a new operations model, a cost feasibility study has been undertaken, simulating an operation where the OCC is set up onshore:

- 5 eROVs are available in this scenario, one in each area (excluding area 6, north).
- Two ROV pilots/supervisors are available 24/7 in addition to an Operations Manager (Company representative) who is overall responsible for the operations located in the OCC.

Cost of front office and back office similar to the Marin Linge operations is not included in the cost listed in this section (ref. chapter 3). The five independent eROVs have their dedicated hubs/clusters and perform work within their area upon request.

A support vessel towing the eROV from one location to another is used to simulate the eROV being able to be moved from a worksite to the next worksite. The support vessel has a more inexpensive day rate (or hourly rate) versus transit with an IMR vessel.

The following assumptions regarding costs are made:

4.1.1. Estimated OPEX cost

Table 3 - Estimated OPEX cost

Description	Cost (NOK)
eROV system complete with communications and Buoy	15 000 per day
Telecommunications	Included in the day rate for the ROV
Operating 24/7 ROVs requires minimum 4 crew day rate (10 000 per operator per day)	40 000 per day
Hard Time Mobilisation/demobilisation NOK 200 000,- each 6 annual replacements of each ROV	1 200 000 per year
Fixed Admin Cost OCC (admin, maintenance, data storage, IT, facilities etc)	90 000 per month

Total cost per day:

Table 4 - Estimated OPEX cost per day

Description	Cost (NOK)
eROV (5 x 15 000)	75 000
Hard Time Mobilisation/demobilisation of ROV (30 mobilisation per year a NOK 200 000)	16 500
ROV Personnel	40 000
Admin cost of OCC	3 000
Subsea Operations Manager (replacing OM and SS onboard IMR vessel)	20 000*
Total OPEX Cost Per day	**154 500**
Total OPEX Cost Per day per area (5 areas)	31 000
Total OPEX Cost Per hour	6 437
Total OPEX Cost Per hour per area (5 areas)	1 300

* Company Responsible Subsea Engineers (IMR or License) will issue applicable Task Plans required and support the operation and are therefore seen as sunk cost in this cost picture.

More information and extract from spreadsheet is made available in Appendix III.

4.1.2. Estimated CAPEX cost

Modification of 3 vessels: One vessel for each location: Mongstad, Florø and Dusavik to gain the operational flexibility and the function of moving the eROV from one location to another location within the dedicated area.

Table 5 - Estimated CAPEX cost

Description	Cost (MNOK)
Winch and chute arrangement: 7 MNOK x 3 vessels	21 (excluding installation cost)
Battery/Hub location - Subsea USB - retrofit setup including battery packs: 5 x NOK 4 085 000	20,4 (excluding installation cost)

All subsea equipment (subsea battery packs, subsea USB connectors etc.) and additional temporary vessel equipment (operation/installation aids for towing) listed below is suggested to be implemented into the Company's Tool pool and shared:

4.1.2.1. Subsea Infrastructure: ROV charging station budget cost

Summarized after a meeting with the company Blue Logic, the following components are required order to set up a charging station at a template/manifold with Blue Logic supplied components:

Table 6 – ROV charging station budget cost

Description	Cost (NOK)
Tronic complete with cable to junction box	120 000
Subsea junction box (can) complete with penetrators	45 000
Cable and connection for each retrofit Subsea (each)	120 000
Internal electronic for topside safety of system	65 000

Description	Cost (NOK)
2 Kw Subsea USB each connection (min 2 each location to speed up charging) = minimum 4 Kw	100 000
ROV Panel	35 000
Subsea battery (100 kwh) (power bank)*	3 500 000
Ca. NOK 585 000,- per charging station (including Blue Logic Subsea Battery Pack - approx 1 500 kg)	4 085 000

(Eide, Helge S., 2017)

* The Company is involved in Batwind, an innovative battery storage solution for for offshore windmills. This solution has not been evaluated as an option (Statoil, 2017).

4.1.3. Planned Inspection Hours (2017)

As a basis for the cost feasibility study the annual 2017 ROV inspection hours for Subsea Assets North, South and West given by the Company is used. It shows that there are 1 593 hours of ROV inspection planned for 2017.

To account for WOW and Transit for a standard IMR operation a factor of 1,4 is used.

- North: 321 hrs
- West: 864 hrs
- South: 408 hrs

Total hours: 1 593 x 1,4 (incl. WOW and transit) = 2 230 hrs x NOK 33 333,- = NOK 75 mill. cost if all hours are completed with an IMR vessel.

Cost of 100 days of annual ROV inspection with an IMR vessel indicates a cost of NOK 80 mill, excluding MGO. Approximately 100 days of annual ROV inspection was the number given by Company in the early phase of the thesis.

All other IMR jobs jobs that do <u>not</u> require any crane/liftline (support vessel) or other tooling should be included in this total number to fully understand how to maximize and utilize the eROV concept. The total number of hours for these kind of operations remains unknown and are not part of this study but should be investigated in detail. This is therefore added to recommendations for further work section.

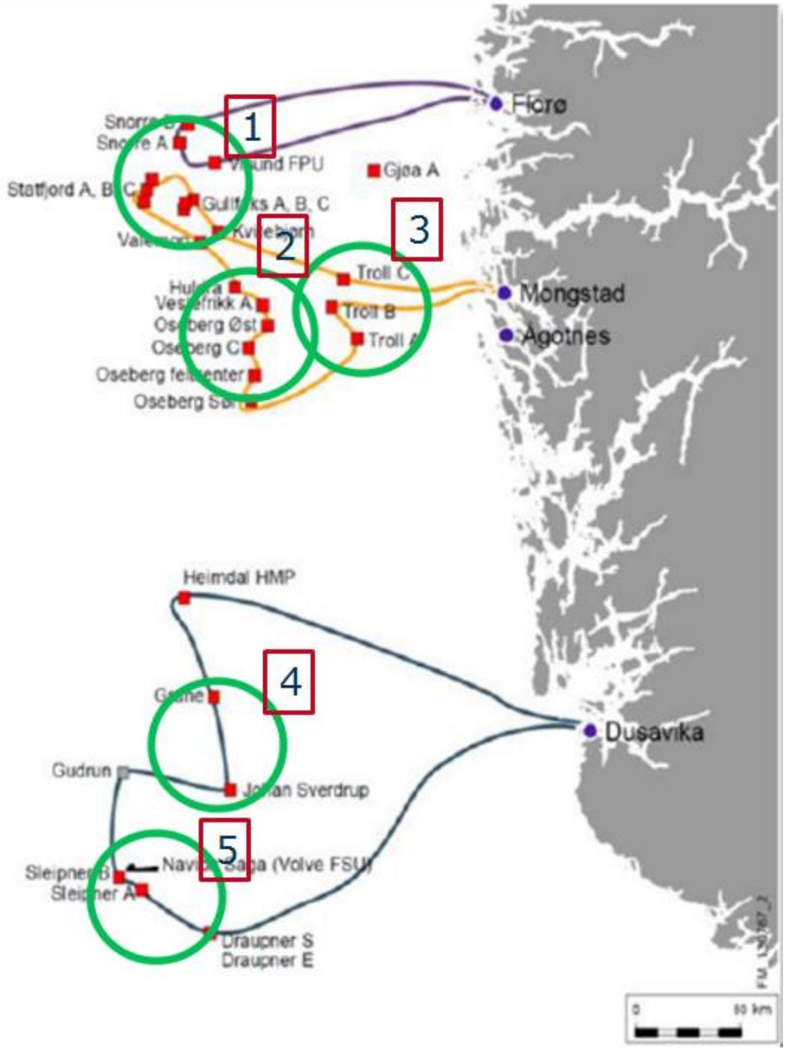


Figure 37– ROV dedicated area overview 1-5 (Amended - Source; http://transportlogistikk.norskindustri.no/siteassets/dokumenter/foredrag-2016/17.okt.-q1-kl.-11.40-eklof-monstad.pdf?id=72115)

If the Subsea Asset ROV inspection estimates are placed into the selected areas (1-5), as described in the future scenario section, this gives the following figures:

- Area 1: 363 hrs
- Area 2: 327 hrs
- Area 3: 183 hrs
- Area 4: 223 hrs
- Area 5: 180 hrs
- Area 6: (north) 321 hrs (not shown in overview)

4.2. Simulating use of the ROV Planner for Area 5

In this section the Annual 2017 Subsea Asset ROV inspection hours for area 5 is used to simulate a case with the eROV being towed from one location to another utilizing a PSV in a optimized sailing pattern. A PSV at a day rate of NOK 200 000 has been used.

As a base case the area has one charging/docking (subsea battery pack) location to a CAPEX cost of NOK 585 000,- (NOK 4 085 000,- complete with subsea battery), excluding installation cost.

This exercise is done to simulate what the ROV planner could optimize if PSV sailing patterns combined with planned annual 2017 subsea asset inspections hours were entered into the ROV planner tool to optimize the operations.

Area 5 has 180 hours of inspection planned for 2017. The inspection hours are distributed as follows:

- Draupner: 75 hrs
- Gina Krogh: 43 hrs
- Sleipner: 62 hrs (Sleipner A, B, R, T)

This exercise assumes the following as initial status:

- Docking/charging location (ROV hub) is imagined to be located at Sleipner A.
- Max operational eROV battery capacity is set to 24 hrs of operations.
- With only one changing station in this cluster means that the ROV needs to do additional towing in order to charge between every inspection period of 24 hrs duration.

The objective is to calculate the cost and simulate the hours spent on these operations using a modified PSV vessel vs. using a more expensive IMR vessel. The proposed ROV Planner tool could be used to perform such calculations automatically to optimize transit and relocation of the eROV.

4.2.1. Step by step inspection program

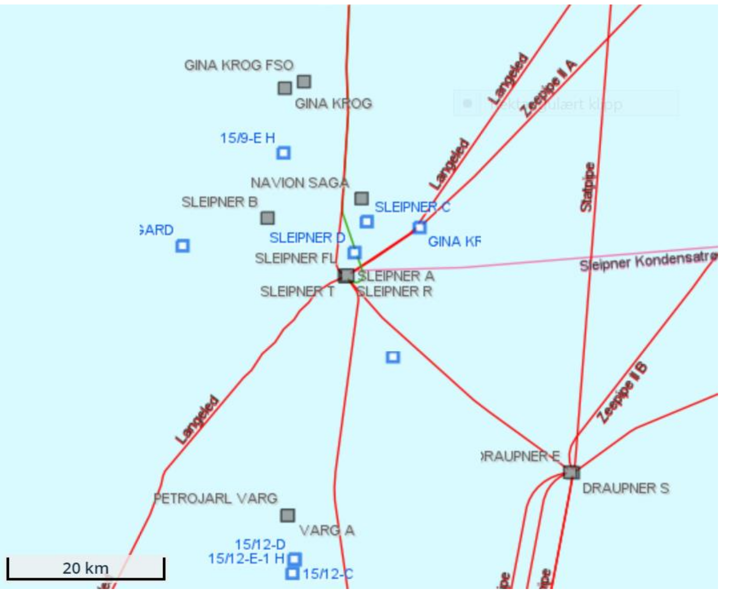


Figure 38 – Area 5, Sleipner A identified as the Hub/charging station for the eROV (kystverket.no, 2017)

The following inspections are to be carried out in sequence:

1. Sleipner A - Periodic ROV Platform Inspection 18 hrs
2. Sleipner R - Periodic ROV Platform Inspection 15 hrs
3. Sleipner T - Periodic ROV Platform Inspection 14 hrs
4. Sleipner B - Periodic ROV Platform Inspection 15 hrs
5. Gina Krogh - Periodic ROV Platform Inspection 43 hrs (24+19 hrs)
6. Draupner - Periodic ROV Riser and Platform Inspection 75 hrs (24+24 +24 + 3 hrs)

The starting point for the ROV is Sleipner A location. The ROV is at site, fully charged:

The following schedule/sequence has been simulated:

	A	B	C	D	E
1	Sequer	Vessel	From	To	Action
2	1	ROV 5	Sleipner A (Hub)	Sleipner A (Hul	Inspection
3	2	ROV 5	Sleipner A (Hub)	Sleipner A (Hul	Charging
4	3	ROV 5	Sleipner R	Sleipner R	Inspection
5	4	ROV 5	Sleipner A (Hub)	Sleipner A (Hul	Charging
6	5	ROV 5	Sleipner T	Sleipner T	Inspection
7	6	ROV 5	Sleipner A (Hub)	Sleipner A (Hul	Charging
8	7	Far Sun	Sleipner A (Hub)	Sleipner B	Tow
9	8	Far Sun	Sleipner B	Sleipner A (Hul	Transit
10	9	ROV 5	Sleipner B	Sleipner B	Inspection
11	10	KL Brofjorc	Sleipner A (Hub)	Sleipner B	Transit
12	11	KL Brofjorc	Sleipner B	Sleipner A (Hul	Tow
13	12	ROV 5	Sleipner A (Hub)	Sleipner A (Hul	Charging
14	13	Far Sun	Sleipner A (Hub)	Gina Krog	Tow
15	14	ROV 5	Gina Krog	Gina Krog	Inspection
16	15	Far Sun	Gina Krog	Sleipner A (Hul	Transit
17	16	KL Brofjorc	Sleipner A (Hub)	Gina Krog	Transit
18	17	KL Brofjorc	Gina Krog	Sleipner A (Hul	Tow
19	18	ROV 5	Sleipner A (Hub)	Sleipner A (Hul	Charging
20	19	Far Sun	Sleipner A (Hub)	Gina Krog	Tow
21	20	ROV 5	Gina Krog	Gina Krog	Inspection
22	21	KL Brofjorc	Sleipner A (Hub)	Gina Krog	Transit
23	22	KL Brofjorc	Gina Krog	Sleipner A (Hul	Tow
24	23	ROV 5	Sleipner A (Hub)	Sleipner A (Hul	Charging
25	24	Far Sun	Sleipner A (Hub)	Draupner	Tow
26	*25*	*Far Sun*	*Draupner*	*Sleipner A (Hu*	*Transit*
27	26	ROV 5	Draupner	Draupner	Inspection
28	27	Far Sun	Draupner	Sleipner A (Hul	Tow
29	28	ROV 5	Sleipner A (Hub)	Sleipner A (Hul	Charging
30	29	Far Sun	Sleipner A (Hub)	Draupner	Tow
31	*30*	*Far Sun*	*Draupner*	*Sleipner A (Hu*	*Transit*
32	31	ROV 5	Draupner	Draupner	Inspection
33	32	Far Sun	Draupner	Sleipner A (Hul	Tow
34	33	ROV 5	Sleipner A (Hub)	Sleipner A (Hul	Charging
35	34	Far Sun	Sleipner A (Hub)	Draupner	Tow
36	*35*	*Far Sun*	*Draupner*	*Sleipner A (Hu*	*Transit*
37	36	ROV 5	Draupner	Draupner	Inspection
38	37	Far Sun	Draupner	Sleipner A (Hul	Tow
39	38	ROV 5	Sleipner A (Hub)	Sleipner A (Hul	Charging
40	39	Far Sun	Sleipner A (Hub)	Draupner	Tow
41	*40*	*Far Sun*	*Draupner*	*Sleipner A (Hu*	*Transit*
42	41	ROV 5	Draupner	Draupner	Inspection
43	42	Far Sun	Draupner	Sleipner A (Hul	Tow
44	43	ROV 5	Sleipner A (Hub)	Sleipner A (Hul	Charging

Figure 39 – Area 5, Detailed Inspection Schedule including towing and transit (further details found in Appendix III) (Source, Bråten, Erik 2017)

The eROV performs the inspection after being towed and left at location. The eROV is controlled from the OCC. Vessels supporting the eROV are optimized using the ROV planner to source the vessel located closest to the eROV to support the operations. This involves towing the eROV from the hub to location. In this scenario additional time has been added to handle the buoy for hookup and release time, vessel operation is started and completed. The PSV then detours its sailing pattern and perform the tow with the eROV and buoy.

Technically the buoy is caught, lifted and locked into the dedicated vessel davit, then the liftline is lowered and connected to the eROV lifting point. The eROV assists in this hook-up and uses standby or emergency power packs for this operation, if main battery is fully drained. The eROV and its cage is then lifted off seabed and the towing operations can commence. After the tow is completed, the eROV is lowered down on the seabed in addition to releasing the buoy in the davit at the next worksite.

The PSV then shortcuts back to its original sailing pattern and continues its operations. Once the eROV battery is drained or operations completed a request for a new tow is planned in the ROV planner. The closest PSV or available vessel then detours its sailing pattern and brings the eROV and buoy locked in the davit to next location. A deep cycle battery charge is then performed or the eROV is being towed to next inspection location, if battery power is found to be sufficient to complete the next planned operation. The ROV Planner will calculate and optimize the vessel planning in order to maximize the whole operation. As seen above several of locations have more than 24 hours of inspection, meaning that the eROV needs to be relocated to hub for recharge several times in order to complete the inspection program at location.

While one eROV is towed or being charged the ROV personnel in the OCC can take control over another eROV and perform tasks at other locations. This is resource management, an efficient way of using staff reducing standby waiting time for the ROV personnel involved.

4.3. OPEX cost of Inspection of Area 5 using the eROV concept combined with towing

The cost of the Annual Subsea Asset for Area 5 is:

- The estimate cost of towing used in case is NOK 8 333,- per hour*
- The estimate cost of inspection used in case is NOK 44 200,- per hour*

Summary:

Towing cost: NOK 511 846,-*

Inspection cost: NOK 7 956 000,-*

Estimated total OPEX cost for ROV inspection of area 5 = **NOK 8 508 000,-***

* Based on a base case of 1275 inspection hours and the assumptions for hourly cost of operating OCC and towing cost are correct, excluding MGO. Full details are found in Appendix III.

4.3.1. OPEX cost of Inspection of Area 5 using traditional IMR vessel

As a comparison to the OPEX cost for for future scenario II the OPEX cost as of today's operational model, using an IMR vessel, is shown for information only.

The total Opex cost of ROV inspection using an IMR vessel for area 5 is estimated to 180 hrs x 1,4 x NOK 33 333,- excluded MGO = **NOK 8.400 000,-**

5. EVALUATION OF SYSTEM CAPABILITY: FUTURE SCENARIO II

Based on the evaluation of the scenarios I, II and III, scenario II was chosen, and this chapter is an evaluation of this concept.

5.1. Introduction

The new eROV technology allows work to be performed independently without a supporting vessel. Successful trials by the Company and eROV service provider have been completed.

Incentives for removal of the umbilical between the ROV and vessel have existed for many years. This was confirmed in a meeting with Olav Bruseth and Erich Luzi 29.03.17 in the Company, where an introduction to the Swimmer project was given. The JIP consisted of Statoil, Oceaneering, Technip and Total (1990s). However, in 2017 - 25 years later - the vessel and the ROV are still connected.

Today's operations require an IMR vessel at all times due to the umbilical. The day rate for an IMR vessel will depend on the market situation, but a typical IMR vessel day rate is NOK 800 000 plus marine fuel. This includes the vessel and ROV crew, typically 2 WROVs and one Observation ROV. Today's operations are planned to perform several IMR jobs at the same location to limit the vessel transit time.

In addition to the cost of operations, all waiting on weather (WOW) and transit time cost is commonly allocated according to number of wells per field ("brønnfordelingsnøkkel").

This means that the actual cost is higher than the budgeted cost for each IMR operation given by the contractor. Feedback from the Company is that this could be 20-30 % (even 40% is mentioned) higher than the budget given. But given that the Company has a high volume of IMR work and that inspection work can be completed when operational weather is not acceptable for any IMR operation, ROV annual inspection work can be completed. This means that this work could be completed as a fill-in job. It could therefore be argued that the subsea asset annual inspection work is used to limit WOW. The cost for WOW will therefore also be less for the Company than any other small operator which cannot divide the cost of WOW and transit on many jobs.

With new eROV/RROV technology available, future operations can be completed without the cost of the vessel supporting the eROV at all times. Some operations will still require vessel support or crane operations.

If no vessel is required to support the operation, the day rate for the vessel can be excluded from the cost. In this case only the cost for transit and towing of eROV to the location will apply, in addition to the cost of operating the OCC. This means that the high cost of an IMR vessel hire can be saved.

Towing operations could be optimized by using available vessels via a computer-based ROV planner tool. The ROV planner tool could also be used to offer ROV services to other operators and industries adding commission to internal Company cost.

5.2. Digitalization

In the theory review work processes were evaluated and it was found that there are many manual actions, including many emails sent with attachments instead of using smart IT platforms. The ROV planner tool described previously could change this, storing information in a common place for all parties involved. Using cloud technology can improve work processes being leaner.

In addition, the ROV path optimization should be looked into in more detail. The question was asked earlier as to why ROVs do not have ROV paths and optimized routes of travel like roads, airways and trains. In the National Transport Plan (2018-2029) (Meld. St.33) page 37 it is stated that: *“Digitalization and ITS can contribute to more efficient and intermodal transport services, better utilization of total transport capacity and reduced costs”.*

The Company has great understanding of planned ROV inspections. Better planning and optimization could lead to higher efficiency.

To simulate a digital platform such as the ROV planner, some mockups have been created for illustration purposes as seen in figure 40. Further screenshots and details are found in Appendix IV.

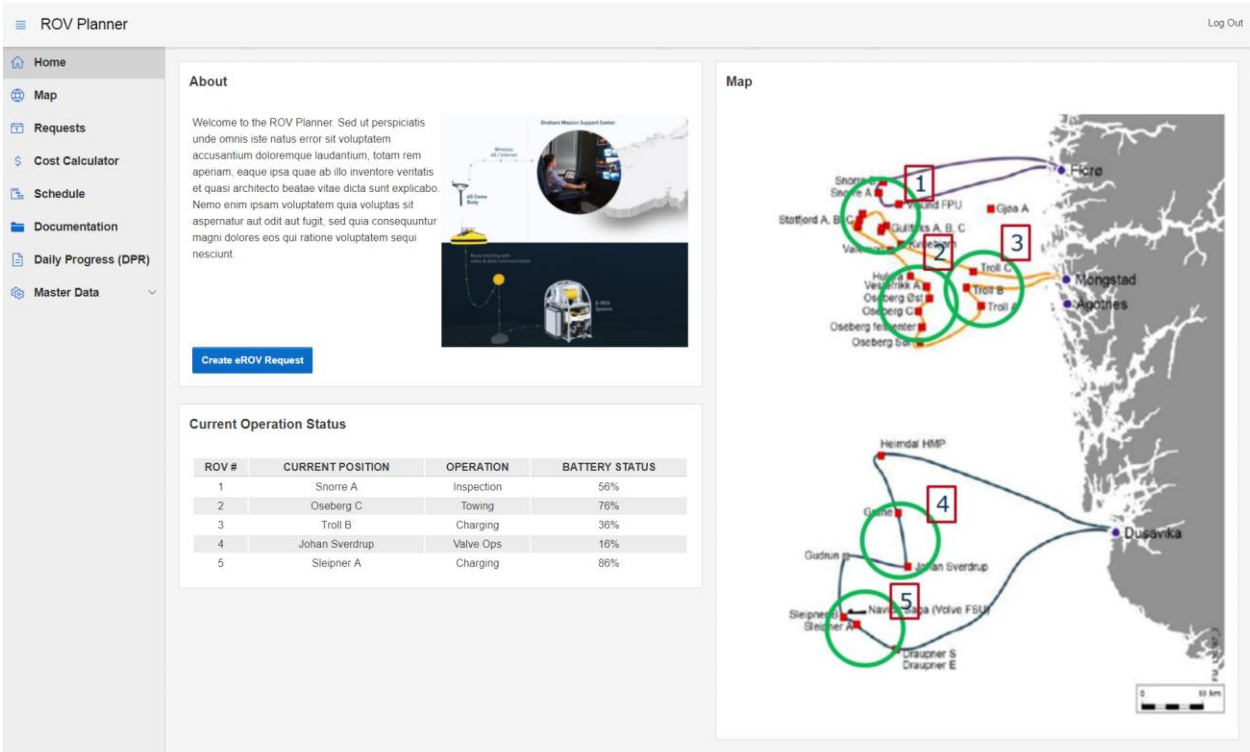


Figure 40 – ROV planner showing dashboard page (Source; Bråten, Erik 2017)

5.3. New business models and business model architecture

In the future we could possibly see more sharing of available ROVs between oil companies. The oil operators need to come together and agree to cooperate to work smarter than today's silos and frame agreements. Compared to the automobile industry shift, where car manufacturers believe that they in the future are more a Mobility Service Provider, making automobiles accessible on demand for the consumer – instead of all consumers owning their own car. This shift is ongoing in the Volkswagen Group.

Could the Uber model be used in the future for ROV operations? In such a case the ROV companies would replace the Drivers in figure 3 and the licensees would replace the Riders. The cloud based ROV Planner (outlined in Chapter 3 and in Appendix IV) would then be the technology platform and the link between the companies involved. In such a business model the ROVs would be made available or accessible in a dedicated area, controlled from a remote location.

Several ROV service providers could offer their services (OCC) to the Company. ROV service provider 1 could offer the ROVs controlling area 1 and ROV service provider 2 could offer ROVs for area 2.

Several ROV service providers and multiple OCCs would ensure a healthy competition in the market and a drive for technology development.

This solution would need a new mindset from people involved and a transformation of the current business platform. This ties into concepts such as Mobility as a Service (MaaS) and Transportation as a Service (TaaS) which is seen more in general society.

The business model canvas in figure 41 below is based on future scenario II. It indicates that the Company is in a unique situation regarding existing capabilities and future required resources adapting to new technology if introducing the eROV concept operationally.

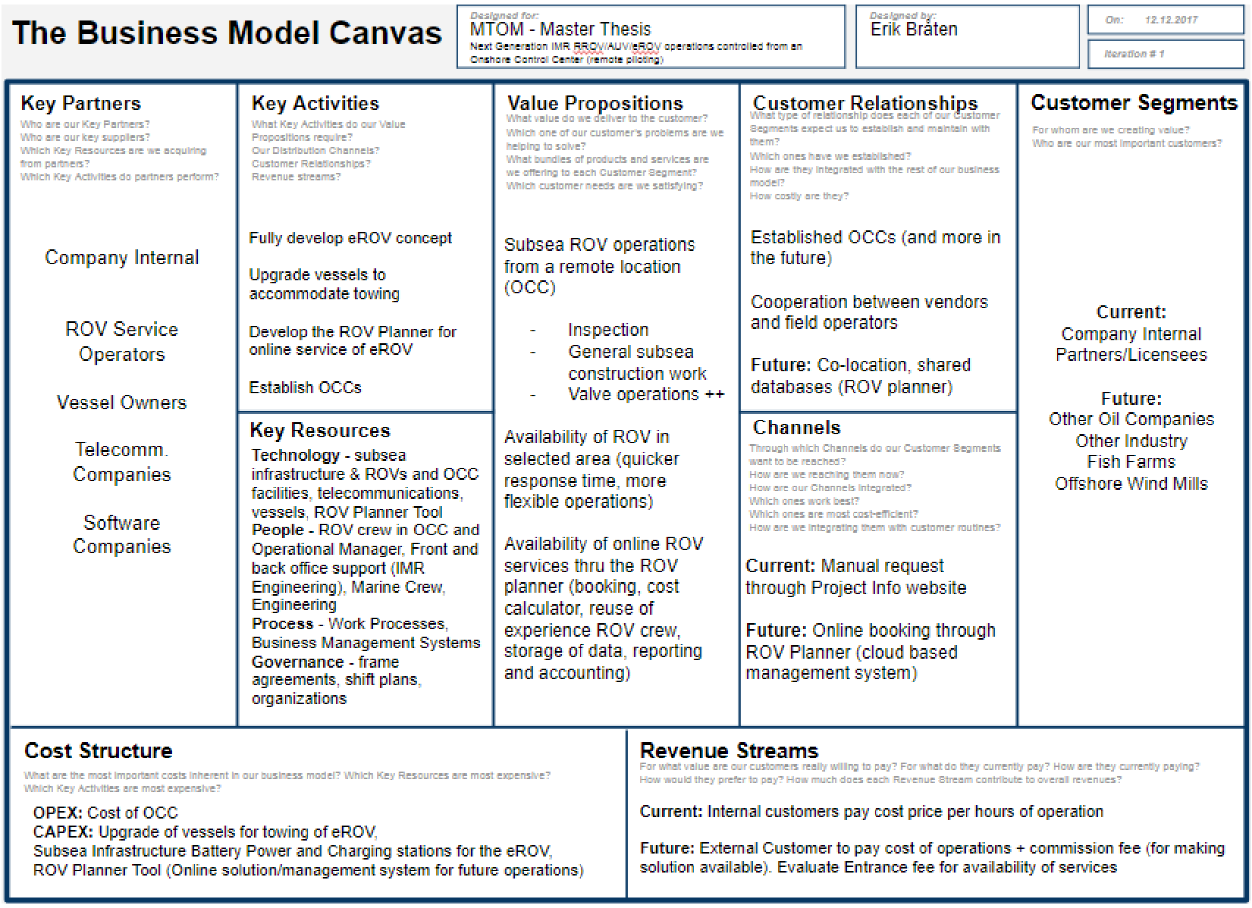


Figure 41 – Business Model Canvas for future operations

5.4. Resource Capabilities (Sharing, Tool Pool)

As outlined in the overview of Company's resources, the Company has an existing "Tool Pool" concept for sharing of tooling among all licensees. It introduces benefits, cutting and sharing cost for the Company as a whole.

The remote piloting concept is based on having ROV personnel centralized (onshore) and smart use of resources (sharing of personnel). The cost of personnel is much higher than the technical assets required for an operation (buoy, eROV, rigging, etc). Instead of having dedicated ROV personnel at site (vessel/rig), the remote piloting concept opens the opportunity for a small team to be controlling the eROVs at multiple locations. This is supported by sharing theory and the resource-based view (RBV) of assets and personnel (Barney J.,1991).

The Company is in a unique situation when it comes to available resources (capabilities):

- Smart use of supporting vessels for towing operations is a resource adding value to the eROV concept.
- Using existing chartered vessels smarter is hard to adopt at scale for other companies meaning doing business differently than competitors.
- The overall business concept is costly to copy due to complex marine operations and logistics.

- The organization can be better exploited, using existing resources, making organizational changes to suit the eROV concept.

An interesting consideration for the remote ROV operation is that the Company is in a position where it can act as the principal in the value chain. The Company is large enough to change the operational context without having to depend on third parties. High number of wells and marine operations gives the Company operational benefits and competitive advantage.

5.5. Factors driving a change into electric ROVs controlled from remote locations

The trend seen is that ROVs become more and more electrified. Electric torque tools are available on the market. Manipulators with feedback signals will be available in the future. If the ROV is fully electric and all tools are electric there is no need for an HPU which drains the battery fast.

Technology advancement leads to lower cost of batteries, data transfer and data storage. The oil and gas industry needs to cut cost and be more sustainable. Future AUVs will also most likely be safer, have more precise manipulators being able to use torque tools, and tooling in general will be more elegant via use of sensors and electronics. This would mean less damage to ROVs, tooling and subsea assets.

5.6. Factors and constraints that may impact or slow down eROV adoption

- Business models need to be changed through new frame agreements. It is challenging to replace existing frame agreements as new models of operations are developing.
- Current eROV battery capacity/technology has some uncertainty because it is new technology with no documented history.
- Electric ROVs will always have some restrictions on power and recharging will take additional time even when new technology is improved.
- Subsea hub/charging stations are not available in subsea infrastructure. It is time consuming, expensive and difficult to build infrastructure that will suit all subsea fields. Areas with high IMR activities should be prioritized.
- Relocation of the eROV from one location to the next work site is required. Towing operations or recovery, transit and deployment constraints use.
- Onshore organization setup needs to be changed/modified to suit the OCC.
- Deployment and recovery of the eROV spread from any vessel is time consuming. Similar weather buoy operations indicated minimum 2 hours for deployment from deck to seabed and 5 hours for recovery from seabed to deck. It is believed that this operation will take significantly shorter time when optimized and experience is gained. Excessive time spent on deployment and recovery can therefore extend towing operations without impacting the cost of towing. The Company has indicated that it is working towards using two hours

for deployment from deck to seabed and two hours for recovery to deck of vessel for a total of 4 hours.

All the main constraints listed are challenges that must be solved in order to make the remote eROV concept operational. The Company needs to make a high level management strategic decision in order to establish the infrastructure required to support the eROV concept.

According to the article ”Skal fjernstyre oljefelt fra Bryne” in Dagens Næringsliv (DN 24.08.2017 p.17), Gro Stakkeland in Statoil states that “...*it is important to work together to work differently. Technology by itself will not change competitiveness, in order for us and the suppliers to make money. We need to use technology correctly and not be afraid to invest in technology. It is also important to focus on finding the right area” (Ånestad, M., 2017).*

This statement is also supported by the theory review where it was stated that technology alone seldom drives value. People, processes and governance also play important roles (Rosendahl T. & Hepsø V., 2013 p. 5).

The Company could learn from the current development in the automobile industry, in which a network of car manufactures have signed a Memorandum of Understanding to create a charging network in Europe: *”Stuttgart, November 29, 2016, BMW Group, Daimler AG, Ford Motor Company and Volkswagen Group with Audi and Porsche have signed a Memorandum of Understanding to create the highest-powered charging network in Europe. The goal is the quick build-up of a sizable number of stations in order to enable long-range travel for battery electric vehicle drivers. This will be an important step towards facilitating mass-market BEV adoption.“* (Daimler, 2016).

Similarly, the Company needs to agree with all involved parties (subsea fields) on a charging network to make the eROV concept successful and where the proposed infrastructure could be applied. This is seen as a top management decision.

5.7. Environmental Perspective

A typical IMR vessel has a consumption of 500 m3 MGO per month, which is 6 000 m3 per year. The average CO2 generated is 1 400 Te per month and 16 500 Te per year. This equals 45 Te CO2 per day.

Converted into more understandable figures the annual CO2 emissions of an IMR vessel equals the same volume as the air in about 500 Empire State Buildings (under standard conditions of pressure and temperature) or one year of electricity use by 2 000 average U.S. households (Arb.ca.gov, 2007).

The Company currently has three IMR vessels on frame agreement. More flexible use of the complete fleet combined with the ROV working independently, without the umbilical and vessel support, could possibly reduce CO2 emissions and pollution. Political actions will most likely be taken to reduce CO2 emissions in general.

5.8. Capability Stack

In the theory review it was argued that creating a capability stack platform could be useful for a complex system described as an ecology i.e. in large organisations. Not all products and services need to be justified through a capability platform. For example, having access to an ROV at location within a given time frame adds great flexibility in operations. The availability of an ROV nearby location when needed is argued to be more important and have a higher value for the Company than the actual cost of the operational model.

A capability stack does not replace the business process approach (net-present value calculations, etc), but it could help to structure an organisation to create economic options and values:

Table 7 – Capability Platform layers for a strategic view

<table>
<tr><th colspan="2">Capability Platform layers</th></tr>
<tr><td>1.Technology resource layer</td><td>The technology forms the basis for the capability stack. The technology is required to create value.

Technology is seen as:
general existing subsea infrastructure (XMT, piping, manifolds, valves, etc.)
vessels
eROVs
infrastructure/hubs to support future eROV operations (battery/tooling stations)
This layer consist of more than the technology; it also requires people, process and governance.

The stakeholders involved are:
The Company
Vessel owners
ROV service providers
Core employees involved in this layer to deploy, adapt and maintain the ROV operations:
ROV pilots
Subsea Engineers (oil Company)
Operations Managers (onshore/offshore)</td></tr>
<tr><td>2. An intelligent infrastructure</td><td>Tele and communications companies (Telenor/Tampnet).

ROV Service Providers - OCCs:
sensors from future subsea infrastructure
subsea battery power availability from future subsea batteries
4G communications
video transfer and general signal transfer</td></tr>
</table>

<table>
<tr><th colspan="2">Capability Platform layers</th></tr>
<tr><td>3. Information and collaboration layer*</td><td>Software companies.

Collecting data, people working to share data.

Use of ROV Planner:

● how to use, store and share smart and relevant information
● ongoing projects
● towing path optimization
● ROV subsea asset inspection optimization
● reuse of ROV staff</td></tr>
<tr><td>4. Knowledge sharing and analytic layer*</td><td>Software companies.

Hardware, people

● Issue reports
● Evaluate data/experience transfer
● Analysis & knowledge</td></tr>
<tr><td>5. A business operations layer</td><td>Current:

● Company internal (licensees/fields)
● ROV service providers (Oceaneering, Subsea 7, IKM Subsea)
Work processes and decisions - see business model canvas

Governance, shift plans etc.

Future:

● Other oil operators
● Other industries requiring ROV operations (fish farms, offshore wind mills, etc.)</td></tr>
</table>

*Layer 3 and 4 are overlapping and not definite.

5.8.1. Evaluation and definition of capability resources required

The following capability resources are required for the new operational setup:

Technology: Building the OCC facilities, including the hardware, software, IT and communications and data transfer at the different ROV service providers facilities. Modification of chartered vessels to accommodate towing of the eROV.

Process: Business processes; the operational set-up of the OCC, the organisations offshore/onshore including front office and back office support functions.

People: ROV crew in OCC, Operations Manager in OCC, front office and back office personnel supporting the operations such as IMR Subsea Engineer and Technical Authorities and their skills, competence and experience.

Governance: Frame agreements, business models, organizations and locations both for Company and ROV service providers, telecommunication companies, organisation charts, location of staff and rights to manage decisions.

5.9. Implementation: Infrastructure and Technology

It is suggested to divide implementation into different phases. It is advised to review the potential ROV hours where the eROV can be used (i.e. operations not requiring vessel with a crane or lift line) before any further actions from Company evaluating the eROV concept. This should be given high priority.

Phase I: Enhance the eROV concept and technology and build networks for future and infrastructure to support use of the eROV:

- Establish a digital platform for planning and execution of operations (ROV Planner)
- Identify hub locations and build subsea infrastructure to support the eROV concept
- Modify vessels to allow for vessel flexibility (access and optimize vessel schedules)
- Set up of organisation to support the Onshore Control Center (OCC)
- Issue ITT (invitation to tender)
- Run pilot project

Phase II: Fully operative eROV OCC, supporting several hubs/areas as required.

Phase III: Enhance existing business model. Consider to open service for other oil operators to access ROV services. Expand platform/online marketplace for booking and planning of ROVs operations/IMR operations (ROV planner).

6. REFLECTIONS ON OWN WORK AND RECOMMENDATIONS FOR FURTHER WORK

6.1. Reflections on own work

In this section I will briefly reflect on my own work writing this thesis. This thesis is the final delivery of the master study Master in Technology and Operations Management (MTOM).

Due to ongoing technology and business developments, I feel that the topic is highly relevant. New ROV technology is developing before knowing the operational context of how to utilize the new technology. It has been very educational to combine theory with an investigation into the future of new concepts and identifying already available resources for the Company.

During the study period I reduced my full-time engagement in the subsea industry, working part time to complete this project and to have dedicated time for the thesis. I hope to have delivered a concept, or ideas, on how to utilize the eROV as part of a permanent subsea infrastructure with charging stations and hubs.

It remains to be seen if the concept of building a subsea infrastructure combined with utilizing existing vessels in a smart way to support the operation is the future. Ultimately it depends on further technology advancement, digitalisation, collaboration, and the right management decisions must be taken to make a shift from today's operational model. It would be a significant change if an ROV could work independently without a supporting vessel at all times.

6.2. Recommendations for further work

The work performed in this thesis is intended to be used as basis for further discussion on how to make the eROV concept operational and to create a sustainable business model for setting up the OCC and running the operations.

The most important recommendation is currently seen to review the potential ROV hours where the eROV can be used. This means operations not requiring vessel with a crane or lift line. This should be given high priority. It is also important to check if cost estimates are realistic and according to market situation (day rates).

Other recommendations to be evaluated are:

- Continue to develop the concept of an online ROV Planner and make a full version of the software with vessel path optimization and information work flows. This will enable smarter collaboration, where users gain access to all information through a centralized, online, cloud-based solution.
- Establish a long term strategic roadmap for charging stations/network with Subsea USB connectors. This must be seen in connection with future AUV

patterns.

- Improve towing hook up philosophy/mooring design.
- Improve GSM Buoy design to allow for higher towing speeds. The buoy itself is according to Fugro currently the limiting factor for towing speed.
- Evaluate whether to set up an online market tool (enhanced ROV Planner tool) to offer ROV services to other operators through a commission-based model.

7. CONCLUSION

The objective of this thesis is to challenge today's operational setup and mindset of ROV operations, to investigate future ROV operations, and to demonstrate possible economic benefit by adapting to new concepts and new technologies through business-driven innovation.

The theory review covers relevant theories. State of the art ROV technology and current operational setup for the Company is described. This includes internal work processes and organizational setup.

In the description of next generation operations, the thesis gives ideas for digitalization of planning and future improvements for better workflows through digitalization. The ROV Planner, a cloud based ROV Planning Management tool is introduced to optimize planning and execution of IMR (ROV) operations. Ideas are given for path planning and optimization for towing of the eROV from one location to the other. Utilization can be improved by using already chartered PSV or vessels that move in fixed patterns supporting the marine operations as of today. Next generation concepts require a subsea infrastructure with battery pack for storage of energy.

Three different future scenarios are described. The thesis selects scenario II as the most relevant case and expands on this in the feasibility analysis section which focuses on cost.

Scenario II is based on the 2017 planned Subsea Assets ROV inspection hours combined with the operational model of an Onshore Control Center (OCC) to allow for controlling the eROV from shore.

Relocation of the eROV is realistically simulated through towing of the eROV from one location to another. Vessels used for towing are Company chartered vessels modified to handle the towing of the eROV. These vessels already circle in an optimized pattern. It is suggested that they make small detours to relocate the eROV, while doing logistics operations for the Company's Marine and Logistics department. The eROV belongs to a dedicated area, which are numbered 1-5 in this thesis.

If the assumptions and the cost figures from the cost feasibility study using the planned hours for planned ROV inspections in 2017 are correct, it indicates that the amount of annual inspection hours in 2017 is not enough to build a strong business case. The cost figures indicate that the fixed cost and hourly rate is similar to today's operations using an IMR vessel. CAPEX investment is not accounted for and must be added.

Cost figures show that the eROV must be utilized more to reduce the hourly cost. OPEX cost of running the OCC 24/7 is high and it is therefore required to have minimum number of hours to break even. If 400 and 800 hrs are added as ad hoc ROV hours (inspection, valve operations, etc.) in addition to the 1 275 planned hours of operations for all 5 areas a lower hourly cost is achieved:

Table 8 – Cost overview showing base case planned Subsea Annual ROV Inspection hours including alternative with additional hours (ad-hoc operations)

Area 1-5	**Base case**	**ALT 1**	**ALT 2**	**Comments**
Planned hrs	1 275	1 275	1 275	
Additional hrs (ad-hoc)	-	400	800	Additional hours for all 5 areas.
Cost per hrs (NOK)	**44 200**	**33 645**	**27 159**	
Cost towing (NOK)	511 846	511 846	511 846	
Total cost (towing and ROV ops) (NOK)	**8 508 311**	**6 608 370**	**5 440 937**	**Cost for 180 hrs of inspection at area 5**
IMR vessel cost per hrs	33 333	33 333	33 333	
IMR vessel cost (NOK) per hour incl transit and WOW	46 666	46 666	46 666	Factor of 1,4 used to account for towing and WOW
Cost IMR vessel for 180 hrs of inspection	8 400 000	8 400 000	8 400 000	

MGO are not included in the above figures. For all towing operations a handling time of 1 hour is added to pick up buoy and eROV for towing.

The example including towing also shows that the cost of towing is a small portion of the total cost. A lesson learned by going in-depth on the towing scenario is that there are multiple legs of towing (transit and towing) per 24 hrs of operations which is the current battery capacity for the eROV. The eROV spread is demanding to deploy and recover due to the buoy and rigging attached to the eROV. Towing should therefore be considered as a feasible solution in combination with chartered, less expensive vessels, in a known pattern which cycle twice a week.

In the future, battery capacity will most likely improve which will lead to extended operational hours for the eROV leading to less towing and transit time. In summary, for the 180 hours of inspection the overall cost of towing was less than 10 % of the total cost. A more advanced subsea infrastructure (more hubs and battery/charging stations) would also led to less towing.

Table 8 above shows that higher utilization of the eROV, by adding additional hours to the base case hours, gives high effect on the total OPEX cost (including towing cost) for the example used in case of 180 hrs of inspection of area 5:

IMR vessel operations (as per today) : **NOK 8.4 mill**

eROV and towing Basecase (1 275 hrs) : **NOK 8.5 mill**

eROV and towing ALT 1 (1 275+400 hrs) : NOK 6.6 mill

eROV and towing ALT 2 (1 275+800 hrs) : **NOK 5.4 mill**

The overall cost picture is complicated. Higher utility of the eROV concept is required to achieve lower operational cost. It is important to emphasize that the Company uses the annual subsea asset inspection hours as fill-in jobs when the weather is limiting other operations, meaning the operational sea state allows for only deployment and recovery of the ROV. For this scenario the annual subsea asset ROV inspection reduces the WOW for other operations.

To put the new eROV technology into operational context it is necessary to think differently about how today's operations are planned and executed. An evaluation of the system capabilities is presented. A new business model and the need for digitalisation is discussed. A new business model canvas details a new business model running operations from an Onshore Control Center supported by an online ROV planning and collaboration tool. A Capability Stack is presented together with the evaluation and definition of the resources needed for a new operation context.

The fact that ROVs would be available offshore at subsea hubs/locations is most likely the largest value gain and gives operational flexibility which is hard to measure in monetary value. If oil and gas production can be shut down and re-established on a faster schedule than waiting for an IMR vessel to become available and arrive at the work site, this could potentially introduce large savings.

The technology for fully autonomous ROVs is further away than building an infrastructure of a charging station for eROVs. The charging/docking stations must be seen as a long-term investment that is also needed the next generation ROVs, when ROVs move independently and autonomously from one location to another.

Time will tell if the eROV concept presented with the remote piloting is the technology and concept that could change today's ROV operations into a more sustainable value network for ROVs operations. The future is a well-built subsea infrastructure to support operations with eROVs working independently, controlled from an OCC, without a support vessel at all times.

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Appendix I

Subsea Asset Annual ROV inspection estimates 2017

(It has been agreed with the Company to make details confidential)

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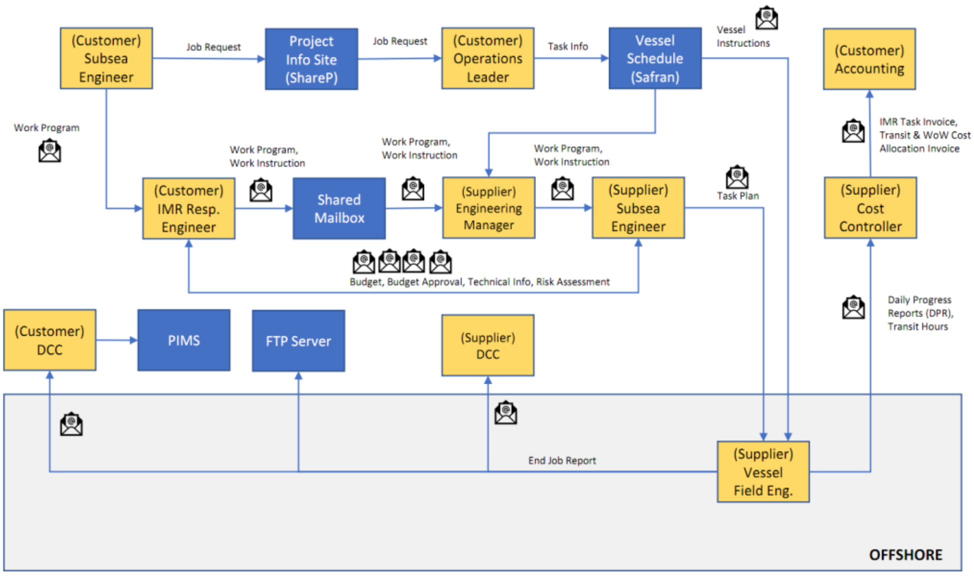
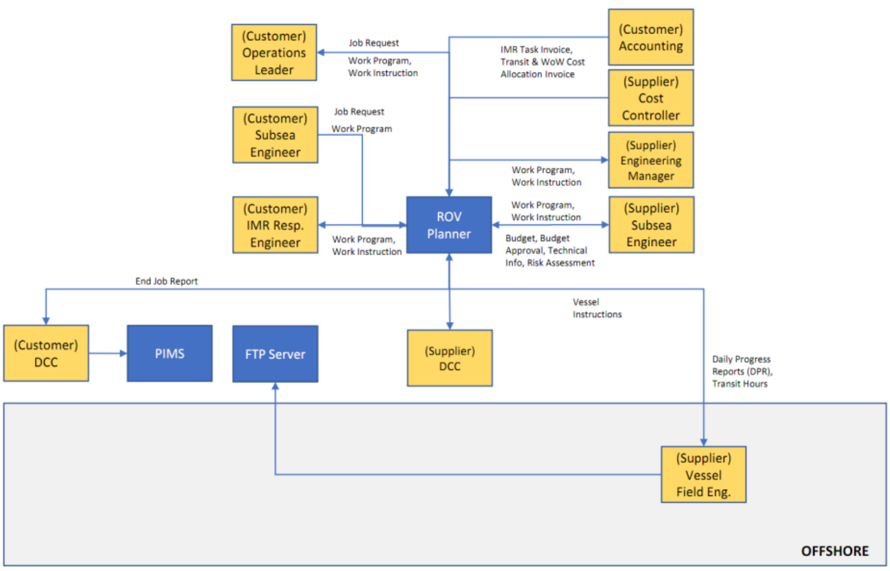
Appendix II

Information workflow, current and future



IMR INFORMATION WORKFLOW (AS-IS)



IMR INFORMATION WORKFLOW (TO-BE)

Appendix III

ROV cost estimates - area 5, including cost of towing

Base case 1275 hrs:

Fixed Cost	Cost per day	Assumptions
Admin cost OCC	2 958,90	1 080 000 per year
ROV personnel	40 000,00	4 persons x 10 000 per person per day
Operations Manager	20 000,00	2 persons x 10 000 per person per day
SUM	62 958,90	
ROV Cost	**Cost per day**	**Assumptions**
eROV	15 000,00	
Demob/Mob ROV spread	3 287,67	6 mobilizations per year x 200 000
Sum	18 287,67	
Number of ROVs	5,00	
Total Fixed Cost + ROV Cost (all)	154 397,26	For all ROVs
Total Fixed Cost + ROV Cost (single)	30 879,45	For single ROV
Cost per hour	1 286,64	For single ROV
Total cost per year per ROV	11 271 000,00	Cost of running one ROV 24/7 for full year
Total cost per year (all)	56 355 000,00	Cost of running all ROVs 24/7 for full year
Total usage (inspection hours)	1 275,00	Areas 1-5
Other ROV operations (estimated)		Areas 1-5
Total cost per hour	44 200,00	

el	From	To	Action	Cargo	Distance (	Speed (kn	Sea Time (hours	Handling Time (hours	Total Time (h	Cost/Hour	Cost	Remarks
5	Sleipner A (Hub)	Sleipner A (Hub	Inspection				18	0	18	44 200,00	795 600,00	ROV Platform Inspection (18 hours total)
5	Sleipner A (Hub)	Sleipner A (Hub	Charging					0				
5	Sleipner R	Sleipner R	Inspection				15	0	15	44 200,00	663 000,00	ROV Platform Inspection (15 hours total)
5	Sleipner A (Hub)	Sleipner A (Hub	Charging					0				
5	Sleipner T	Sleipner T	Inspection				14	0	14	44 200,00	618 800,00	ROV Platform Inspection (14 hours total)
5	Sleipner A (Hub)	Sleipner A (Hub	Charging					0				
Sun	Sleipner A (Hub)	Sleipner B	Tow	ROV 5	6,56	5	1,312	1	2,312	8333	19 265,90	
Sun	Sleipner B	Sleipner A (Hub	Transit		6,56	10	0,656	0	0,656	8333	5 466,45	
5	Sleipner B	Sleipner B	Inspection				15	0	15	44 200,00	663 000,00	Periodic ROV Platform Inspection 2017 (15 hours total)
rofjord	Sleipner A (Hub)	Sleipner B	Transit		6,56	10	0	0	0	8333	-	
rofjord	Sleipner B	Sleipner A (Hub	Tow	ROV 5	6,56	5	1,312	1	2,312	8333	19 265,90	
5	Sleipner A (Hub)	Sleipner A (Hub	Charging				0	0	0		-	
Sun	Sleipner A (Hub)	Gina Krog	Tow	ROV 5	14	5	2,8	1	3,8	8333	31 665,40	
5	Gina Krog	Gina Krog	Inspection				24	0	24	44 200,00	1 060 800,00	Periodic ROV Platform Inspection 2017 (43 hours total)
Sun	Gina Krog	Sleipner A (Hub	Transit		14	10	1,4	0	1,4	8333	11 666,20	
rofjord	Sleipner A (Hub)	Gina Krog	Transit		14	10	1,4	0	1,4	8333	11 666,20	
rofjord	Gina Krog	Sleipner A (Hub	Tow	ROV 5	14	5	2,8	1	3,8	8333	31 665,40	
5	Sleipner A (Hub)	Sleipner A (Hub	Charging						0		-	
Sun	Sleipner A (Hub)	Gina Krog	Tow	ROV 5	14	5	2,8	1	3,8	8333	31 665,40	
5	Gina Krog	Gina Krog	Inspection				19	0	19	44 200,00	839 800,00	
rofjord	Sleipner A (Hub)	Gina Krog	Transit		14	10	1,4	0	1,4	8333	11 666,20	
rofjord	Gina Krog	Sleipner A (Hub	Tow	ROV 5	14	5	2,8	1	3,8	8333	31 665,40	
5	Sleipner A (Hub)	Sleipner A (Hub	Charging								-	
Sun	Sleipner A (Hub)	Draupner	Tow	ROV 5	21	5	4,2	1	5,2	8333	43 331,60	
Sun	*Draupner*	*Sleipner A (Hub)*	*Transit*		*21*	*10*	*2,1*	*0*	*2,1*	*8333*	*-*	*Not necessary*
5	Draupner	Draupner	Inspection				24	0	24	44 200,00	1 060 800,00	Periodic ROV Platform and Riser Structure Inspection 2017 (75 hours total)
Sun	Draupner	Sleipner A (Hub	Tow	ROV 5	21	5	4,2	1	5,2	8333	43 331,60	
5	Sleipner A (Hub)	Sleipner A (Hub	Charging									
Sun	Sleipner A (Hub)	Draupner	Tow	ROV 5	21	5	4,2	1	5,2	8333	43 331,60	
Sun	*Draupner*	*Sleipner A (Hub)*	*Transit*		*21*	*10*	*2,1*	*0*	*2,1*	*8333*	*-*	*Not necessary*
5	Draupner	Draupner	Inspection				24	0	24	44 200,00	1 060 800,00	
Sun	Draupner	Sleipner A (Hub	Tow	ROV 5	21	5	4,2	1	5,2	8333	43 331,60	
5	Sleipner A (Hub)	Sleipner A (Hub	Charging									
Sun	Sleipner A (Hub)	Draupner	Tow	ROV 5	21	5	4,2	1	5,2	8333	43 331,60	
Sun	*Draupner*	*Sleipner A (Hub)*	*Transit*		*21*	*10*	*2,1*	*0*	*2,1*	*8333*	*-*	*Not necessary*
5	Draupner	Draupner	Inspection				24	0	24	44 200,00	1 060 800,00	
Sun	Draupner	Sleipner A (Hub	Tow	ROV 5	21	5	4,2	1	5,2	8333	43 331,60	
5	Sleipner A (Hub)	Sleipner A (Hub	Charging									
Sun	Sleipner A (Hub)	Draupner	Tow	ROV 5	21	5	4,2	1	5,2	8333	43 331,60	
Sun	*Draupner*	*Sleipner A (Hub)*	*Transit*		*21*	*10*	*2,1*	*0*	*2,1*	*8333*	*-*	*Not necessary*
5	Draupner	Draupner	Inspection				3	0	3	44 200,00	132 600,00	
Sun	Draupner	Sleipner A (Hub	Tow	ROV 5	21	5	4,2	1	5,2	8333	43 331,60	
5	Sleipner A (Hub)	Sleipner A (Hub	Charging									
										Total Cost	**8 508 311,24**	
										Inspection Cost	7 956 000,00	
										Towing Cost	511 846,19	

Alternative I

(base case, 1275 hrs + 400 hrs)

Fixed Cost	Cost per day	Assumptions
Admin cost OCC	2 958,90	1 080 000 per year
ROV personnel	40 000,00	4 persons x 10 000 per person per day
Operations Manager	20 000,00	2 persons x 10 000 per person per day
SUM	62 958,90	
ROV Cost	**Cost per day**	**Assumptions**
eROV	15 000,00	
Demob/Mob ROV spread	3 287,67	6 mobilizations per year x 200 000
Sum	18 287,67	
Number of ROVs	5,00	
Total Fixed Cost + ROV Cost (all)	154 397,26	For all ROVs
Total Fixed Cost + ROV Cost (single)	30 879,45	For single ROV
Cost per hour	1 286,64	For single ROV
Total cost per year per ROV	11 271 000,00	Cost of running one ROV 24/7 for full year
Total cost per year (all)	56 355 000,00	Cost of running all ROVs 24/7 for full year
Total usage (inspection hours)	1 275,00	Areas 1-5
Other ROV operations (estimated)	400,00	Areas 1-5
Total cost per hour	33 644,78	

Sequen	Vessel	From	To	Action	Cargo	Distance (	Speed (kn	Sea Time (hours	Handling Time (hours	Total Time (h	Cost/Hour	Cost	Remarks
1	ROV 5	Sleipner A (Hub)	Sleipner A (Hub	Inspection				18	0	18	33 644,78	605 605,97	ROV Platform Inspection (18 hours total)
2	ROV 5	Sleipner A (Hub)	Sleipner A (Hub	Charging					0				
3	ROV 5	Sleipner R	Sleipner R	Inspection				15	0	15	33 644,78	504 671,64	ROV Platform Inspection (15 hours total)
4	ROV 5	Sleipner A (Hub)	Sleipner A (Hub	Charging					0				
5	ROV 5	Sleipner T	Sleipner T	Inspection				14	0	14	33 644,78	471 026,87	ROV Platform Inspection (14 hours total)
6	ROV 5	Sleipner A (Hub)	Sleipner A (Hub	Charging					0				
7	Far Sun	Sleipner A (Hub)	Sleipner B	Tow	ROV 5	6,56	5	1,312	1	2,312	8333	19 265,90	
8	Far Sun	Sleipner B	Sleipner A (Hub	Transit		6,56	10	0,656	0	0,656	8333	5 466,45	
9	ROV 5	Sleipner B	Sleipner B	Inspection				15	0	15	33 644,78	504 671,64	Periodic ROV Platform Inspection 2017 (15 hours total)
10	KL Brofjord	Sleipner A (Hub)	Sleipner B	Transit		6,56	10	0	0	0	8333	-	
11	KL Brofjord	Sleipner B	Sleipner A (Hub	Tow	ROV 5	6,56	5	1,312	1	2,312	8333	19 265,90	
12	ROV 5	Sleipner A (Hub)	Sleipner A (Hub	Charging				0	0	0		-	
13	Far Sun	Sleipner A (Hub)	Gina Krog	Tow	ROV 5	14	5	2,8	1	3,8	8333	31 665,40	
14	ROV 5	Gina Krog	Gina Krog	Inspection				24	0	24	33 644,78	807 474,63	Periodic ROV Platform Inspection 2017 (43 hours total)
15	Far Sun	Gina Krog	Sleipner A (Hub	Transit		14	10	1,4	0	1,4	8333	11 666,20	
16	KL Brofjord	Sleipner A (Hub)	Gina Krog	Transit		14	10	1,4	0	1,4	8333	11 666,20	
17	KL Brofjord	Gina Krog	Sleipner A (Hub	Tow	ROV 5	14	5	2,8	1	3,8	8333	31 665,40	
18	ROV 5	Sleipner A (Hub)	Sleipner A (Hub	Charging						0		-	
19	Far Sun	Sleipner A (Hub)	Gina Krog	Tow	ROV 5	14	5	2,8	1	3,8	8333	31 665,40	
20	ROV 5	Gina Krog	Gina Krog	Inspection				19	0	19	33 644,78	639 250,75	
21	KL Brofjord	Sleipner A (Hub)	Gina Krog	Transit		14	10	1,4	0	1,4	8333	11 666,20	
22	KL Brofjord	Gina Krog	Sleipner A (Hub	Tow	ROV 5	14	5	2,8	1	3,8	8333	31 665,40	
23	ROV 5	Sleipner A (Hub)	Sleipner A (Hub	Charging								-	
24	Far Sun	Sleipner A (Hub)	Draupner	Tow	ROV 5	21	5	4,2	1	5,2	8333	43 331,60	
25	*Far Sun*	*Draupner*	*Sleipner A (Hub)*	*Transit*		*21*	*10*	*2,1*	*0*	*2,1*	*8333*	*-*	*Not necessary*
26	ROV 5	Draupner	Draupner	Inspection				24	0	24	33 644,78	807 474,63	Periodic ROV Platform and Riser Structure Inspection 2017 (75 hours total)
27	Far Sun	Draupner	Sleipner A (Hub	Tow	ROV 5	21	5	4,2	1	5,2	8333	43 331,60	
28	ROV 5	Sleipner A (Hub)	Sleipner A (Hub	Charging									
29	Far Sun	Sleipner A (Hub)	Draupner	Tow	ROV 5	21	5	4,2	1	5,2	8333	43 331,60	
30	*Far Sun*	*Draupner*	*Sleipner A (Hub)*	*Transit*		*21*	*10*	*2,1*	*0*	*2,1*	*8333*	*-*	*Not necessary*
31	ROV 5	Draupner	Draupner	Inspection				24	0	24	33 644,78	807 474,63	
32	Far Sun	Draupner	Sleipner A (Hub	Tow	ROV 5	21	5	4,2	1	5,2	8333	43 331,60	
33	ROV 5	Sleipner A (Hub)	Sleipner A (Hub	Charging									
34	Far Sun	Sleipner A (Hub)	Draupner	Tow	ROV 5	21	5	4,2	1	5,2	8333	43 331,60	
35	*Far Sun*	*Draupner*	*Sleipner A (Hub)*	*Transit*		*21*	*10*	*2,1*	*0*	*2,1*	*8333*	*-*	*Not necessary*
36	ROV 5	Draupner	Draupner	Inspection				24	0	24	33 644,78	807 474,63	
37	Far Sun	Draupner	Sleipner A (Hub	Tow	ROV 5	21	5	4,2	1	5,2	8333	43 331,60	
38	ROV 5	Sleipner A (Hub)	Sleipner A (Hub	Charging									
39	Far Sun	Sleipner A (Hub)	Draupner	Tow	ROV 5	21	5	4,2	1	5,2	8333	43 331,60	
40	*Far Sun*	*Draupner*	*Sleipner A (Hub)*	*Transit*		*21*	*10*	*2,1*	*0*	*2,1*	*8333*	*-*	*Not necessary*
41	ROV 5	Draupner	Draupner	Inspection				3	0	3	33 644,78	100 934,33	
42	Far Sun	Draupner	Sleipner A (Hub	Tow	ROV 5	21	5	4,2	1	5,2	8333	43 331,60	
43	ROV 5	Sleipner A (Hub)	Sleipner A (Hub	Charging									
											Total Cost	**6 608 370,94**	
											Inspection Cost	6 056 059,70	
											Towing Cost	511 846,19	

Alternative 2

(Base case 1275 hrs + 800 hrs)

Fixed Cost	Cost per day	Assumptions
Admin cost OCC	2 958,90	1 080 000 per year
ROV personnel	40 000,00	4 persons x 10 000 per person per day
Operations Manager	20 000,00	2 persons x 10 000 per person per day
SUM	62 958,90	
ROV Cost	**Cost per day**	**Assumptions**
eROV	15 000,00	
Demob/Mob ROV spread	3 287,67	6 mobilizations per year x 200 000
Sum	18 287,67	
Number of ROVs	5,00	
Total Fixed Cost + ROV Cost (all)	154 397,26	For all ROVs
Total Fixed Cost + ROV Cost (single)	30 879,45	For single ROV
Cost per hour	1 286,64	For single ROV
Total cost per year per ROV	11 271 000,00	Cost of running one ROV 24/7 for full year
Total cost per year (all)	56 355 000,00	Cost of running all ROVs 24/7 for full year
Total usage (inspection hours)	1 275,00	Areas 1-5
Other ROV operations (estimated)	800,00	Areas 1-5
Total cost per hour	27 159,04	

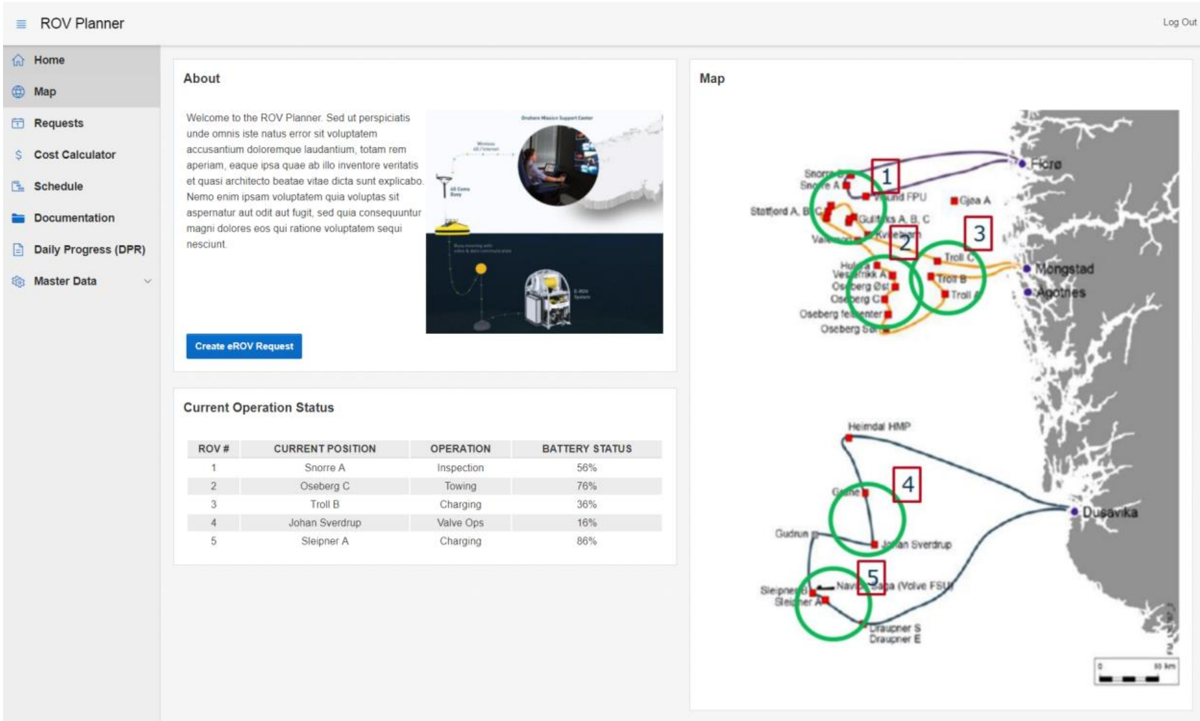
Sequen	Vessel	From	To	Action	Cargo	Distance (	Speed (kn	Sea Time (hours	Handling Time (hours	Total Time (h	Cost/Hour	Cost	Remarks
1	ROV 5	Sleipner A (Hub)	Sleipner A (Hub	Inspection				18	0	18	27 159,04	488 862,65	ROV Platform Inspection (18 hours total)
2	ROV 5	Sleipner A (Hub)	Sleipner A (Hub	Charging					0				
3	ROV 5	Sleipner R	Sleipner R	Inspection				15	0	15	27 159,04	407 385,54	ROV Platform Inspection (15 hours total)
4	ROV 5	Sleipner A (Hub)	Sleipner A (Hub	Charging					0				
5	ROV 5	Sleipner T	Sleipner T	Inspection				14	0	14	27 159,04	380 226,51	ROV Platform Inspection (14 hours total)
6	ROV 5	Sleipner A (Hub)	Sleipner A (Hub	Charging					0				
7	Far Sun	Sleipner A (Hub)	Sleipner B	Tow	ROV 5	6,56	5	1,312	1	2,312	8333	19 265,90	
8	Far Sun	Sleipner B	Sleipner A (Hub	Transit		6,56	10	0,656	0	0,656	8333	5 466,45	
9	ROV 5	Sleipner B	Sleipner B	Inspection				15	0	15	27 159,04	407 385,54	Periodic ROV Platform Inspection 2017 (15 hours total)
10	KL Brofjord	Sleipner A (Hub)	Sleipner B	Transit		6,56	10	0	0	0	8333	-	
11	KL Brofjord	Sleipner B	Sleipner A (Hub	Tow	ROV 5	6,56	5	1,312	1	2,312	8333	19 265,90	
12	ROV 5	Sleipner A (Hub)	Sleipner A (Hub	Charging				0	0	0		-	
13	Far Sun	Sleipner A (Hub)	Gina Krog	Tow	ROV 5	14	5	2,8	1	3,8	8333	31 665,40	
14	ROV 5	Gina Krog	Gina Krog	Inspection				24	0	24	27 159,04	651 816,87	Periodic ROV Platform Inspection 2017 (43 hours total)
15	Far Sun	Gina Krog	Sleipner A (Hub	Transit		14	10	1,4	0	1,4	8333	11 666,20	
16	KL Brofjord	Sleipner A (Hub)	Gina Krog	Transit		14	10	1,4	0	1,4	8333	11 666,20	
17	KL Brofjord	Gina Krog	Sleipner A (Hub	Tow	ROV 5	14	5	2,8	1	3,8	8333	31 665,40	
18	ROV 5	Sleipner A (Hub)	Sleipner A (Hub	Charging						0		-	
19	Far Sun	Sleipner A (Hub)	Gina Krog	Tow	ROV 5	14	5	2,8	1	3,8	8333	31 665,40	
20	ROV 5	Gina Krog	Gina Krog	Inspection				19	0	19	27 159,04	516 021,69	
21	KL Brofjord	Sleipner A (Hub)	Gina Krog	Transit		14	10	1,4	0	1,4	8333	11 666,20	
22	KL Brofjord	Gina Krog	Sleipner A (Hub	Tow	ROV 5	14	5	2,8	1	3,8	8333	31 665,40	
23	ROV 5	Sleipner A (Hub)	Sleipner A (Hub	Charging								-	
24	Far Sun	Sleipner A (Hub)	Draupner	Tow	ROV 5	21	5	4,2	1	5,2	8333	43 331,60	
25	*Far Sun*	*Draupner*	*Sleipner A (Hub)*	*Transit*		*21*	*10*	*2,1*	*0*	*2,1*	*8333*	*-*	*Not necessary*
26	ROV 5	Draupner	Draupner	Inspection				24	0	24	27 159,04	651 816,87	Periodic ROV Platform and Riser Structure Inspection 2017 (75 hours total)
27	Far Sun	Draupner	Sleipner A (Hub	Tow	ROV 5	21	5	4,2	1	5,2	8333	43 331,60	
28	ROV 5	Sleipner A (Hub)	Sleipner A (Hub	Charging									
29	Far Sun	Sleipner A (Hub)	Draupner	Tow	ROV 5	21	5	4,2	1	5,2	8333	43 331,60	
30	*Far Sun*	*Draupner*	*Sleipner A (Hub)*	*Transit*		*21*	*10*	*2,1*	*0*	*2,1*	*8333*	*-*	*Not necessary*
31	ROV 5	Draupner	Draupner	Inspection				24	0	24	27 159,04	651 816,87	
32	Far Sun	Draupner	Sleipner A (Hub	Tow	ROV 5	21	5	4,2	1	5,2	8333	43 331,60	
33	ROV 5	Sleipner A (Hub)	Sleipner A (Hub	Charging									
34	Far Sun	Sleipner A (Hub)	Draupner	Tow	ROV 5	21	5	4,2	1	5,2	8333	43 331,60	
35	*Far Sun*	*Draupner*	*Sleipner A (Hub)*	*Transit*		*21*	*10*	*2,1*	*0*	*2,1*	*8333*	*-*	*Not necessary*
36	ROV 5	Draupner	Draupner	Inspection				24	0	24	27 159,04	651 816,87	
37	Far Sun	Draupner	Sleipner A (Hub	Tow	ROV 5	21	5	4,2	1	5,2	8333	43 331,60	
38	ROV 5	Sleipner A (Hub)	Sleipner A (Hub	Charging									
39	Far Sun	Sleipner A (Hub)	Draupner	Tow	ROV 5	21	5	4,2	1	5,2	8333	43 331,60	
40	*Far Sun*	*Draupner*	*Sleipner A (Hub)*	*Transit*		*21*	*10*	*2,1*	*0*	*2,1*	*8333*	*-*	*Not necessary*
41	ROV 5	Draupner	Draupner	Inspection				3	0	3	27 159,04	81 477,11	
42	Far Sun	Draupner	Sleipner A (Hub	Tow	ROV 5	21	5	4,2	1	5,2	8333	43 331,60	
43	ROV 5	Sleipner A (Hub)	Sleipner A (Hub	Charging									
											Total Cost	**5 440 937,75**	
											Inspection Cost	4 888 626,51	
											Towing Cost	511 846,19	

Appendix IV

Extracts and screenshots from the “ROV Planner” Tool

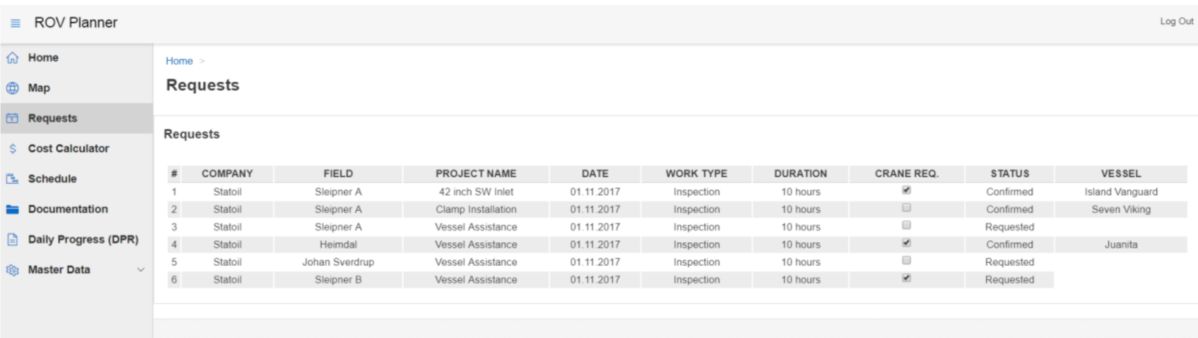
Details for the ROV Planner is described in section 3.2

Below are some screenshots from the application made to illustrate the ROV Planner:

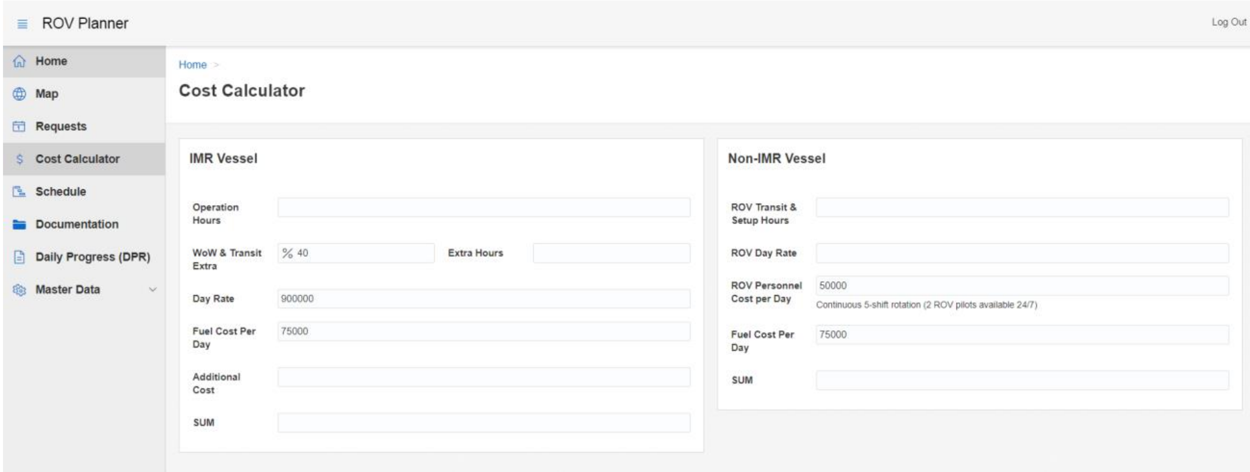


Main page: The home page contains a real time dashboard of the ROV Planner. The map on the right hand side illustrates the areas and location for each ROV. Color codes can be used to identify status of the ROV (Green = Available, Amber = Booked/Check schedule, Red = Unserviceable Unit).

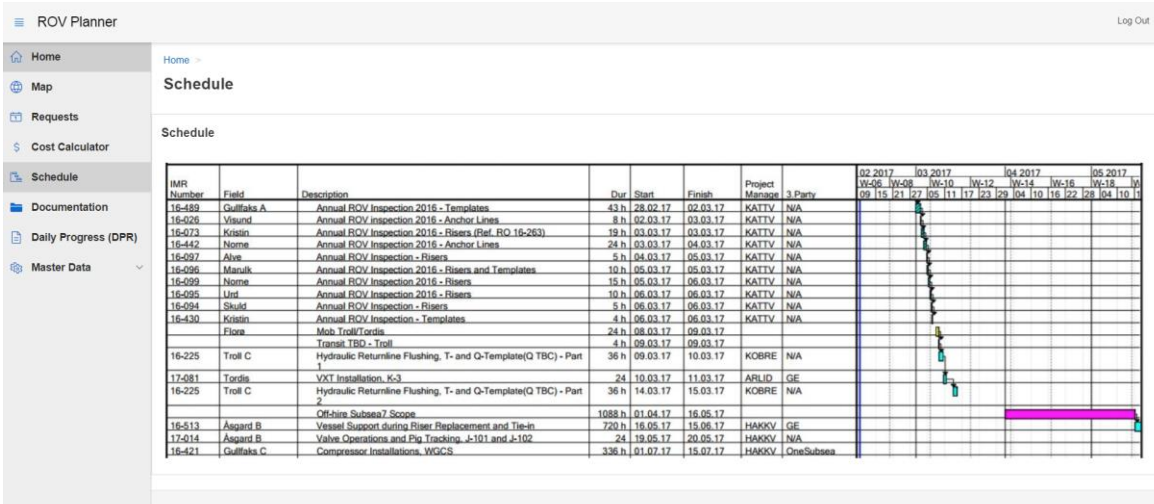
The lower left table gives the overall Current Operations Status, including position, operation type and battery status and estimated remaining time for Task.



Request page: Summarizes the IMR jobs planned and requested. Including Company, Field Location, Project Name, Date Work Type, Planned Duration, and if Crane Operations are required supporting the operations. Vessel name and Status of operation.

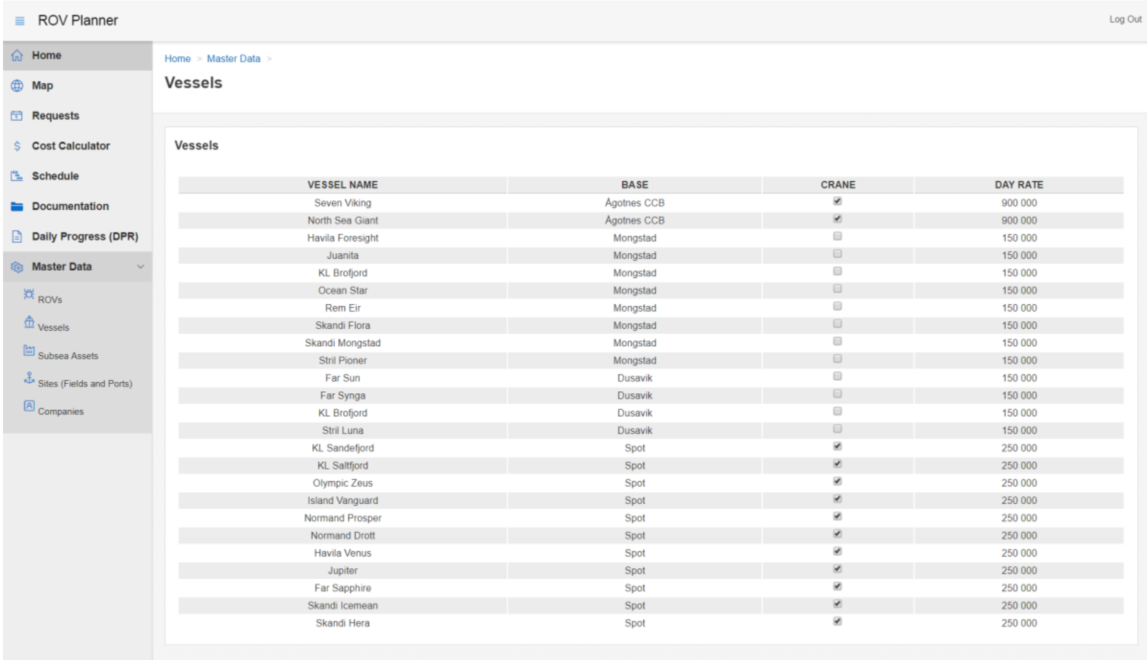


The cost calculator page: Has the functionality to estimate the cost and compare to a regular IMR vessel vs using the eROV concept including towing operations. This is used in the early stage planning the operations through identifying if the IMR task requires crane operations. The system accounts for waiting on weather, ROV day rates and vessel fuel consumption based on estimated hours of operations.



IMR Number	Field	Description	Dur	Start	Finish	Project Manage	3.Party
16-489	Gullfaks A	Annual ROV Inspection 2016 - Templates	43 h	28.02.17	02.03.17	KATTV	N/A
16-026	Visund	Annual ROV inspection 2016 - Anchor Lines	8 h	02.03.17	03.03.17	KATTV	N/A
16-073	Kristin	Annual ROV Inspection 2016 - Risers (Ref. RO 16-263)	19 h	03.03.17	03.03.17	KATTV	N/A
16-442	Norne	Annual ROV Inspection 2016 - Anchor Lines	24 h	03.03.17	04.03.17	KATTV	N/A
16-097	Alve	Annual ROV Inspection - Risers	5 h	04.03.17	05.03.17	KATTV	N/A
16-096	Marulk	Annual ROV Inspection 2016 - Risers and Templates	10 h	05.03.17	05.03.17	KATTV	N/A
16-099	Norne	Annual ROV Inspection 2016 - Risers	15 h	05.03.17	06.03.17	KATTV	N/A
16-095	Urd	Annual ROV Inspection 2016 - Risers	10 h	06.03.17	06.03.17	KATTV	N/A
16-094	Skuld	Annual ROV Inspection - Risers	5 h	06.03.17	06.03.17	KATTV	N/A
16-430	Kristin	Annual ROV Inspection - Templates	4 h	06.03.17	06.03.17	KATTV	N/A
	Flora	Mob Troll/Tordis	24 h	08.03.17	09.03.17		
		Transit TBD - Troll	4 h	09.03.17	09.03.17		
16-225	Troll C	Hydraulic Returnline Flushing, T- and Q-Template(Q TBC) - Part 1	36 h	09.03.17	10.03.17	KOBRE	N/A
17-081	Tordis	VXT Installation, K-3	24	10.03.17	11.03.17	ARLID	GE
16-225	Troll C	Hydraulic Returnline Flushing, T- and Q-Template(Q TBC) - Part 2	36 h	14.03.17	15.03.17	KOBRE	N/A
		Off-hire Subsea7 Scope	1088 h	01.04.17	16.05.17		
16-513	Åsgard B	Vessel Support during Riser Replacement and Tie-in	720 h	16.05.17	15.06.17	HAKKV	GE
17-014	Åsgard B	Valve Operations and Pig Tracking, J-101 and J-102	24	19.05.17	20.05.17	HAKKV	N/A
16-421	Gullfaks C	Compressor Installations, WGCS	336 h	01.07.17	15.07.17	HAKKV	OneSubsea

Schedule page: The overall schedule is displayed the Annual Subsea Asset ROV. Automatically updated and optimized with the Annual ROV inspection program.



VESSEL NAME	BASE	CRANE	DAY RATE
Seven Viking	Ågotnes CCB	☑	900 000
North Sea Giant	Ågotnes CCB	☑	900 000
Havila Foresight	Mongstad	☐	150 000
Juanita	Mongstad	☐	150 000
KL Brofjord	Mongstad	☐	150 000
Ocean Star	Mongstad	☐	150 000
Rem Eir	Mongstad	☐	150 000
Skandi Flora	Mongstad	☐	150 000
Skandi Mongstad	Mongstad	☐	150 000
Stril Pioner	Mongstad	☐	150 000
Far Sun	Dusavik	☐	150 000
Far Synga	Dusavik	☐	150 000
KL Brofjord	Dusavik	☐	150 000
Stril Luna	Dusavik	☐	150 000
KL Sandefjord	Spot	☑	250 000
KL Saltfjord	Spot	☑	250 000
Olympic Zeus	Spot	☑	250 000
Island Vanguard	Spot	☑	250 000
Normand Prosper	Spot	☑	250 000
Normand Drott	Spot	☑	250 000
Havila Venus	Spot	☑	250 000
Jupiter	Spot	☑	250 000
Far Sapphire	Spot	☑	250 000
Skandi Icemean	Spot	☑	250 000
Skandi Hera	Spot	☑	250 000

Master data – vessels available: The ROV Planner is using structured database technology. Master data is searchable and easy to find in the future. Logging personnel involved (smart reuse of staff). ROV service provider involved, all searchable. Documentation is stored in one location, avoiding the need for parties to use attachments to mails as of today. Solution is cloud based and should be considered with the Company’s Digitalization plan for the future.

Appendix V

The Company's currently available vessels

The Company has the following vessels on frame agreement running frequently from Mongstad, Florø and Dusavik:

Vessels with scheduled departures from Mongstad/Florø:

- Havila Foresight
- Juanita
- KL Brofjord
- Ocean Star
- Rem Eir
- Skandi Flora
- Skandi Mongstad
- Stril Pioner

Vessels with scheduled departures from Dusavik

- Far Sun
- Far Synga
- KL Brofjord
- Stril Luna

Other currently available vessels in the market (spot market) are:

Operated by Company (with ROV spread):

- Skandi Vega, WROV
- Normand Ferking, WROV
- Stril Merkur / Stril Herkules, OBS ROV operated by vessel crew for small inspections.

Other vessels typically used from the spot market for anchor handling operations with WROV are:

- KL Sandefjord / KL Saltfjord
- Olympic Zeus
- Island Vanguard
- Normand Prosper / Normand Drott
- Havila Venus/Jupiter
- Far Sapphire
- Skandi Iceman
- Skandi Hera