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MASTER'S THESIS

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Abstract

The key to maintaining well integrity, minimizing production decline and improving recovery efficiency, is to provide well services to the subsea wells (Lonnes, Williams and Burleson, 2009). The Subsea Well Intervention (SWI) industry is a specialized segment of the petroleum industry, and represents a very complex work setting in the offshore environment. The RLWI (Riserless Light Well Intervention) and AX-S are two different types of SWI concepts studied in this thesis. RLWI has been used for decades, while AX-S is still in the commercial phase. The RLWI vessel Island Constructor and the AX-S vessel Havila Phoenix was chosen as the study basis.

The SWI concepts may face challenges due to Human-Technology-Organization (HTO) factors which may cause consequences that might affect the decision making, work performance, safety and organizational goals. The purpose of this thesis is to present the methods for identifying and analyzing the challenges which may affect decision making and work performance at SWI vessels, from a human perspective. The Performance Influencing Factors (PIFs) and error causation paradigms with reference to the human performance model were used to present and identify the challenges based on the collected data from the interviewed SWI personnel. The thesis is a contribution to increase the focus on the wide range of factors that affect decision making and work performance from a human perspective, and it also shows that every factor may introduce different effects and consequences. Challenges within areas like the environment, panels and alarm, information processing, communication, procedures, manning, competence, planning, management, individual and motivation were identified.

A proper knowledge and analysis of the complex work settings, from a human perspective, can give the personnel a safer and better working environment and an opportunity to improve their decision making and work performance. By providing the challenges presented in this thesis, I believe that it can contribute to improve the decision making and work performance conditions at the vessels performing SWI, together with an achievement of a safer and more productive operation. By conducting further studies within the HTO area combined with implementations of proactive measures, can from my point of view result in a complete "best decision making and work performance practice" for the different SWI concepts performing complex operations.

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This thesis marks the end of my Master of Science degree in Industrial Economics at the University of Stavanger. The thesis was written during the spring of 2012 under the auspices of DeepWell AS and Polytec AS which have initiated an interdisciplinary Subsea Well Intervention (SWI) research project.

First, I will express my gratitude to my guidance counselors Research Scientist Thorvald Gundersen from Polytec AS and the Director of DeepWell AS Martha Kold Bakkevig for the help and advices along the way. A big thank you also goes to the employees at Polytec for always letting me feel welcome.

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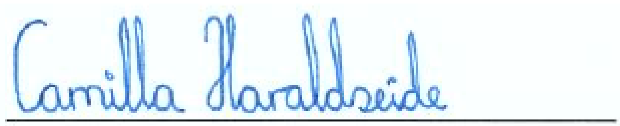
My sincere gratitude goes to my supervisor at the UiS, Professor Jayantha P. Liyanage, for his valuable inputs, knowledge and advices throughout the process of writing this thesis.

Finally, special thanks goes to my dear Thor Helge for being very supporting and patient throughout my studies at the University of Stavanger.

Haugesund, June 15th, 2012



Camilla Haraldseide

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Abbreviations

AWS	=	Aker Well Service
CCTV	=	Closed-Circuit Television Camera
CT	=	Coiled Tubing
DNV	=	Det Norske Veritas
FJM	=	Fitting the Job to the Man
FMJ	=	Fitting the Man to the Job
FMP	=	Fluid Management Package
GUI	=	Graphical User Interface
HF	=	Human factors
HMI	=	Human Machine Interface
HPU	=	Hydraulic Power Units
HSE	=	Health, Safety and Environment
HTO	=	Human, technology and organization
ICT	=	Information and Communication Technology
IMR	=	Inspection, Maintenance and Repair
IOS	=	Island Offshore Subsea
IO	=	Integrated Operation
IOR	=	Increased Oil Recovery
ISO	=	International Organization for Standardization
LARS	=	Launch and Recovery System
LLC	=	Lower Lubricator Connector
LUB	=	Lubricator
MHS	=	Module Management system
MODU	=	Mobile Offshore Drilling Unit
NTVA	=	Norges Tekniske Vitenskapsakademi
OIM	=	Offshore Installation Manager
PCH	=	Pressure Control Head
PIFs	=	Performance influencing factors
PSA	=	Petroleum Safety Authority Norway
RLWI	=	Riserless Light Well Intervention

ROV	=	Remotely Operated Vehicle
RT	=	Running Tool
SRK	=	Skill-, Rule-, Knowledge
SWI	=	Subsea Well Intervention
TSP	=	Tool Storage Package
TTRD	=	Through Tubing Rotational Drilling
ULP	=	Upper Lubricator Package
WCP	=	Well Control Package
WIS	=	Well Intervention Superintendent
WIS	=	Well Intervention Supervisor
WL	=	Wireline
WOCS	=	Workover Control System
WWP	=	Wireline Winch Package

Basic definitions and terms

Human performance model: The human performance model is an analysis which examines what is involved in human performance, and it gives an overview of the complex work setting analyzing the human, activity and context (Bailey, 1996).

Human Factors (HF): It describes the HF technical area as a systematic analytic tool which includes methods and knowledge that can be used to improve, evaluate and assess the HTO interactions (PSA, 2011). The focus is on the human beings and their interactions with tools, machines, procedures, environments and workplace.

Mistakes: Actions which occur when a plan deviates from some adequate path towards a desired goal (Redmill and Rajan, 1997).

Paradigm: A collection of shared concepts, perceptions and practices that forms a particular view of reality, and which guides understanding, collective actions and research (Redmill and Rajan 1997).

Performance Influencing Factors (PIFs): Those factors which determine the likelihood of error or effective human performance (Embrey, 2000). These factors are often the reason for human errors, and they may also affect the ability to improve and improvise work performance.

Slips and lapses: Actions which deviate from the intended plan (Redmill and Rajan, 1997).

SRK-Framework: The Skill, Rule and Knowledge-based (SRK) framework is a structured framework that can be used for integration of the workstation, job and organizational design in complex sosio-technical systems. It consists of three behavioral levels of cognitive control related to a decreasing familiarity with task and environment (Redmill and Rajan, 1997).

Subsea Well Intervention (SWI): Well intervention performs measures to maintain well performance and integrity in the subsea well and it enables greater utilization of the resources. It provides higher efficiency, lower operating costs, improved production profile and extended life of subsea wells (Eni Norge, 2011).

1. Introduction

1.1 Background

There is over 5000 subsea production wells worldwide and the number is growing (Friedberg, Nordbø, Gramstad and Dalane, 2010). Ultimate recovery of reservoirs from subsea production systems is substantial lower than for platform production systems. Increased Oil Recovery (IOR) is a prioritized objective for oilfield operators. The key to maintaining well integrity, minimizing production decline and improving recovery efficiency, is to provide well services to the subsea wells (Lonnes, Williams and Burleson, 2009). The Subsea Well Intervention (SWI) industry is a specialized segment of the petroleum industry. Lake Erie is said to have had the first underwater-completed well, traced back to 1943 at a 35-ft water depth. Shell completed its first subsea well in the Gulf of Mexico in 1961. In the 1990s, operators began designing a more cost-efficient building block subsea system (PennEnergy, 2010).

The subsea technology has emerged during the last decade and has enabled growth in the development of subsea fields in ever deeper waters. The access for well intervention is more complicated on subsea wells, as the x-mas trees are located on the seafloor. Subsea wells have been serviced in a significantly lower rate than traditional wells with dry x-mas trees, which in turn result in a low oil recovery and production rate. The offerings on the market today are dominated by Riserless Light Well Intervention (RLWI) solutions which have been used since the 90’s. RLWI have been performed successfully in the North Sea in shallow water up to 600 meters (Mathiassen, Munkerud and Skeels, 2008). The frontiers of the knowledge and technology for riserless solutions are driven by the North Sea Alliance consisting of Island Offshore Subsea (IOS), FMC Technologies and Aker Well Service (AWS). Expro is in the end of testing their mammoth seafloor wireline system, called AX-S, and is an example of a new type of SWI technology not yet in commercial use. It is a seafloor based system which can be used at sea depths up to 3000 meters (AX-S, 2011). There are many other types of SWI technologies, for example the use of a rigid riser which is designed to enable coiled tubing (CT) and Through Tubing Rotational Drilling (TTRD). The RLWI- and AX-S technologies are chosen as the study basis in this thesis to limit the scope.

Subsea wells require some sort of intervention work every fourth year, or even more often (Munkerud and Inderberg, 2007). As the installed base of subsea wells has been limited until the last decade, well intervention has not been configured in an optimal way. The new challenge in the future is what type of concept will be successful in deeper water like in the Brazilian cost where the depth can go up 5000 meters or more. Technology development must be focused on solving the wellbore, cost and safety challenges, but it is also very important to focus on risk management and an increased knowledge and awareness from a human perspective together with a better understanding of the Human-Technology-Organization (HTO) interactions. SWI technology and risk management studies, and a focus on the human and HTO interactions are also considered as important in relation to future development potential in the industry.

1.2 The Subsea Well Intervention main project

The companies Deepwell AS and Polytec AS have initiated a Subsea Well Intervention (SWI) project for SWI technology evaluation and optimization. The project aims to develop a framework that incorporates technology characteristics and capabilities, risk management and HTO considerations into a decision support and optimization system to maximize overall safety and cost efficiency for SWI technology and operations. The project will help to provide transparency in the decision process for investing in technology, in the process of selecting the best concepts for specific combinations of fields and to identify barriers and bottlenecks to be unblocked to achieve better performance from technologies and associated methods. By providing an analysis of the available methods of intervention for subsea wells, one will get an overview of the potential or shortcomings of different technology paths associated to efficiency, effectiveness, reliability and safety level. An identification and analysis of different *technological* solutions for deep water SWI will be performed by exploring the limitations and opportunities these represent in regards to design, material integrity and relevant external conditions from the surface, through the water column and down into the wellbore. An assessment of the degree of *risk* associated with different SWI solutions will also contribute to the main objective of the project. An analysis which provides increased understanding from a *human perspective* and the interplay between *human, technology and organization (HTO)* in complex decision making and work performance matters, will help to "see the whole picture", and to present a best practices for current and future SWI operation. This is of value to the operators and the service industry, as well as the technology providers.

The findings of the main project will be published in scientific journals and there will be made efforts to present results at industry and scientific conferences. A pilot project, which aims to find the specific orientation of the main project through three Master's Theses, will first be conducted. The results from the pilot project will form the basis for educating three PhD candidates as a part of the main project, planned to start summer of 2012.

1.3 The Subsea Well Intervention pilot project

DeepWell and Polytec introduced three main Master's theses topics for the pilot project:

SWI - Technology	(Mohamed Ben Khemais Triki)
SWI - Risk Management	(Einar Arthur Kolstad)
SWI - Human Perspective	(Camilla Haraldseide)

Three Master's students were going to write and study one SWI area each through individual Master theses during the spring semester 2012. This Master's thesis will consider the human perspective aspects of the operations at SWI vessels.

1.4 The project partners

1.4.1 DeepWell AS

DeepWell AS was established in the end of 2004 and provides industrial knowledge and experience in well intervention and project management. The company is located at Avaldsnes and focus on high-tech based next generation well intervention wireline services. Dr. Martha Kold Bakkevig is the Director of DeepWell, and works with the SWI project.

1.4.2 Polytec AS

Polytec AS pursues research and development in the areas of environment, energy, technology, safety, gas, multiphase flow and maritime operations. They are located in Haugesund, and originated from Haugesund Maritime College in 1988, becoming an independent research institute in 1995. The Polytec Scientist Thorvald Gundersen is working with the SWI project.

1.4.3 The Stord/Haugesund University College (HSH)

Stord/Haugesund University College (HSH) contributes with subsea engineering and technical safety education and knowledge. The SWI project result will be included in the Master's program in Technical Safety now being developed at the University College, and associate Professor Jens Christian Lindaas contributes to the SWI project.

1.5 Problem definition

SWI work processes represent a very complex work setting in the offshore environment. Operations of complex technological SWI systems can affect the human in several ways which can lead to challenges affecting decision making processes and work performance. There is a need for correct decision making and effective work performance to achieve a safe, efficient and reliable SWI operation.

The RLWI- and AX-S concepts may face challenges due to Human Factors (HF), including personnel behavior, motivation, human errors, competence, complex decision making and work performance, but they can also face technological challenges like complex equipment and software, technical limitations and implementation of new and complex technology. The organization challenges may include management, procedures and hierarchy issues. This can cause consequences which can affect the decision making, work performance, safety and organizational goals. When the humans in the organizations are installing and using equipment and software, it is important to have a good understanding of the human element and the work processes, and to look at the situation from a human perspective to be able to facilitate the workplace for the personnel to conduct the correct decisions and to achieve acceptable or close to optimal performance in the context that the activity is performed in. For the humans it may be challenging to cooperate and communicate, understand and operate, know the reporting lines, maintain an overview of all the incoming information, and simultaneously provide an acceptable work performance and correct decision making. This led me to the following question:

"How can an incorporation of a human perspective better the decision making and work performance at SWI vessels performing complex SWI operations?"

1.6 The scope

The thesis will focus on SWI operations based challenges, from a human perspective, that may affect decision making and work performance carried out by the managers at the vessel and by the operators located in the Tower Control and operational rooms (RLWI), and in the Deployment Cabin, Intervention Cabin and at the Bridge (AX-S) that perform and monitor the operations. The RLWI and AX-S concepts will be further studied in this thesis, and the RLWI vessel Island Constructor and the AX-S vessel Havila Phoenix is chosen as the study basis. The purpose is to gather knowledge and experience from the SWI industry and to present the methods for identifying and evaluating the concept challenges that might have a potential to affect decision making and work performance. The Performance Influencing Factors (PIFs) and the error causation paradigms will be used in the challenge identification and in the further analysis of the dynamic connections between the human, the activity and the context. The intention is to use the human performance model as a basis to provide an overview of the complex work setting and to help identify the challenges. The Skill-, Rule-, and Knowledge (SRK) framework will be used as a background to suggest solutions to the challenges, but various solutions from other standpoints will also be proposed. The importance of the “What, How and Why” questions and how they can be used to shape interview guides and thereby contribute to identify challenges, will also be illustrated. As a result it is desirable that the identified challenges, results and analysis in this thesis will contribute to a best practice to improve future SWI operations, from a human perspective.

The project tasks will be further presented in this section. The reason why these tasks were chosen are because they, from my point of view, are the right way to reach the objectives of the thesis, and I see these tasks as important and relevant.

The following project tasks will be conducted to achieve the thesis’ objective:

1. Defining the challenges the RLWI and AX-S concepts have within the given scope.
2. Identify where the operators and managers relevant for this thesis are located at the vessels, together with the workplace arrangement.
3. This is achieved through well prepared interviews with the companies which supply the SWI technology, in this case Island Offshore Subsea (IOS), FMC Technologies, Aker Well Service (AWS), Statoil and Expro.

4. The challenges are defined through four paradigms; the engineering, individual, cognitive and organizational paradigms (Redmill, 1997) to understand and provide an opportunity to reduce human errors. The paradigms aim to look at the challenges from different points of view. The defined challenges will be viewed in the context of the human performance model to elaborate the challenges of the system, and to get an overview of the complex work setting.
5. A fifth paradigm which I have composed, the work sociological paradigm, will also be presented and will be used to identify challenges. It describes team work and group dynamics, and will be viewed in context of the human performance model for the same reason as described above.
6. The Performance Influencing Factors (PIFs) perspective will also be used to identify the challenges within the give scope.
7. The identified challenges need to be discussed in relation to what can be done to improve the working situations. In this thesis the SRK-framework is used as a background to propose solutions, but solutions from different viewpoints will also be suggested. It is desirable that the results in this thesis will contribute to a “decision making and work performance best practice”, from a human perspective.

1.7 Data collection – Method

Relevant articles, documents, brochures and presentations were gathered and relevant online websites and literature from academic articles and books were collected from the University of Stavanger library and databases. Literature studies have been performed in the research, which enables the opportunities to identify, evaluate and study the challenges, and to suggest improvement opportunities. The compendium for the University of Stavanger subject MOM 410 Human-Technology-Organization composed by Professor Jayantha P. Liyanage, is one of the main literature sources in addition to the articles, websites and books listed in the references. The interviews for the information and result collection were directed to operational personnel for clarification of specific challenges of interest. The interview guide is given in Appendix 1. Also, visiting the Havila Phoenix vessel in “Onarheimsfjorden”, a 35 minutes helicopter flight from Bergen Flesland, was very useful when collecting the AX-S information and results. In addition, a presentation of the RLWI concept, held by Morten Iversen from Welltec, helped to increase the understanding of the thesis theme.

1.8 Limitations

The identified challenges in the SWI operators working situation are limited to the literature review within the scope of this thesis. When writing a Master's thesis, time is a limiting factor when collecting information and analyzing the results. Also, in the beginning it was quite challenging to reach the correct personnel to be able to conduct the interviews. They are busy, and they have many important tasks which must be performed, but in the end the right personnel were reached and interviewed with success. I also want to mention that I am a student and not a professional within the areas studied in this thesis, but through the literature studies, visits and presentations I feel that I have developed a good understanding and knowledge within the scope of the thesis.

The intention is not to study and develop technological and pure organizational based challenges and solutions. This thesis studies challenges from a human perspective, and critical factors potentially contributing to human errors. It also proposes solutions to the identified challenges potentially affecting decision making and work performance. The thesis touches the organizational element through the PIFs and the error causation paradigms (allocation of responsibility, management, standardization, team structure, procedures etc.), but the human perspective is the main focus.

There are some limitations in the AX-S results, due to the fact that the concept is not yet commercialized and is still in a testing phase. Therefore, the AX-S personnel could not answer all of the questions with the same amount of background experience as the RLWI personnel. Also, when identifying the challenges at a RLWI vessel, some choices had to be made. There are several vessels performing RLWI operations, and the alliance between IOS, FMC and AWS are operating three vessels. The Island Constructor vessel was chosen to be studied in this thesis, but in addition some results were gathered from the two other vessels, the Island Frontier and the Island Wellserver.

2. State of the Art and Literature Review

This chapter will first present the Subsea Well Intervention (SWI) technology concepts followed by a presentation of the vessels and the personnel's workplace arrangement. After this, the reader will gain an insight into the human performance model, decision making, work performance, PIFs and the error causation paradigms. Finally, a presentation of the HTO- and HF perspectives will be provided, followed by a description of the SRK-framework and an illustration of the use and importance of the "What", "How" and "Why" questions.

2.1 Subsea Well Intervention (SWI)

The SWI Industry is a specialized segment of the petroleum industry. There is a demand for an efficient well intervention system in order to increase oil recovery. Currently a number of technology tracks are under development addressing the service requirements for subsea wells. To have a future deep-water intervention system which is both technically and commercially successful, it is important and critical to have a well thought out concept selection (Browning and Moss, 2006).

Effectiveness, risk and cost balance is common to every offshore project, but this is especially true for SWI where success might include a broader spectrum of outcomes, and risks may be more difficult to quantify (Hurzeler, 2010). Well intervention provides higher efficiency, lower operating costs, improved production profile and extended life of subsea wells (Eni Norge, 2011). Figure 1 show a improved production profile when performing interventions.

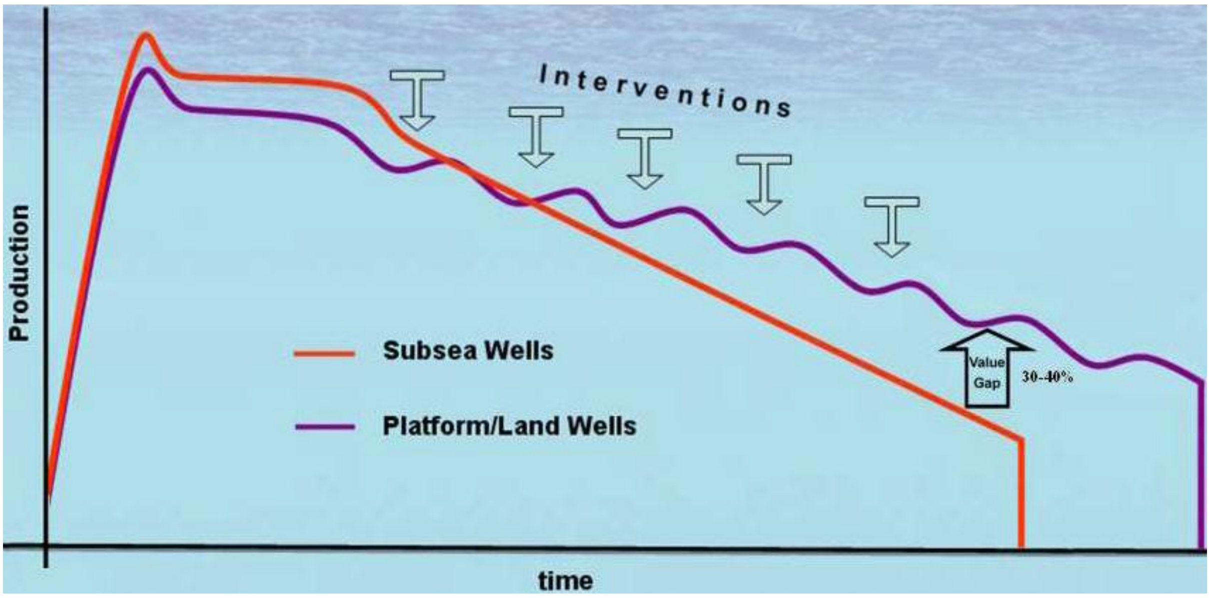

Figure 1: Illustrates production profile improvement when performing interventions (Welltec, 2012).

SWI also enables greater utilization of the resources, and the technology also allows a reassessment of the unprofitable oilfields because intervention costs are reduced and the recovery rate is improved. It provides the possibility of the cost saving opportunity of using vessels, instead of renting MODUs (Mobile Offshore Drilling Units). The intervention costs are therefore reduced by 1/3, resulting in better exploration of the subsea wells and enabling more intervention work (Island Offshore, 2012). Figure 2 illustrates that intervention costs are significantly lower when using vessels, compared to MODUs. Another benefit is that vessels are much easier to move than a moored rig.

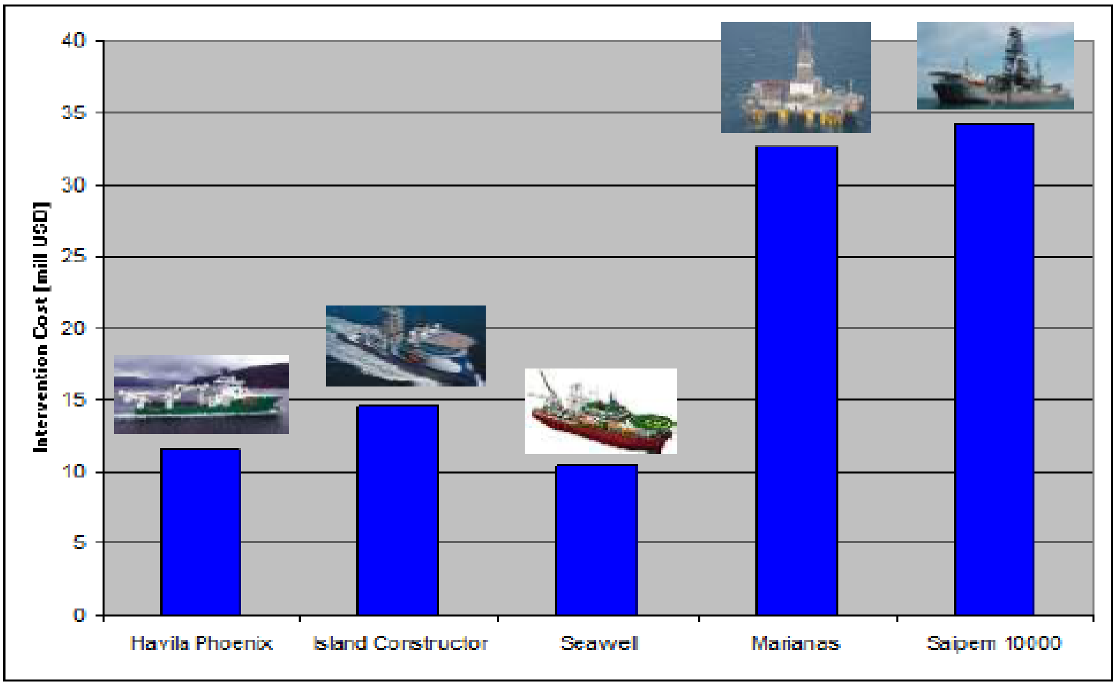

Figure 2: Intervention cost comparison for some vessels and big mobile units (Eni Norge, 2011).

The complex ship based RLWI- and AX-S concepts, belonging to the Category A in figure 3, will be further presented later in this chapter. Complex systems are characterized by the fact that subsystems interact. RLWI and AX-S is complex, not only because of the complex technology, but because of the many subsystems, teams, operators and clients involved in the operation with different tasks, communication structures and responsibilities. An important issue is how to provide an integrated service team and to establish onboard the vessel a safe and efficient working environment (Jøssang, Friedberg and Buset, 2008).

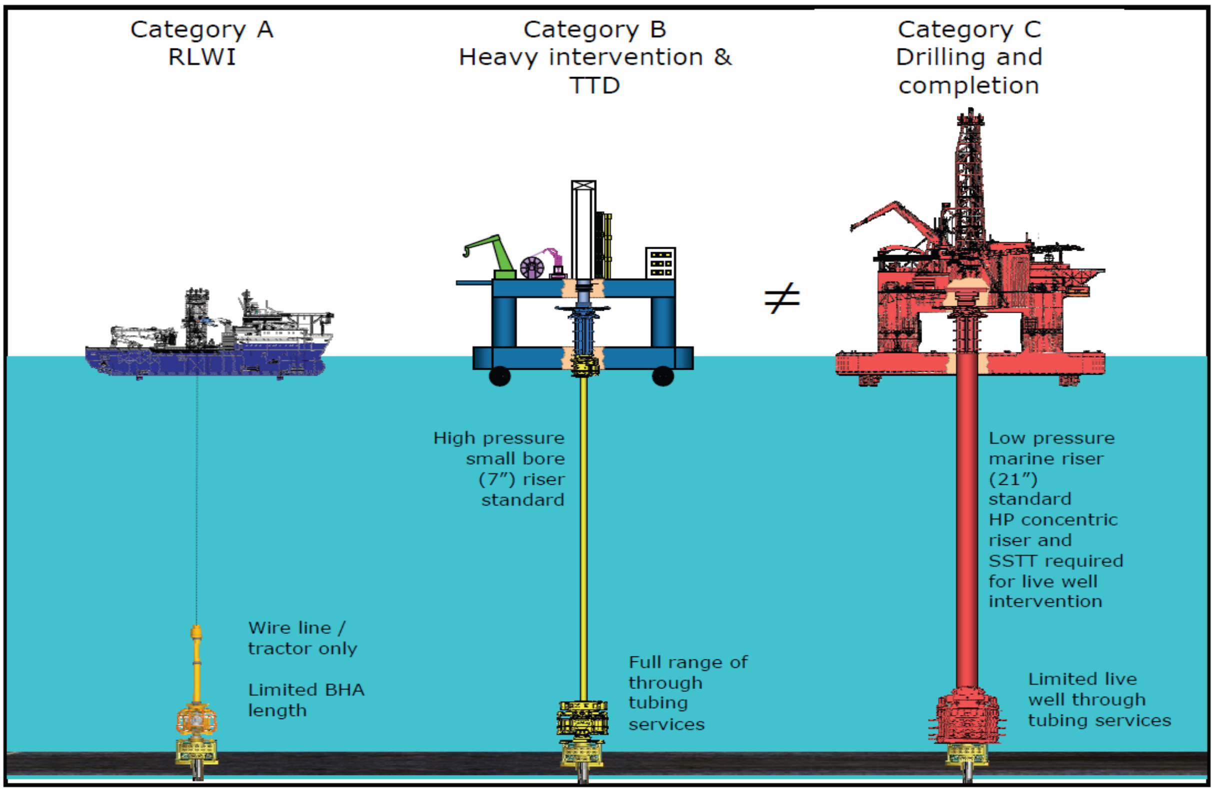

Figure 3: Illustrates the Category A, B and C well intervention technologies, and the difference between RLWI, heavy intervention rig and conventional rigs (Fjærtoft and Sønstabø, 2011)

2.1.1 Riserless Light Well Intervention (RLWI)

The offerings on the market today are dominated by Riserless Light Well Intervention (RLWI) solutions which have been used for decades. FMC Technologies has developed the RLWI technology which enables maintenance and inspection in a more optimal way (NTVA, 2005), and they have developed and operated RLWI equipment in the North Sea since 2003. Statoil was the first company to qualify the RLWI technology.

RLWI provides safety gains including avoidance of hydrocarbon transportation to the facility at the surface, but it also experience safety challenges due to complex operations and the need of special knowledge and control in every part of the preparation and execution. Figure 4 shows FMC's RLWI concept. RLWI units are optimal for installation and manipulation, repair and scale removal of some equipment (such as valves, plugs, etc.), fluid sampling, re-perforations, zone isolation, chemical treatment and well abandonment, among other services (DNV, 2010).

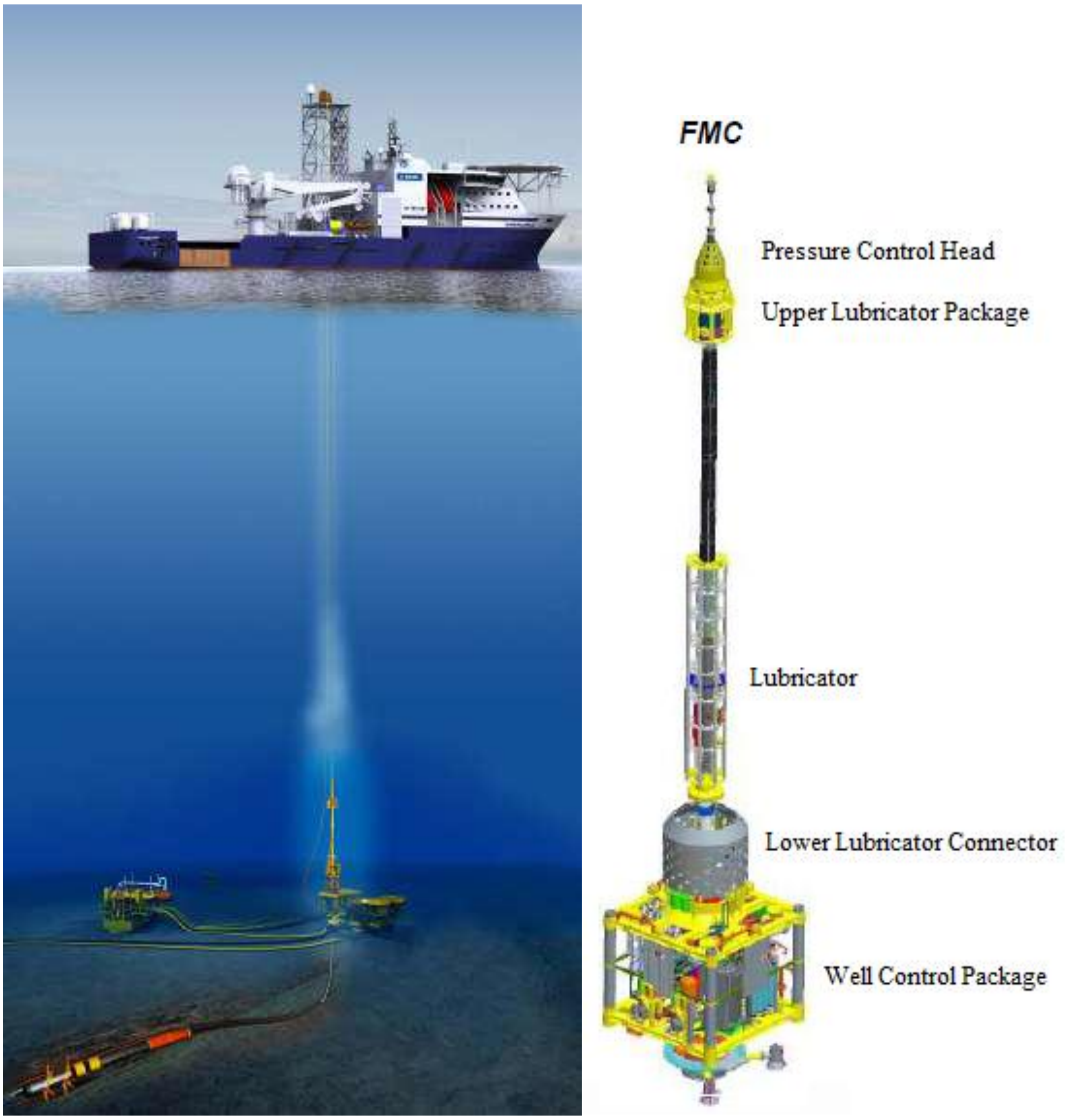

Figure 4: The company FMC's RLWI concept (Eni Norge, 2011).

RLWI has been performed successfully in the North Sea up to 600 meters (Mathiassen, Munkerud, Skeels, 2008). It is a great need for RLWI technology both nationally and internationally with a growing number of subsea wells with now over 5000 worldwide. The groundbreaking part of RLWI is the use of cables instead of the riser, which then allows vessels to perform the intervention. This saves huge costs for the oil industry (NTVA, 2005). The figures 5-8 shows the different main parts of the RLWI concept.

Pressure Control Head

The Pressure Control Head (PCH) is connected on the top of the lubricator section, and it functions as a pressure barrier. It consists of the wireline flow tubes and emergency packing elements. It also seals around the wire towards the pressure in the wellbore during operations (Jøssang, Friedberg and Buset, 2008). It can keep oil and gas to remain inside the PCH and well if the grease pressure is higher than the existing well pressure.

Upper Lubricator Package

The Upper Lubricator Package (ULP) provides a barrier element during intervention of the well and is connected between the PCH and lubricator (Jøssang, Friedberg and Buset, 2008). The PCH and ULP gives dynamic sealing against running wireline. The ULP is equipped with Shear Seal Ram which has the capacity to cut all slick and braided wires.

Lubricator

The Lubricator (LUB) Tubular is a temporary storage position for the wireline tool string on its way down into the well, or on the way out. It is a tubular section capable of storing a 22 meter long toolstring. It is used to house wellwork toolstring lowered into it from the surface (Jøssang, Friedberg and Buset, 2008).

Figure 5: The Pressure Control Head and the Upper Lubricator Package (FMC Technologies, 2008)

Figure 6: The subsea Lubricator, the Lower Lubricator Connector and the Well Control Package (FMC Technologies, 2008)

Lower Lubricator Connector

The Lower Lubricator Connector (LLC) provides a well safety barrier and connection to the lubricator section and to the WCP (Jøssang, Friedberg and Buset, 2008). It acts as a safety joint capable to disconnect the lubricator section from WCP, by remotley operated disconnect connector.

Well Control Package

The Well Control Package (WCP) has many functions and enables well control during wireline operations (Jøssang, Friedberg and Buset, 2008). The WCP is the heaviest module and consists of shear/seal ram able to cut wireline, wireline tool string and coiled tubing. It also supplies hydraulic pressure to the x-mas three functions, and is equipped with a x-mas three connector, which function as an interface between the WCP and x-mas three re-entry.

Figure 7: Lower Lubricator Connector Package (Welltec, 2012)

Figure 8: Well Control Package (Island offshore, 2009).

2.1.2 AX-S - Seabed system

Expro's AX-S team has their offices in Westhill, Aberdeen. Expro is in the end of the testing of their AX-S mammoth seafloor wireline system. It is a new type of seafloor based concept not yet in commercial use. It can operate in depths up to 3000 meters and negates the need of rig and riser systems by using remote intervention from a dedicated monohull vessel (Svensen, Williamson and Law, 2011). The wireline winch and well control systems are located on the seafloor with no tension lines between subsea systems and vessel, hence no vessel motions transferred to the subsea system. Figure 9 shows the packages that are deployed onto the subsea tree, and the figures 10-14 illustrates the packages individually.

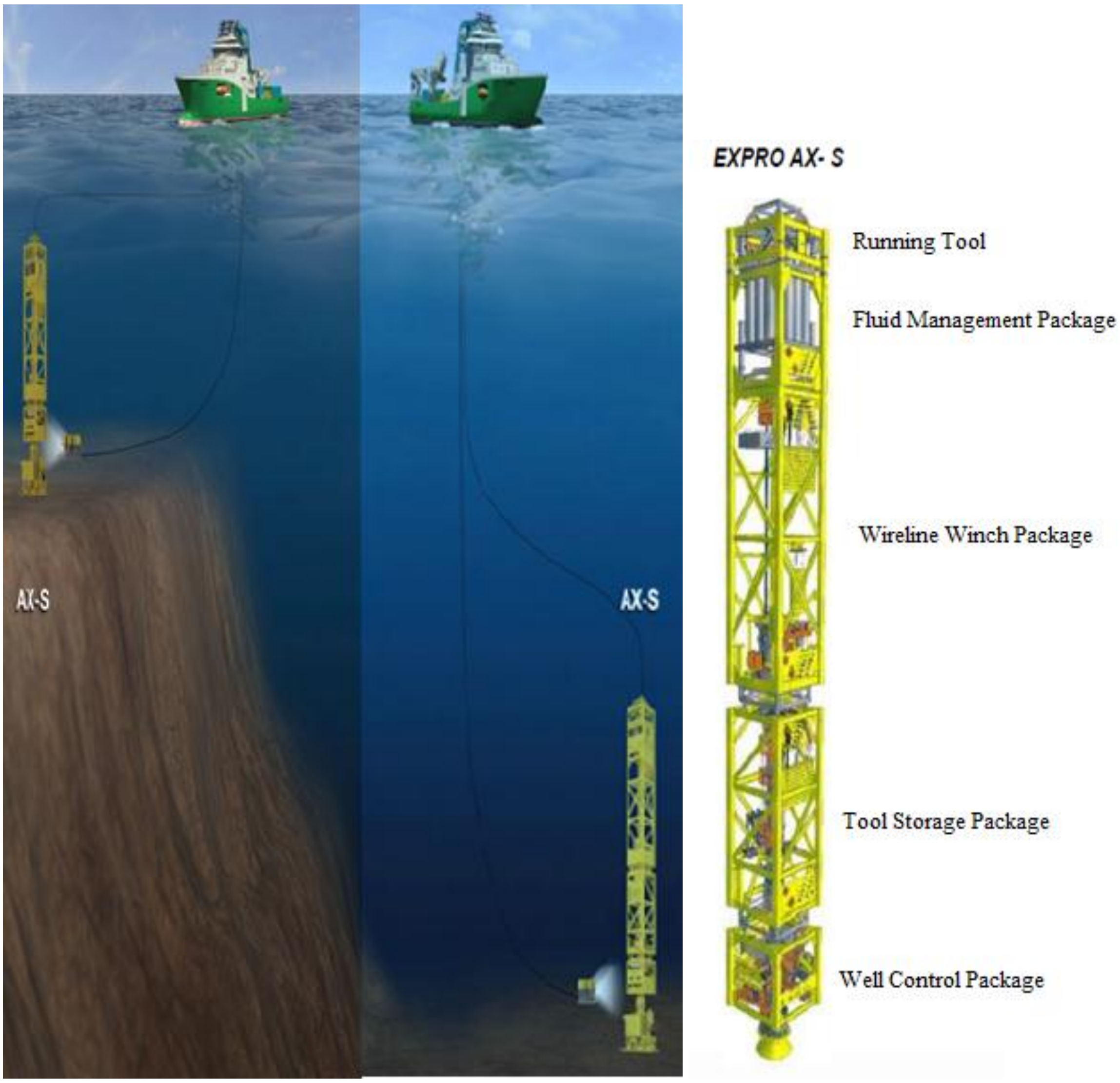

Figure 9: The company Expro's seabed concept, AX-S. Right picture (DNV, 2011); left picture (AX-S, 2011).

Running Tool

The AX-S deployment has a Running Tool (RT) in which the four main AX-S packages is deployed and recovered. The running tool is a load-bearing ROV, and it mechanically latches to all the packages through the four corner posts of their support frames (DNV Energy Report, 2011).

Figure 10: The Running Tool (AX-S, 2011).

Fluid Management Package

The Fluid Management Package (FMP) is the final subsea section and can deploy glycol fluid into the system to flush out hydrocarbons which are then circulated back into the well or subsea production system. The FMP contains the Glycol Chemical Injection Unit which provides glycol (and/or filtered seawater) for pressure testing and purging to help prevent hydrate formation. Methanol injection (for the dissolution of hydrates) is provided from an ROV skid (DNV Energy Report, 2011).

Figure 11: The Fluid Management Package (AX-S, 2011).

Wireline Winch Package

The Wireline Winch Package (WWP) is a winch with pressure housing and the tools are run in the well by the WWP. The winch has 25,000ft of mono-conductor which conveys the various intervention tools into the well (DNV Energy Report, 2011).

Figure 12: The Wireline Winch Package (AX-S, 2011).

The Well Control Package

The Well Control Package (WCP) is the dual safety barrier with standard interfaces, and contains industry-proven shear seal and gate valves. The operator has time to identify the problem if any safety issues arise, as the system is fully-enclosed pressure housing with no dynamic seals between wellbore and surrounding environments (DNV Energy Report, 2011).

Tool Storage Package

The Tool Storage Package (TSP) is a subsea warehouse with fast, remote tool change-out where tools are swapped at seabed. The TSP contains eight tool pockets which are located around the inner circumference of the package, and the tool are swapped on the seabed (DNV Energy Report, 2011).

Figure 13: The Tool Storage Package (AX-S, 2011).

Figure 14: The Well Control Package (AX-S, 2011).

2.1.3 The Subsea Well Interventions Vessels

Today, one type of vessel, the Havila Phoenix, is planned to perform AX-S operations for the company Expro since this is a new type of concept not yet commercialized. In contrast, there are several vessels performing RLWI operations since this technology has been used for decades. The North Sea Alliance consisting of Island Offshore Subsea (IOS), FMC Technologies and Aker Well Service (AWS) are the frontiers of the knowledge and technology for RLWI solutions. The Island Frontier, the Island Constructor and the Island Wellserver are RLWI vessels performing workovers. The three companies operate on these three RLWI vessels under a joint alliance. Statoil is a client for interventions in the North Sea. An overview of some of the vessels performing RLWI and AX-S operations are shown in table 1.

Table 1: An overview of some of the vessels performing interventions operations.

Vessels/Companies	FMC Technologies	Island Offshore	Aker Solutions	Expro Group	WellOps
Island Frontier (RLWI) Year 2004	✓	✓	✓		
Island Wellserver (RLWI) Year 2008	✓	✓	✓		
Island Constructor (RLWI) Year 2008	✓	✓	✓		
Seawell (RLWI) Year 1987					✓
Well Enhancer (RLWI) Year 2009					✓
MODU Q4000 (RLWI) Year 2002					✓
Havila Phoenix (AX-S) Year 2009				✓	

Seawell, Well Enhancer and MODU Q4000 are RLWI vessels operated by the company WellOps, but will not be further discussed due to the thesis's scope.

The project task number two, presented earlier, was to identify where the personnel relevant for this thesis are located at the vessels together with the workplace arrangement. I have chosen to present this location and arrangement in this section, since it fits quite well here when presenting the different vessels. The ROV (Remotely Operated Vehicle) personnel location will be presented shortly, but will not be further studied due to the thesis' scope.

The RLWI Vessels: The Island Frontier, Island Constructor and Island Wellserver

The Island Frontier, Island Contructor and Island Wellserver vessels are capable to meet and fulfill some of the toughest requirements in the industry and have been built for worldwide operation (Island Offshore, 2012). The Island Constructor will be the main study basis for the RLWI part of this thesis, but the Island Frontier and the Island Wellserver will also be presented shortly. The vessels main activities are:

- Well intervention services with subsea lubricator system (LWI/RLWI)
- Subsea construction and equipment installation
- Inspection, Maintenance and Repair (IMR)
- ROV services

The Island Frontier

The Island Frontier is designed as an offshore construction and Light Well Intervention vessel, and was delivered by Sørviknes Verft AS in 2004 (Island Offshore, 2012). This vessel is the oldest vessel compared to the Island Constructor and the Island Wellserver, which both are produced in 2008. The installation is able to fulfill subsea installation and module handling operations, RLWI services, trenching and ROV operations (Island Offshore, 2012). Its accommodation is 72 persons. Figure 15 shows the Island Frontier.

Figure 15: The Island Frontier, delivered in 2004 (PSA, 2006).

The Island Frontier personnel location and workplace arrangement

The following personnel have their workplace located in the Tower Control on deck next to the moonpool:

- Tower operator
- Wireline operator

The tower operator sits next to the wireline operator and they have an overview to the deck work area from the Tower Control.

The following personnel have their office spaces located in other operational rooms (in the recidential part), elsewhere than the Tower Control:

- Well Intervention Superintendent (WIS)
- Well Intervention Supervisor (WIS)
- Statoil supervisor
- FMC supervisor
- WOCS operator
- ROV operator
- Service personnel

The Well Intervention Superintendent (WIS) (IOS) reports to the onshore facility, where the Operations Managers have their offices. The Well Intervention Supervisor (WIS) (IOS) reports to the Well Intervention Superintendent (WIS). The operators report to the supervisors and to the Well Intervention Superintendent (WIS). Note that the "WIS" abbreviation is used for both the Well Intervention Superintendent and the Well Intervention Supervisor and this applies to all three vessels.

The Well Intervention Supervisor (WIS) sits at the WIS control desk in between the ROV and WOCS (Workover Control System) operator in the recidental part of the vessel. The Well Intervention Superintendent (WIS) also has his/her office in the residential part at the floor above the WIS control. The Statoil supervisor has an office next to the Well Intervention Superintendent and the FMC supervisor has his/her office at the floor underneath the WIS control. The service personnel have their office in the landscape in the recidental part next to the WOCS office.

The Island Constructor

The Island Constructor is a Well Intervention Unit delivered in 2008 from Ulstein Verft AS (Ulsteingroup, 2008) and is the main study basis for the RLWI concept in this thesis. It has been designed as an offshore construction and Light Well Intervention Vessel, and is able to fulfill construction work, tower and module handling, installation work, IMR work, survey, crane and diving (Island Offshore, 2012). All of the navigation and communication equipment is delivered and installed by Ulstein Elektro (Maritimt Magasin, 2012). Its accommodation is 90 persons and has already experience from several types of subsea projects (Island Offshore, 2012). Figure 16 shows the Island Constructor.

Figure 16: The Island Constructor, delivered in 2008 (Island offshore, 2010).

The Island Wellserver

The Island Wellserver was delivered the same year as the Island Constructor from Aker Yards Langsten (Maritimt Magasin, 2012). The installation is able to fulfill RLWI, installation and module operations, trenching, ROV operations, construction work and diving (Island Offshore, 2012). The vessel is equipped with a moonpool for the handling of subsea equipment, and a Launch and Recovery System (LARS) for handling ROV. MHS (Module Management system) is included in the tower (Maritimt Magasin, 2012). Its accommodation is 97 persons, and all navigation and communication equipment are provided by O. Øverland in Molde. Figure 17 shows the Island Wellserver.

Figure 17: The Island Wellserver, delivered in 2008 (PSA, 2009).

The Island Constructor and the Island Wellserver personnel location and workplace arrangement

The following personnel have their workplace located in the Tower Control on deck next to the moonpool:

- Well Intervention Supervisor (WIS)
- WOCS operator
- Tower operator
- Wireline operator
- Service personnel

Figure 18 shows the location of the Tower Cabin at the Island Constructor, which will be studied in this thesis. The tower operator sits in between the WOCS and wireline operator and they have an overview to the rest of the work area from the Tower Control, while the Well Intervention Supervisor (WIS) sits in the back in his/her own office. This is shown in figure 19. The figure also shows the AWS and FMC desk location. The Schlumberger logging personnel are also located here.

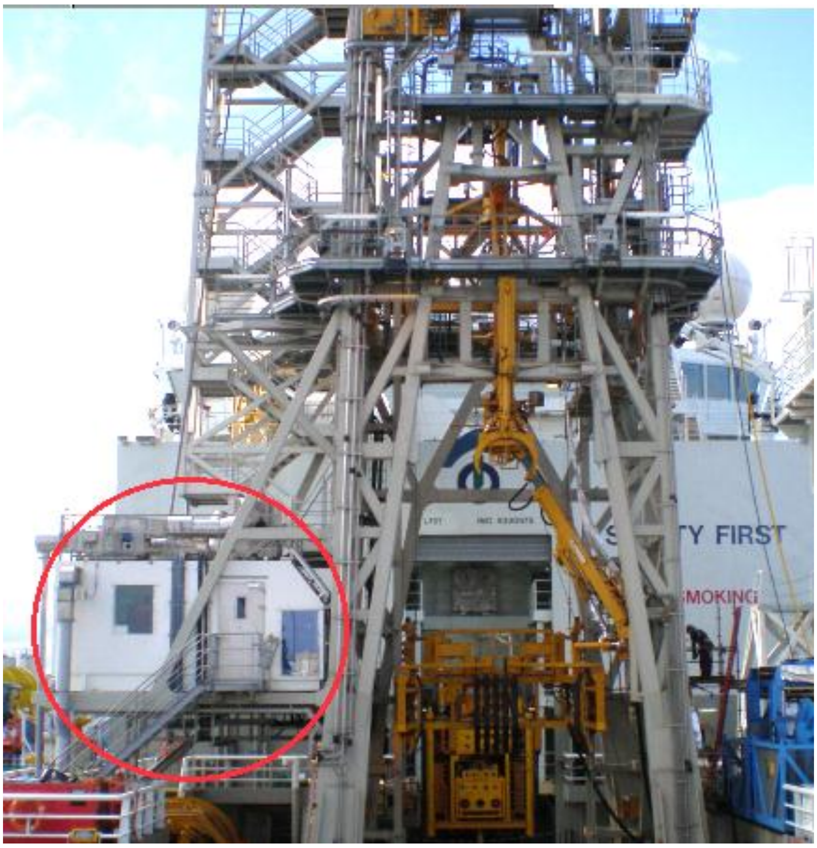

Figure 18: The Tower Control cabin at the Island Constructor. The picture was received from IOS to be used in this thesis.

Figure 19: The Tower Control where RLWI operations are performed. The picture was taken at the Island Constructor vessel to be used in this thesis.

The following personnel have their office spaces located in other operational rooms (in the recidential part called “A-Deck”), elsewhere than the Tower Control:

- Well Intervention Superintendent (WIS)
- Statoil supervisor
- FMC supervisor
- ROV operator

The FMC supervisor has his/her desk in between the Statoil supervisor and the Well Intervention Superintendent (WIS) in the recidental part called “A-Deck”. The ROV sits in his/her own big separate ROV room with all ROV pilots and screens collected next to the Well Intervention Superintendent (WIS). Operations managers are located primary onshore.

The difference is that the Island Constructor and the Island Wellserver has the Well Intervention Supervisor (WIS), WOCS operator and service personnel located in the Tower Control, in addition to the tower operator and wireline operator, while the Island Frontier only have the tower operator and wireline operator located in the Tower Control. All three vessels have additional personnel at the vessel such as the Offshore Installation Manager (The Captain, OIM), the deck crew, the marine crew and the service personnel responsible for logging and tractor.

The RLWI Control System

The Control System enables remote control of the RLWI subsea well intervention operation. Depending upon the required function operated through Human Machine Interface - HMI, there is a combination of manual and automated system. The Control System communications system and remote control of subsea intervention operations performed by the operators in the Tower Control are shown in figure 20 and 21.

The Tower Control is a communication interface and includes power distribution, real-time computers and software. FMC WOCS (Workover Control System) provision for control during intervention is also included in the control system. This operator maintains, test and control subsea stack and related topside equipment. They operate and monitor well and subsea stack during operation from the Control System, and they also redress and test PCH between wireline runs.

Figure 20: The WOCS and wireline operator's panels and seats. The pictures are taken at the Island Constructor vessel to be used in this thesis.

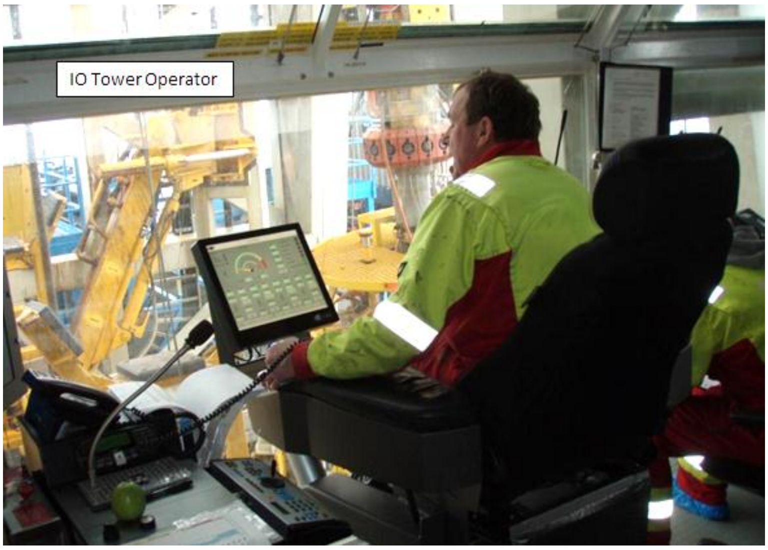

Figure 21: The tower operator panels and seats. The picture is taken at the Island Constructor vessel to be used in this thesis.

The Island Offshore tower operator handle tower winch and cursor frames during installation and retrieval of subsea equipment from the Control System remote control. The wireline unit is operated by the wireline operator from the Control System in the tower control. The ROV Oceaneering operator handles ROV from the Control System on directions from Well Intervention Supervisor (WIS), FMC or Aker.

The AX-S Vessel: The Havila Phoenix

The Havila Phoenix is a Havyard 858 design subsea construction vessel. It was built at the Havyard Leirvik facility in Norway and delivered in 2009 (DNV Energy Report, 2010). The vessel is planned to conduct well intervention activities using Expro designed AX-S system. It is able to fulfill well intervention services, subsea construction and equipment installation, Inspection, Maintenance and Repair (IMR) and ROV services. The living quarters are located forward and provide accommodation for up to 114 people (Havila, 2011). The core crew is expected to be 63 persons (DNV Energy Report, 2011). Ulstein Elektro has delivered navigational and communication equipment. Figure 22 shows the Havila Phoenix.

Figure 22: The Havilia Phoenix vessel (AX-S, 2011).

The Havila Phoenix personnel location and workplace arrangement

Aside from the management there are projects, intervention, deployment, maintenance, and deck and ROV departments within the AX-S operating team at the vessel. Operations managers are located onshore, while the different supervisors (shift supervisor, well intervention supervisor, deployment supervisor and ROV supervisor etc.) and deck team are located offshore at the vessel. The deployment supervisor, interventions supervisor, maintenance leader, ROV supervisor and their teams and the deck foremen, reports to the shift supervisor. The shift supervisor report to the project engineer and to the Offshore Installation Manager (The Captain, OIM). The onshore operational manager is on top in the reporting hierarchy after the AX-S Managing Director.

The vessel has two cabins on deck, the Deployment Cabin and the Intervention Cabin. The Deployment Cabin is stationed above deck overlooking the handling system, to be able to oversee all operations on deck and in the tower/moonpool. Figure 23 shows the location of the Deployment- and Intervention Cabin and their inside layout is illustrated in figure 24 and 25. The Intervention Cabin is placed under the Deployment Cabins and is hid in the picture. The deployment supervisor and the deployment team are located in the Deployment Cabin, while the well interventions supervisor is located in the Intervention Cabin together with the team. At the Bridge the shift supervisor is stationed, together with Dynamic Positioning (DP) team, survey and other crew members. The Bridge provides a central controlling station for the AX-S system, coordinating subsea and marine activity. Station keeping is handled with the use of DP. The vessel also has two ROV shacks, with a team of three people in each shack.

Figure 23: The location of the Deployment Cabin. The Intervention Cabin is placed straight under this cabin. The picture was received from Expro to be used in this thesis.

Figure 24: The Deployment Cabin showing the panels and the operators view. The picture was received from Expro to be used in this thesis.

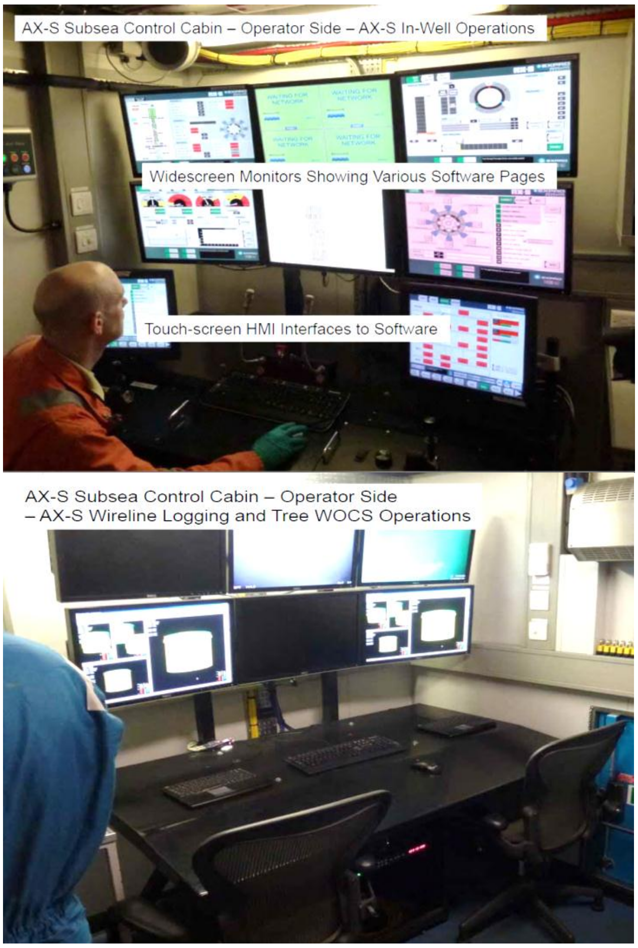

Figure 25: Subsea Intervention Cabin layout where the WOCS, wireline and other intervention operations are performed. The pictures were received from Expro to be used in this thesis.

The AX-S Control System

The Control System enables remote control of the AX-S subsea well intervention operation. The system is based on subsea deep water ROV controls architecture and components, and it comprises all hydraulic controls including subsea hydraulic power units (HPUs) and valves, electronic signal communication, the wireline winch electric drive, power distribution and data collection. There is a remote control of the subsea intervention operations with touch-screen fly-by-wireline control. The handling system is controlled via the control room on deck. There is a combination of manual and automated system depending upon the required function operated through Human Machine Interface - HMI (AX-S, 2011).

The Control System also includes acoustic communications system, remote control of subsea intervention operations and wireless telemetry (health check) system during AX-S intervention operations. Workover Control System (WOCS) provision for the well head/tree control during intervention is also included in the Control System (AX-S, 2011). All control of the subsea tree will be “local” if required by utilizing the AX-S WOCS or Tree Vendor WOCS or host platform specific to the type of subsea tree to be interfaced with during the intervention operation.

The interventions team is responsible for running of the subsea AX-S system, well control operations and wireline (electric-line & mechanical services) operations. The deployment team is responsible for safe handling of the deck handling system, running tool operation and deployment of the AX-S subsea packages. They operate the automated handling system which consists of back deck transfer, tower, main winch with rope and running tool. The wireline carry out the downhole operations. This may involve testing and recoding readings which give data that can be used for reservoir analysis and remedial works. Figure 25 and 26 shows some of the control systems layout in the Deployment- and Intervention Cabins.

Figure 26: The control system layout in the Deployment Cabin presented at the screens. The pictures were received from Expro to be used in this thesis.

2.2 Human and Organizational issues

2.2.1 The Human Performance Model

The human performance model is an analysis which examines what is involved in human performance and it gives an overview of the complex work setting. It helps to spot factors that may have a large potential to contribute to work performance (Bailey, 1996). The model can thereby contribute to identify human and organizational issues.

Performance can be divided into two levels (Bailey, 1996):

- The perfect performance
- The acceptable performance

The human performance is the activities carried out by the system's human elements (Reason, 1997). Few designers have the requirements and resources to design for optimal performance, but they must be able to ensure an acceptable level of human performance. Work performance will be further described in section 2.4. One can take into account the following components to achieve a near perfect or acceptable level of human performance (Bailey, 1996):

- The general state or condition of the *human*
- The *activity* being performed (including required equipment or tools)
- The *context* in which the activity is performed

In other words, to predict human performance and to achieve an acceptable or close to optimal performance, one has to understand the human, the activity the human performs and the context the human performs the activity in. The human performance model is shown in figure 27. The interfaces and interactions between the human, activity and context components are also important to study. In human-machine activities the interaction between the human and activity component are a critical interface, while organizational barriers can create interface problems by providing resistance to change, or that the management does not pay attention to or reward good user interfaces. It is also important to understand that it is equally important to assess the human, activity and context together, and the interactions between them, as to study them separately (Bailey, 1996).

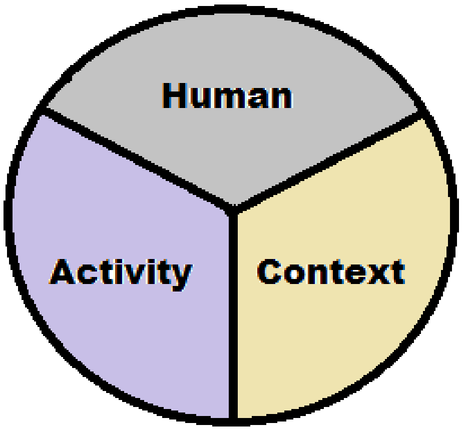

Figure 27: The Human Performance Model.

The Human

The human is the most complex of the three elements in the human performance model (Bailey, 1996). The sensors (vision, hearing, etc.), the brains at cognitive level (the ability to think, find reasons and make decisions) and the responders (arms, fingers, mouth, etc.) are considered in the human component. The designers do not know the humans who will work in their systems, but it is important to understand and implement in the design how people sense, respond and process information (Bailey, 1996).

Human performance can be affected in a negatively and positively way, where reduced performance would be expected for example because of poor sleep, unsatisfactory hearing, unacceptable behavior (due to for example lack of motivation, conflicts, attitude), poor eyesight or lack of abilities. The following excerpts shows as an example were lack of knowledge, abilities and wrong attitude may be an obstacle for correct decision making and acceptable performance:

"One day a very very senior manager of the Dow Chemical Company walked into the control room of an ethylene production plant. He pointed to a pipe rack in the production area and asked an operator, "Tell me, what would you do if the flange on that ethylene line cracked and ethylene poured all over the deck?" "Well." said the operator. "Unless there is a shut off valve in the car park. Nothing!"." (From Chambers, 2005)

Attitude, knowledge and ability limitations illustrate how the human capabilities and response to an unexpected situation may hinder them to achieve the main purpose of the task.

The designer or engineer should understand the human qualities, characteristics and deficiencies, and in the best possible way take them into account when producing the system and making decisions. They have to handle the strengths and weaknesses expected in an expected population of users (Bailey, 1996).

The Activity

The next component is the activity performed, and includes any required tools or equipment (Bailey, 1996). The designer controls the conditions of performance and execution of the activity, and must know and control the factors that affect performance, both positively and negatively. It is important to know which types of work can be performed by people and what can best be performed by computer- or automation systems. To build sufficient skills for an acceptable or near perfect level of human performance, it is important to know what kind of training is required and needed for the human to perform the activity.

The Context

The context in which humans perform the activity may affect performance and can make a big difference for human performance. Working conditions must be provided to enable the operators to function efficiently without distraction to ensure a safe operation of the system, and it is also important to match the system to the mental ability and skills of the staff (Wong, 2002). Bailey (1996) defines the context as *"the circumstances in which an event occurs"* and three context considerations are described:

- The physical context
- The social context
- The psychological context

Physical context

The physical context includes the location and the environmental conditions. Examples are noise level, temperature, lighting, vibration and pollution. Noise is probably the single most studied factor in the physical context (Bailey, 1996).

Social context

The social context includes conditions that may affect human performance, such as the effects of other people, crowding, isolation and clustering (Bailey, 1996).

Psychological context

The psychological context may affect human behavior (Wong, 2002). Humans have emotions that can influence the way they behave and how they respond to the culture at work. It is important to have attention on developing a safety culture, including training and education related to the work performed.

2.3 Decision making

2.3.1 Potential decision making challenges and risks

The decision making processes at the SWI vessels are very complex due to close couplings, interactions and dependency between system components which may make it difficult for decision makers to keep an overview of the critical events. Many activities take place in parallel in complex systems and these parallel activities may interact in non-obvious manners if the system is characterized by high interactive complexity (Rossnes, Guttormsen, Steiro Tinmannsvik and Herrera, 2004). This may lead to risks due to an increased probability of taking the wrong decisions with serious consequences. Serious accidents may occur because decision making has been deficient due to that a incorrect decision was taken or because no decision was taken when required. According to Hollnagel (1984) the decisions the person makes can shape the performance.

Today, operation centers may have more real-time data than their capacity, and offshore personnel have to cope with more information from the operation centers than they can handle (Grøtan and Albrechtsen, 2008). Decisions are often taken at a distance from the actual operation without a proper understanding and knowledge of the work settings. The condition under which decisions are made, strongly influence the outcomes and decision processes (Rossnes, 2001). According to the Sintef report (2008) written by Grøtan and Albrectsen, the real-time availability for a wide range of expertise from all stakeholders together with new forms of decision support, can lead to "the more cooks, the more mess". Communication and cooperation problems, conflicting objectives and a demand of unnecessary information or too little information can cause risks. Also, more group-based decision making may obscure who is responsible for performing the action.

2.3.2 Two dimensions and five categories for decision making

Some decisions are made at the “sharp end” close to the hazard sources, while others are made at the “blunt end” away from the hazard sources (Rossnes, Guttormsen, Steiro Tinmannsvik and Herrera, 2004), illustrated in figure 28. The different categories of human decision making and action can be defined in several ways (Hollnagel, 1984):

- decisions in situations that are familiar and frequent
- decisions in situations that are familiar but infrequent
- decisions in situations that are unfamiliar and infrequent

According to Rossnes, Guttormsen, Steiro, Tinmannsvik and Herrera in the Sintef report (2004), one expects decision criteria, procedures and outcomes to be related to two dimensions, presented in figure 28:

- *Proximity to the hazard source* (operators facing a gas leak is in a different situation than the designer of the system)
- *Level of authority* (who can give orders and directives to whom)

Many managers will move to the right in figure 28 in crisis situations and take a more operational role and even "sharp-end" - decisions, which under normal conditions are left to the operator (Rossnes, 2001).

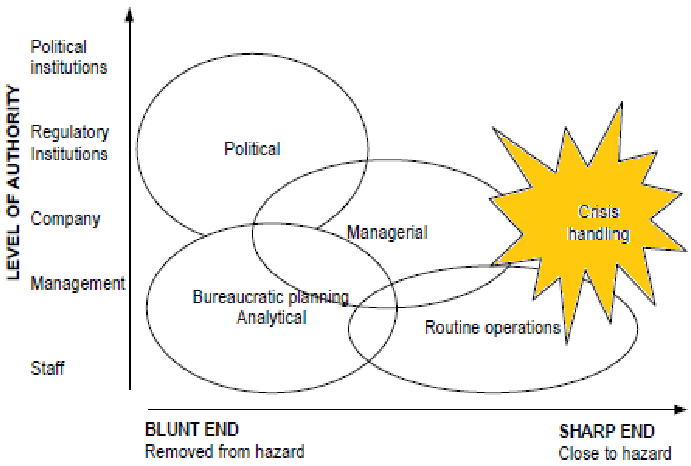

Figure 28: Five classes of decision processes (Rossnes, Guttormsen Steiro, Tinmannsvik and Herrera, 2004; Rossnes, 2001).

Figure 28 also illustrates that the introduction of the two dimensions can help to simplify the range of decision situations into five rough categories (Rossnes, 2001):

1. Political and bureaucratic decision making is applicable in situations characterized by conflict of interest. This conflict is between the parties who have roughly equal power in relation to the decision. Typical decision problems may be inconsistency, non-optimal decisions and erosion of safety margins (Rossnes, 2001).
2. Managerial or satisficing decision making characterizes many management decision makers that does not have the capacity to search for the optimal action alternative. The manager therefore chooses the first acceptable alternative. The working day for managers at high levels are characterized by many decisions, lack of time and

large amounts of information to be handled. Typical decision problems are inadequate problem definitions and erosion of safety margins (Rossnes, 2001).

3. Bureaucratic planning or optimization means that one under the given constraints seek optimal decision alternative based at models that do not capture the reality together with incomplete knowledge. Designers, planners and risk analysts often have sufficient time to focus on optimization, but they often lack experience with the systems they are working with. Other problems may be unrealistic assumptions, limited feedback, deficient models and erosions of safety margins (Rossnes, 2001).
4. Routine operations decision may lead to conflicting objectives between process operators and others who work close to sources of danger. The most of the time they have a focus on operating efficiently, avoidance of interruption and keeping their workload to an acceptable level. The routine decisions can be fully automated or programmed through procedures and instructions. Typical problems may be slips, missed warnings, local rationality and erosion of safety margins (Rossnes, 2001).
5. Crisis handling decision happens when the decision maker face imminent threats. A typical problem may be unpleasant stress, psychological limitations and defective coping if danger materializes (Rossnes, 2001).

2.3.3 The "Step ladder" Decision Model

Models of decision making are proposals for how the internal processes of the decision making system are organized and structured, and account for how decisions are made. The empirical sequential "Step-ladder" model described by Rasmussen is the best known model. This model is the basis of the skill, rule, knowledge distinction which will be described later. The "Step- ladder" model identifies eight steps of decision making from activation to execution (Redmill and Rajan, 1997):

1. Activation - Detection of need for data processing.
2. Observation - Gathering of information and data.
3. Identification - Naming the present state of the system.
5. Interpretation - Considering the consequences for current task, safety, efficiency, etc.
4. Evaluation - Evaluating the alternatives in relation to the chosen performance criteria.
6. Goal Selection - Selecting the appropriate change of system conditions.
7. Procedure selection - Planning the sequence of actions.
8. Execution - Carrying out the planned actions and coordinating them.

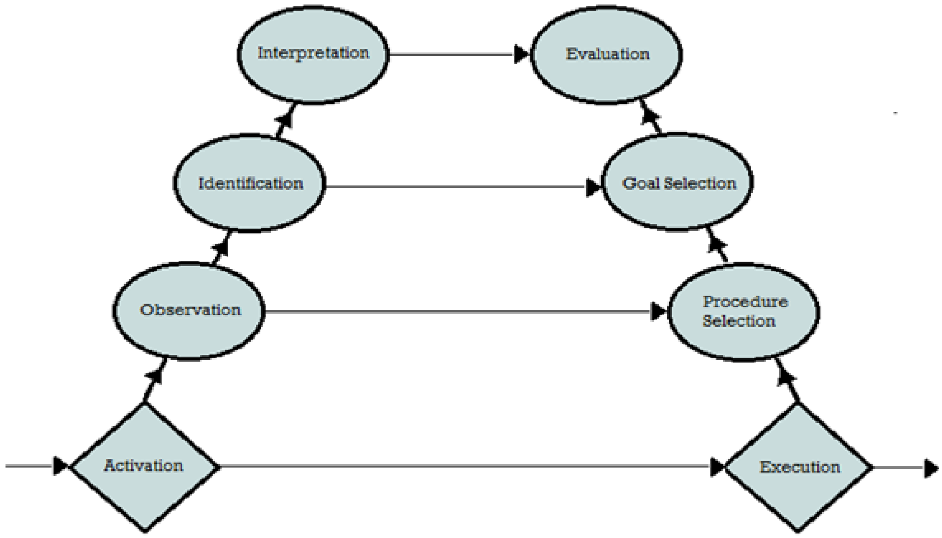

Figure 29: The “Step-ladder” model of decision making (simplified) (Redmill and Rajan, 1997).

Figure 29 shows the short cuts (transverse links between stages of decision making) that human decision makers take in real-life situations (Redmill and Rajan, 1997). There is no stage called decision or choice, but instead the decision is the outcome of a number of iterations between interpretation and evaluation. This model has been applied with some success by a number of researchers (Redmill and Rajan, 1997). One of the advantages of the “Step-ladder” model is that it specifies the correct and complete way to execute the procedure and it also accounts for the various ways in which shortcuts may be made (Hollnagel, 1984).

2.4 Work Performance

To assess and improve the human performance, HTO and the HTO interactions in complex work settings, the knowledge of work performance can be used to create a work situation which actively contributes to a safe and efficient operation, taking into account opportunities, limitations and human needs. The understanding of work performance can thereby be used to assess and improve the human performance and HTO interactions. The work performance has to be better understood in the SWI context, to achieve an acceptable or close to optimal human performance.

One must strive to optimize work performance, but this is challenging due to many unexpected factors influencing the work performance under different working conditions and operational settings. To understand what is meant by work performance, is the first step in making informed people decisions (Redmill and Rajan, 1997). Different performance influencing factors (PIFs) affect the work performance and the human ability to improve performance. Also, error causation paradigms can help to elaborate and improve work performance in complex work settings, with the advantage of contributing to a challenge evaluation and identification from different point of view.

2.4.1 Performance Influencing Factors (PIFs)

Performance Influencing Factors (PIFs) can affect the human performance and the human abilities to perform actions in a safe and efficient manner. Embrey (2000) defined PIFs as *"those factors which determine the likelihood of error or effective human performance"*. These factors are often the reason for human errors, and they may also affect the ability to improve and improvise work performance. Performance will be optimal and error likelihood will be minimized when PIFs relevant to a particular situation are optimal (Embrey, 2000).

The understanding and knowledge about PIFs is critical to achieve the goals of safe and effective performance, and it gives valuable information, so specific measures can be done to reduce the negative effects on performance. The human sense organs eyes, ears, nose, taste and sensory receptors in the skin receive stimuli which are processed in the human brain, and may affect the performance.

PIFs can be classified as (ExproBase, 2008):

- *Workplace-related factors* (routines, environment, equipment, layout, interaction personnel policy, economy)
- *Human-related factors* (Personal - , Psychological - and Physiological - factors)

Different researchers may tend to classify the factors differently, and figure 30 shows how Redmill (1997) views the PIFs.

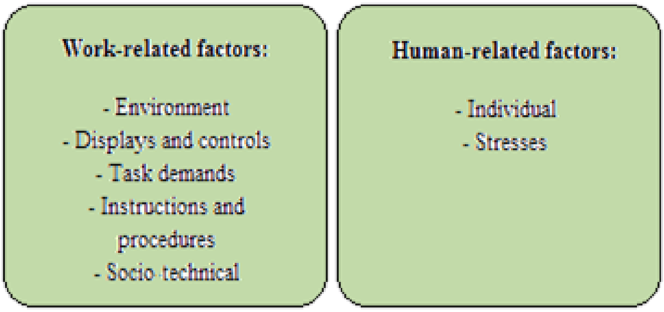

Figure 30: PIFs, work-related and human-related factors (Redmill and Rajan, 1997).

Basic human error and PIFs are factors that together can create critical operational situations with serious consequences, but the error likelihood can be minimized and the work performance can be improved when PIFs are identified, classified and optimized. A lack of this identification is may contribute to human errors, poor decision making and reduced performance.

2.4.2 The Paradigms of Human Error Causation

Niccolo Machiavelli, an Italian historian, philosopher, humanist, and writer once wrote:

"A common failing of mankind is to never to anticipate a storm when the sea is calm"

Human error can be caused by various conditions, issues and sources in a given work setting. The human error causation paradigms presented in this section, were proposed by Redmill (1997) and are used to elaborate complex interactions and to get an instructive overview of the complex work settings. It can thereby contribute to be "prepared for a storm" or to implement measures to hinder such situations by spotting the critical influence factors that have a great potential to influence and contribute to safety and work performance risks.

The human error causation paradigms include the engineering error paradigm, the individual error paradigm, the cognitive error paradigm and the organizational paradigm (Redmill and Rajan, 1997). The paradigms are different from each other and evaluate challenges from different points of view. They identify and seek to answer what are the challenges and influencing factors in the given working situations and what can be done to improve the work setting. Figure 31 illustrates the four paradigms. In addition, I wish to present a work sociological paradigm I have put together and defined in the end of this section.

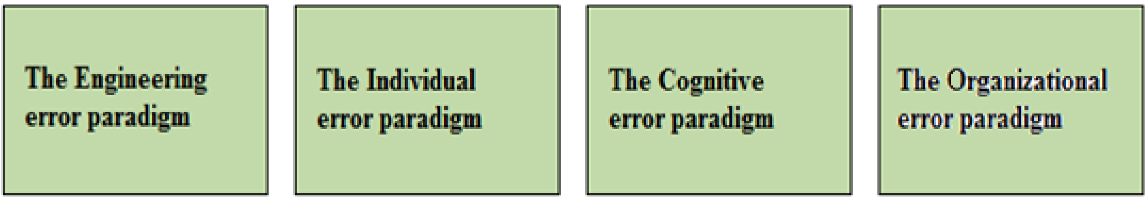

Figure 31: The four error causation paradigms (Redmill and Rajan, 1997).

The Engineering error paradigm

The engineering error paradigm relates to the design, technical aspects of the system and the characteristics of the system. This paradigm looks at the human as an unreliable part or almost equivalent to hardware components in the system. Important aspects are the human-machine design, human-computer design and automation (Redmill and Rajan, 1997).

Automation is performed to “engineer out” human failures and is often performed to reduce risk and cost, but it is important to remember that the automation can create new sources of reducing human reliability. Designing the man “out of the loop” through automation is often considered as a proposal for reducing risk, but the system designer may introduce errors into a system during the design process (Redmill and Rajan, 1997). Therefore, automation is not always proven to be cost-reducing and effective. Errors may for example occur when a non-automated task have to be performed by an operator. Failures or errors in an automated process are considerably more complicated than in a manual process, therefore an important issue is related to risk and the recovery from failures.

From a human-machine interaction view errors often occurs as a result of a human-machine mismatch between the demands of the task, the characteristics of the interface provided to enable the person to carry out the task and the physical capabilities of the person (Redmill and Rajan, 1997). This part of the engineering error concentrates on the individual and the immediate work situation, which has a clear connection to the socio-technical working context and the human-machine interactions which is in direct contact with the operator. All attributes of an interactive system (displays, screens, controls, task aids, alarm management, panels and other hardware and software devices) that provide the information and controls necessary for the user to perform tasks is included in the term Human Machine Interface - HMI, illustrated in figure 32. Humans perceive information from technical systems or machines through the senses and relate it to previous experience, rules and procedures (cognition) before taking action. The actions are performed on the controls of a system like “press a button” or “pull the handle” and the technical system handles the input. The feedback from the machine is presented by displays. The engineering view promotes recognition solutions to human reliability through ergonomic design changes, improved training and procedures. There is also a clear focus on PIFs (Redmill and Rajan, 1997).

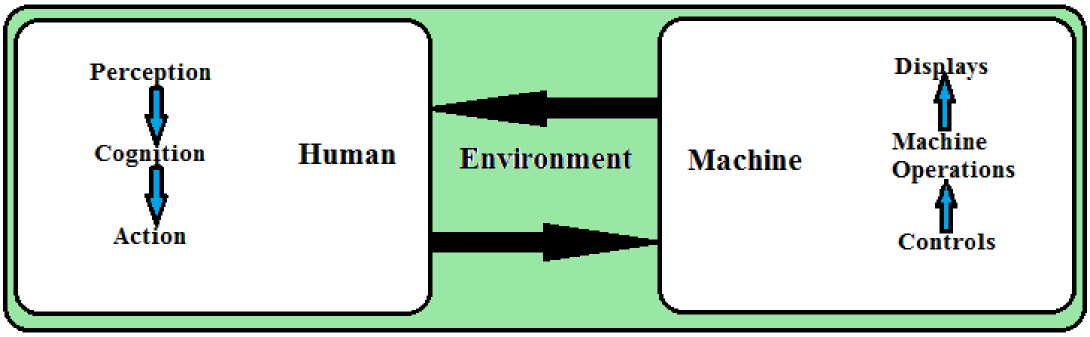

Figure 32: A simple Human Machine Interphase (HMI) model.

The Individual error paradigm

The individual error paradigm considers the personnel characteristics like attitude, safety attributions, motivational and personality issues. Even a very professional design may have the tendency to lead to errors in the presence of such personnel characteristics. The humans are very unpredictable because of their great diversity. This view relates to and presents that human errors occur because the person is “not trying hard enough” or “not paying sufficient attention to the task” (Redmill and Rajan, 1997). A person can make an error that is well known and well understood with tragic consequences. The motivation of the worker is often questioned by an investigator, and solutions to human error from this view are often related to disciplinary measures, such as suspension and dismissal. Human performing “corner cuttings” in work situations can be attributed to safety attitudes, beliefs, risk-taking behavior, conflict and motivation (Redmill and Rajan, 1997).

The Cognitive error paradigm

The cognitive error paradigm focuses on the psychological attributes and information processing causes of human error, and it covers both skills and decision making errors and considers the capabilities and limitations of the individual human information processing system (Redmill and Rajan, 1997). The human errors are analyzed in relation to the abilities of information processing, the interaction with individual tasks and situations, and human error tendencies. Mismatches between mental and physical capabilities of people and the demand of the job performed are assumes to be the cause of the human errors. The cognitive paradigm consider error reduction to be dependent on the cognitive root causes of failure like attention failure, information overload, memory failure and decision making failures, but errors related to the "I don't care" attitude, emotional state of mind and the mental state of humans may occur, resulting in lack of motivation, concentration, performance, and rules and regulations violations. Human errors related to the emotional state of mind, that is for example divorce or death in the family, can never be totally eliminated, but the person can be removed from critical work tasks until the situation has improved.

The Organizational error paradigm

The organizational error paradigm has a broader perspective than the paradigms earlier presented, and relates to the managerial practices, the management decision making and issues such as safety culture, participation, competence, control, and communication (Redmill and Rajan, 1997). It assumes that human errors are caused by certain preconditions in the work context which can include aspects such as poorly designed procedures, unclear allocation of responsibilities, lack of knowledge or training, low morale, poor equipment design, and time pressure. These preconditions can be tracked back to management and organizational policies and decisions. Other general failure types and aspects which may cause unsafe acts and affect decision making are poor management decision making and planning, communication failures, poor safety management, inappropriate workload levels and lack of competence (Redmill and Rajan, 1997).

The Work sociological paradigm

This thesis will also study challenges which may affect decision making and work performance from a work sociological perspective. This is a paradigm I have put together, with group dynamics and team work as the main elements, and I feel that adding such a paradigm can be useful to reach this thesis objectives. A work sociological paradigm considers the direction and implications of trends in group dynamics, team work, relationships, human cooperation, culture, and other employment relations in the work organization. In modern societies, changing trends may be related to changing patterns in work sociology. All spheres of human activity are affected by the interplay between the individual and social structure. The focus is on the influence of human relationships and how these relations affect attitude and behavioral patterns. The sociological elements may affect decision making and work performance if the elements are not satisfying.

Group dynamics within teams of social groups refers to different systems of behaviors and psychological processes occurring within a group or between groups, also referred to as intra - and intergroup dynamics. An understanding of such dynamics can be useful in understanding decision making and performance behavior. The humans may resist, challenge or contribute to the patterning of the work sociology and shaping of the work institutions. Psychosocial factors and provocations are rarely identified as the underlying cause for lack of human action at the work place (Bento, 2001). The result of this lack of identification is erroneous actions, and the real problem is not resolved. Team work is a way to get a group of people to achieve results and can lead to significant improvements in productivity and quality. It can also make basic changes in behavior, thinking and values both positively and negatively. Within a team there is a set of norms and roles together with relations and common goals. Some teams are developing positive partnerships and group dynamics, commitment and views, while others develop the opposite. A well-functioning team is task-and group-oriented, with mutual support and thus a positive cooperation, while a poorly functioning team may have internal competition, criticism, lack of confidence and uncertainty. Knowledge is the key to organizational performance (Mankin, Cohen and Bikson, 1996). Organizations will have to learn how to generate, organize, manage and apply knowledge and information more effectively to succeed in the fast-paced and intensely competitive global marketplace. Team work is essential for organizational effectiveness and success, while information is the key to effective team work (Mankin, Cohen and Bikson, 1996).

2.5 Human, Technology and Organization (HTO)

SWI operations will be affected by the Human, Technology and Organization (HTO) elements. Knowledge and understanding of HTO and the HTO interactions is critical to achieve a safe and effective operation, decision making and work performance. The human performance model, PIFs and error causation paradigms presented above, can help to identify and solve challenges, and are all a part of the HTO perspective or “way of thinking”. This can contribute to better decision making and higher performance, safety, reliability and effectiveness.

2.5.1 Application of HTO knowledge

The application of HTO knowledge can provide clarity, increased understanding and awareness of the interplay between human, technological and organizational matters. It may contribute to reduce system vulnerability and to improve safety, performance and the decision making quality. The enabling of technologies and infrastructure to support complex operations draw attention to critical interactions and interfaces between human and organizational components of the systems (Vinnem and Liyanage, 2008). Technology has solved several problems in various communities by simplifying and streamlines our lives, but the technology also has its drawbacks and can lead to incidents and accidents.

"*Technology ... is a queer thing. It brings you great gifts with one hand, and it stabs you in the back with the other*" Charles Percy Snow, New York Times, 15 March 1971. (Britannica, 2012).

The quotation points out that one can never predict the impact of the technology being put into use. The technology creates the potential, and the human-teams and organizations help the technology to fulfill that potential (Mankin, Cohen and Bikson, 1996). Therefore, also better knowledge of the interactions between the HTO elements is crucial in understanding the underlying causes of incidents and accidents in work processes and to achieve success in the preventive work (PSA, 2011). A situation can lead to big losses when human, technology, organization and work processes are combined and cause complex interactions. The interactions are illustrated in figure 33 and 34.

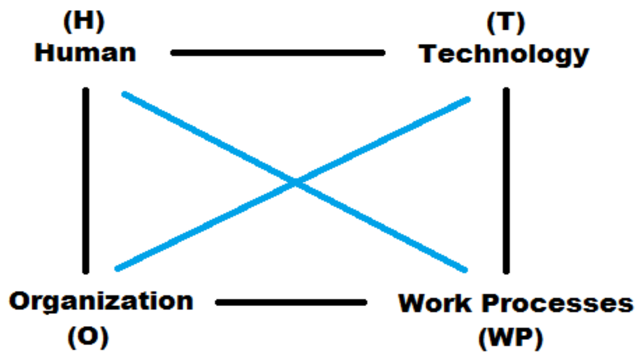

Figure 33: HTO - and Work Process interactions.

Bridger (1995) wrote that by improving the interactions between human components, technical components and organizational components one can enable a work system to function better. This is a basic element in the HSE (Health, Safety and Environment) regulations in the petroleum activities (PSA, 2011). Efforts to improve the safety of systems have often, and some may say always, been hindsight dominated (Hollnagel, Woods and Leveson, 2006). The combination of HSE and HTO can, from my point of view, be defined as *"hindsight in advance"* where one can prevent incidents and achieve safe, effective and cost efficient operations by learning, studying, understanding and using the knowledge from previous experiences and mistakes.

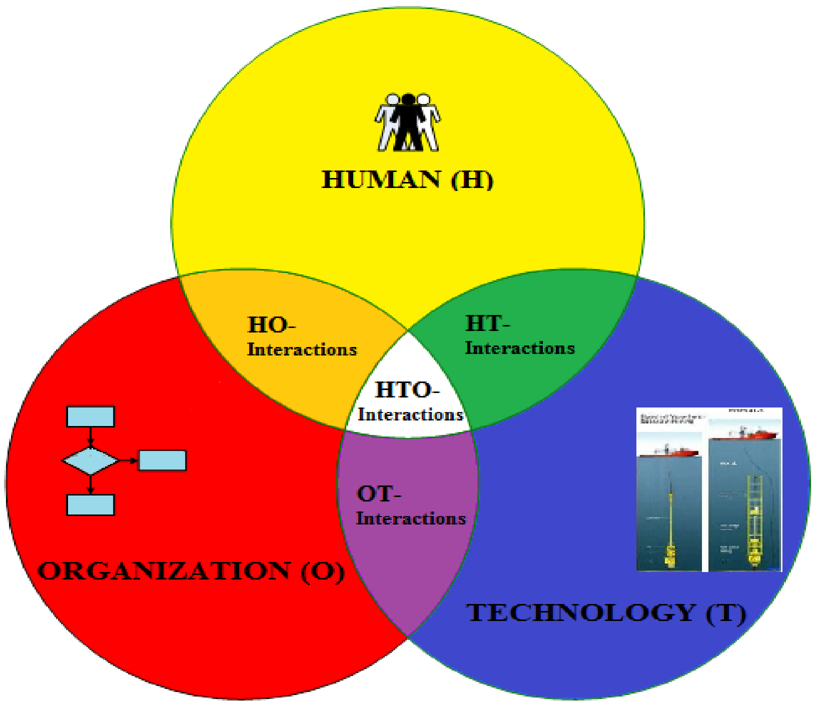

Figure 34: HTO and HTO interactions.

Figure 34 shows the importance of studying how changes in one HTO element can affect another. Modern complex work systems operate under much tighter constraints than their predecessors (Bridger, 1995). Systems become more complex and opaque to the people who manage and operate them (Reason, 1997). Modern work systems employ large numbers of specialists in fields such as industrial engineering, work study, personnel management, operations research and ergonomics. This introduces greater demands for coordination of large numbers of people and machines. Humans have also become increasingly remote, both physically and intellectually, from the systems in which they control (Reason, 1997). The petroleum industry comprises a growing number of Integrated Operation (IO), based on information and communication technology (ICT) advances (PSA, 2011). IOs means changes to organization, staffing, management systems and technology and its interaction. Statoil defined IO as:

"Collaboration across disciplines, companies, organizational and geographical boundaries made by possible real-time data and new work processes in order to reach safer and better decisions faster" (Roland, Yttredal and Moldskred, 2008)

ICT enables real-time data transfer and thus the basis for the decision surface found anywhere. Decisions can therefore also be done everywhere. There must be clear-cut ways of reporting problems, and it must be present for everyone for the simple reason that a problem that stays with whoever discovers it, is a problem that remains unknown (Hollnagel, Woods and Leveson, 2006). IO may lead to new technological opportunities and changes in responsibilities and roles related to the transfer of decision making authority. It can also cause more complex systems with confusions, uncertainty and work overload.

The socio-technical system on which modern society is based, tend to increase the system complexity. This has an unavoidable consequence, namely that the interactions and dependency between the individual systems increase, and thereby the systems become more closely coupled (Hollnagel, 2004). The tighter couplings leads to those systems become more difficult to use, in terms of maintenance, operation, monitoring, management and control (Hollnagel, 2004). In a complex setting, harmony between the human, technological and organizational elements of operational settings is extremely critical for exposure of operational risk. Table 2 describes some components and situations concerning the human, technology and organizational elements which must be handled during complex operations.

Table 2: Describes components and situations concerning the human, technology and organizational elements.

The Human element	The Technology element	The Organization element
✓ Competency and education ✓ Abilities, experience and learning ✓ Planning ✓ Manning and training ✓ Communication and cooperation ✓ Physiology, Psychology and sociology ✓ Time and human limitations ✓ Human needs and responsibility ✓ Operational work tasks ✓ Decision making ✓ Work Performance ✓ Complex work tasks ✓ Stress and workload ✓ Data interpretation ✓ Too much or too little information ✓ Attention ✓ Personality and motivation ✓ Behavior during operations ✓ Alertness ✓ Ability to perceive abnormal conditions ✓ Cognitive workload and demands ✓ Fatigue ✓ Memory and attention ✓ Attitude to safety ✓ Etc.	✓ Design of the system ✓ Limitations due to the design ✓ How the technical element supports the operators to perform their work safe and effectively ✓ Degree of automation ✓ Functionality ✓ Usability ✓ Integration ✓ Operational tasks ✓ Noise, vibration and temperature level ✓ Compatibility of user-technology interface ✓ Functional characteristics of control panels ✓ False alarms ✓ Design faults ✓ Technical error ✓ Clarity of signals and user-friendliness ✓ Work space ✓ Compatibility and reliability of displays and controls ✓ New technology and equipment ✓ Location ✓ Etc.	✓ Responsibility, roles and management ✓ Procedures ✓ Communication ✓ Competency ✓ Organizational manning ✓ Resource availability ✓ Training programs ✓ Planning and routines ✓ Culture and structure ✓ Framework ✓ Power relations and ✓ Cooperation ✓ Decision making ✓ Work Performance ✓ Handover documentation ✓ Standardization ✓ Contractual issues ✓ Psychosocial working conditions ✓ Working environment ✓ Sharing of experience ✓ Control of environment ✓ Team structure ✓ Decision support systems ✓ Physical working conditions ✓ Conflicts ✓ Work instructions ✓ Time constraints ✓ Interaction with other tasks ✓ Etc.

HTO knowledge application can create a better understanding of the interactions between the elements, and it can provide a greater overview of the modern complex work systems. This perspective gives valuable information to do specific measures to reduce the risk and the negative effects when performing complex operations. A lack of identification and classification of HTO limitations, together with PIFs studies, may lead to human errors and reduced work performance. It illustrates the importance and advantages of a proper knowledge of complex work settings from an HTO perspective and that an overall understanding of the capabilities, interactions and PIFs is critical to achieve the organizational goals, and a safe and effective operation.

2.5.2 Human Factors (HF)

Human factors (HF) are a part of the human element in the HTO context, and have over the last few years gained great attention in the petroleum sector in Norway. Legend has it that circa 450 BC Confucius, a Chinese community activist and philosopher, uttered the following dictum:

"Tell me, and I will forget. Show me, and I may remember. Involve me, and I will understand" (From Chambers, 2005).

The quotation shows the importance of involving humans in the situation to achieve skills through learning, which is the process by which humans acquire knowledge. A better understanding of HF provides a basis for preventing what causes human errors. The human factor plays a major role in causing and preventing accidents, since people design, manage, operate, maintain and defend hazardous technologies (Reason, 1997). HF also influences work performance and must be accounted for during design of systems and workplaces.

There are many definitions of HF. PSA (2011) describes the HF technical area as a systematic analytic tool which includes methods and knowledge that can be used to improve, evaluate and assess the HTO interactions. The focus is on the human beings and their interactions with tools, machines, procedures, environments and workplace. Humans are both assets and liabilities in these different settings. According to Wong (2002) engineering, maintenance and operations are human interfaces to be considered. HF includes environmental conditions, workplace layout, and cognitive demands of interface design. Chapanis' (1996) HF definition is as follows:

"Human factors are a body of information about human abilities, human limitations, and human characteristics that are relevant to design" (Chapanis, 1996).

The International Ergonomics Association (2000) has a more recent definition of HF:

"Ergonomics (or human factors) is the scientific discipline concerned with the understanding of the interactions among humans and other elements of a system, and the profession that applies theoretical principles, data and methods to design in order to optimize human well being and overall system performance. Practitioners of ergonomics, ergonomists, contribute

to the planning, design and evaluation of tasks, jobs, products, organizations, environments and systems in order to make them compatible with the needs, abilities and limitations of people." (International Ergonomics Association, 2000)

HF objective is to minimize human errors and the effects of human errors and maximize the safety and effectiveness of human performance by making it hard to do things wrong and easy to do things right. Chapanis (1996) suggests that HF and ergonomics could be used equally. According to Bridger (1995) HF and ergonomics have always had much in common but their development has moved along somewhat different lines. HF puts much emphasis on the integration of the human considerations into the total design process, while ergonomics sometimes is more piecemeal and has traditionally been more tied to its basic science or to a particular topic or application area. The concept of ergonomics has been involved in the improvement of quality of life since the beginning of human era. Ergonomics studies have become more academic, accurate and concrete since the World War 2 (Bridger, 1995). The guiding philosophy of ergonomics is known as "Fitting the Job to the Man" (FJM). Both HF and ergonomics take the FJM approach and state that jobs should be made appropriate for people rather than the other way around ("Fitting the Man to the Job" (FMJ)). It has become clear that FJM is almost always superior approach to the design, and also during operations, of work systems (Bridger, 1995).

A number of serious incidents and accidents have highlighted failures in HTO- and HF aspects which are important to achieve a safe operation and high performance. Barriers are a central concept to describe the preventive elements to prevent an accident from occurring and to reduce the impact (PSA, 2011). A barrier consists of one or more barrier elements, and the element can be of different types; for example technical, operational, organizational or human components. All the defensive layers would in an ideal world be intact and not allow any penetration by possible accident trajectories (Reason, 1997). Latent errors in the work tasks and environments can be "moldering" under the surface without causing damage (Wenner and Drury, 1997). "Holes" in the security barriers will lead to that error can pass through the Reasons "Swiss cheese model" in figure 35.

The “Swiss cheese model” is a good illustration of how different defensive layers, i.e. human, organizational and technical barriers, under a given set of conditions, can lead to hazards and potential human, economical or material losses. Poor senior management decisions and local workplace problems such as poor training or unsafe acts can be considered as “holes” leading to breach of the organizational defenses, barriers and safeguards leading to incidents, accidents or catastrophic events.

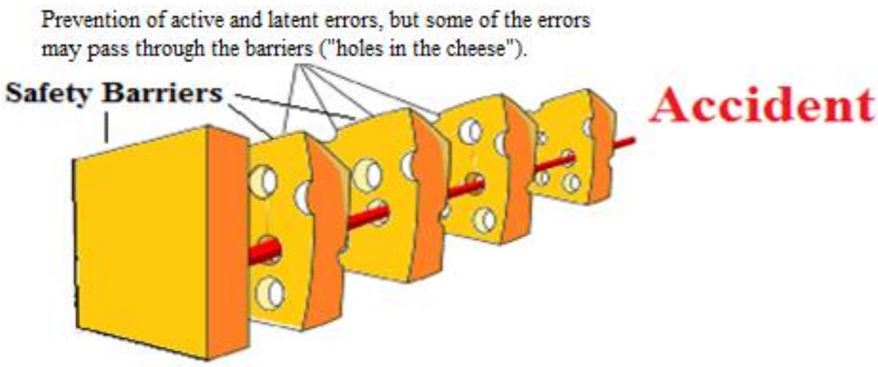

Figure 35: Reason’s “Swiss cheese model”, where "cheese slices" illustrates barriers (nft, 2010)

The HF knowledge can contribute to improve the elements people use and the environment in which they use these elements and thereby better match their capabilities, limitations and needs. It can also improve the efficiency, effectiveness, and productivity of systems and work environments.

2.5.3 The SRK-Framework

The Skill, Rule and Knowledge-based (SRK) framework is a good conceptual and structured framework that can be used for integration of workstation, job and organizational design in complex socio-technical systems, and can thus contribute to suggest improvement opportunities to identified challenges. The SRK-model was developed by Rasmussen (1983), and is an innovative approach to create a flexible and adaptive organizational design. The SKR-framework consists of three behavioral levels of cognitive control which are related to a decreasing familiarity with task and environment (Redmill and Rajan, 1997). First, the terms workstation, job and organizational will be presented, followed by an elaboration of the SRK-framework.

Workstation, job and organizational design

Complex technological systems brings with it new demands and needs of human operations in the *workstation design*. The role of the operator has changed from manual to modern complex human-machine systems that constantly require that the operators must adapt to new systems and requirements with the risk of unforeseen events. Lack of understanding of changing conditions in the system is synonymous with lack of knowledge about the system (Meshkati, 1990). New information technology in workstation design can cause problems in the human reaction-time at the various hierarchical levels, and “information overload" challenges.

The key factor to a successful *job design* is the identification of tasks and understanding of the specified conditions and performance requirements (Meshkati, 1990). The main job of the operators is to adapt to the changing requirements and operating conditions. To achieve a successful operation, it must easily be switched between different levels of cognitive control, but most task analysis and job design methods do not facilitate this, which is a challenge.

If *organizational design* prevents the employees to respond to unknown events correctly, this will cause problems. Organizations may have limited capacity to process information, and they also have limitations when it comes to adopting different organizational designs to cope with increased task uncertainty. The available communication channels can be overloaded and this may lead to delays, distortion and less performance. In the centralized design structure the information must be brought up through the hierarchy through more or less overloaded information channels. The decentralized design structure enables decisions to be taken by employees down in the organizational structure but with inadequate training and commitment, inappropriate behavior and incorrect decisions can be the result (Meshkati, 1990).

Three behavioral levels of cognitive control

Skill-based behavior refers to sensory-motor performance which takes place without conscious control. Routine and highly-practiced tasks are carried out in a highly automatic fashion with occasional conscious checks on progress (Reason, 1997). The person may be unable to describe how they control and on what information they bases the performance through the highly integrated smooth automated patterns of behavior (Redmill and Rajan, 1997). At the skill-based level the information from the environment is perchieved as signals. Here, slips and lapses are types of errors that may occur when a skilled person are performing a familiar task.

Rule-based behavior refers to a composition of sequence of subroutines in a familiar work situation and is typically consciously controlled by a set of memorized or written rules or procedures (Redmill and Rajan, 1997). The rules which are used can be reported by the human. One operate automatically and matching the problem to stored knowledge, and may then use conscious thinking to verify if the situation is appropriate (Reason, 1997). Typically, at the rule-based level the information is perceived as signs. The tendency to use familiar solutions even when these are not the most convenient or efficient, are general types of errors that occur at this level of behavior.

Knowledge-based behavior represents when a person is faced with an unfamiliar situation, or an environment for which no know-how or rules for control are available from previous experience. This level is something we come to very reluctantly (Reason, 1997). At the knowledge-based level the information must be perceived as symbols. Performance is controlled at this level, which is the highest conceptual level, and misdiagnosis and miscalculations are mistakes occurring at this level of behavior (Redmill and Rajan, 1997). Using analogies or reasoning from first principles rather than employing existing rules from action, are typically involved in planning or problem solving.

Application of the SRK-framework

During times of unexpected change and in unfamiliar situations, the SRK-framework can provide a natural transition from “skill” to “rule” to “knowledge” based decision making to respond and adapt to changes in a safe and efficient manner. Information is gathered from the interfaces at the workstation site, and are analyzed according to the humans stipulated descriptions at the job level. It is then passed through organizational communication network according to the organizational structure to the appropriate team members responsible for decision making (Meshkati, 1990). The SRK-framework help to increase the capacity to process information adapt workstation design to people, improve response time and prevent information "overload". It can help the operators, designers and managers to determine the optimal mix between centralization and decentralization, and they can adapt job designs to the changing requirements and operating conditions. The framework can also contribute to integrate and coordinate organizational design, system safety and human factors, and enabling in the organization and optimization of the design.

The SRK-framework shows the main distinctions between three levels of human performance (Reason, 1997). These performance levels are distinguished by psychological and situational variables that together define an “activity space” where the three performance levels can be mapped (Reason, 1997). The performance levels can coexist at the same time. Figure 36 show that humans can control their actions through various combinations of two control modes - conscious (paying attention to something) and automatic (largely unconscious) (Reason, 1997). It also illustrates the second dimension defining the “activity space” of the situation, where the two extremes are highly familiar everyday situations and routines, and entirely novel problems.

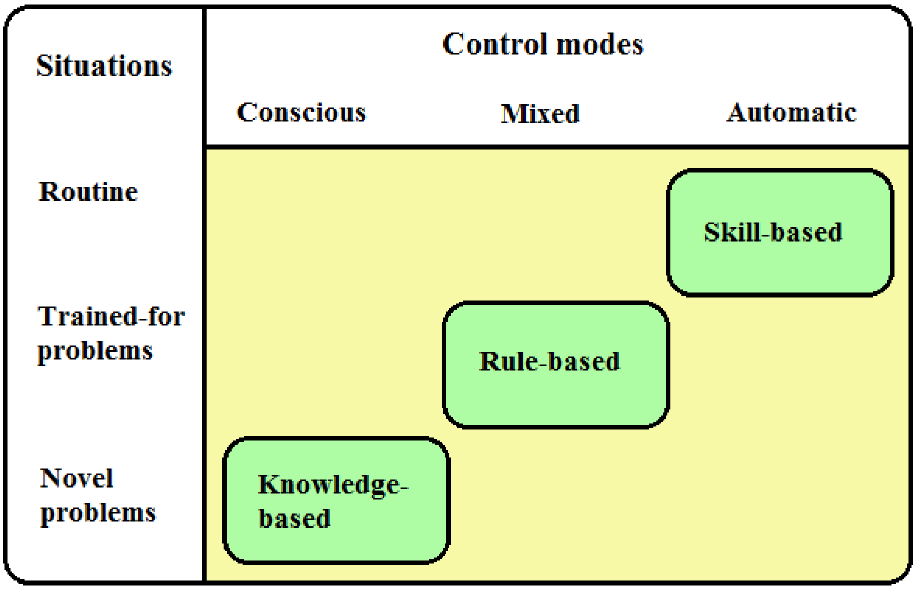

Figure 36: Location of the three performance levels within the “activity space” defined by control modes and situation (Reason, 1997).

According to Meshkati (1990), it exist so-called “design induced error” that operators are forced to deal with. Using the SRK-framework can help managers and designers to make better decisions in terms of workstation, job and organizational design to prevent "design-induced errors”. To obtain an optimal design that can prevent human error, this framework is a valuable means to improve the existing human automation involvement, and it offers a systematic and useful approach to perform analysis, choose levels of automation, control advanced control systems, and to choose the type of automation (Lin, Yenn and Yang, 2010).

2.5.4 The importance of the What, How and Why questions

There exist several different classifications of human error by using knowledge of human cognitive behavior. Most classifications have multiple levels of analysis, such as what happened, how it happened and why did it happened. Asking these questions is a way to classify human error, and can be a tool for practical application of acquired knowledge and to increase competence. This classification was used as a basis when making the interview guide for the collection of the results, given in Appendix 1. There are three categories of taxonomy that can help to study and analyze the nature and extent of human error (Redmill and Rajan, 1997):

1) Phenomenological taxonomy (What happened?) describes the error in superficial terms that refer to observable events, and are widely used in human reliability assessments. Substitutions, repetitions and omissions are typical categories.

2) Cognitive mechanism taxonomies (How did it happen?) classify errors in the stages of human information processing, and are increasingly used in post-accident investigations. Memory lapses, misinterpretation, mistake alternatives, attention errors and perceptual errors are such examples.

3) Taxonomies for bias and deep-rooted tendencies (Why did it happen?) that error is believed to reveal, and currently tends to be research tools. The classification at this level of the performance error-shaping factors can be done by using Skill- Rule and Knowledge based behavior theory.

By asking "What", "How" and "Why" questions, one can learn from, analyze and study human error and accidents that have occurred in complex work systems. Thereby, one could improve the performance, procedures, rules, procedures, reliability and behavior. One can eliminate, reduce and control the errors in situations that are safety critical. The questions can also provide input to a human reliability analysis and can be used for post-accident investigations and research (Redmill and Rajan, 1997). This gives the opportunity to improve the technical system design and operations, and provide input to risk and safety analysis. Organizational design, management and planning can also apply this knowledge (Redmill and Rajan, 1997). This shows a wide range of factors that can utilize the results from the "What", "How" and "Why" questions for improvement, learning, control and increased security. The importance of these questions addresses how the use of knowledge will contribute to a safe and improved performance and operation of complex work systems where humans are involved.

3. Results and Analysis

This thesis shows that there are different ways of looking at the factors affecting the decision making and work performance situation at the SWI vessels performing complex operations (the human performance model, the error causation paradigms and PIFs). It shows that these methods can be useful to identify, evaluate and analyze work related challenges. They are one way to reach this thesis' objective, and contribute in the conduction of the project tasks. This chapter will present the identified RLWI- and AX-S concept challenges within the given scope of the thesis, as mentioned earlier in project task number one. This is achieved through well prepared interviews with personnel from the companies which supply the SWI technology, in this case Island Offshore Subsea (IOS), FMC Technologies, Aker Well Service (AWS), Statoil and Expro. This was presented as project task number three.

First, a short presentation of the interviewed personnel will be given but before presenting these results, I wish to point out some of the challenges I experienced while writing this thesis. There were some time and resource limitations when collecting the information and results. It was a difficult process reaching the correct personnel to be able to conduct the interviews, but the right people were reached in the end. Also, I want to emphasize that the intention of this thesis is not to identify and study technological- and operational based, and pure organizational based challenges and solutions. This thesis studies and proposes solutions to challenges from a human perspective, and critical factors potentially contributing to human errors. The thesis touches the organizational element through the PIFs and error causation paradigms, but the human element is the main focus. There are also some limitations in the AX-S results, due to the fact that the concept is not yet commercialized. I also want to mention that I am not a professional and that I am "new to the game" as a student.

3.1 RLWI

3.1.1 Personnel Interviewed

Representatives from the companies FMC Technologies, Island Offshore Subsea (IOS), Aker Well Service (AWS) and Statoil (client) have been interviewed to map the challenges that may affect decision making and work performance when operating RLWI. This thesis mainly focuses on the personnel located in the Tower Control and operational rooms at the Island Constructor. Therefore, personnel from these parts of the vessel were interviewed and the results are based at these answers. In addition some experiences and challenges from the Island Wellserver and the Island Frontier were covered. Also, many of the interviewed personnel from the Island Constructor had been employees at the Island Frontier for several years since this vessel is an older vessel, produced in 2004. Table 3 presents the personnel and positions which were interviewed.

Table 3: The following hierarchical positions were interviewed at the Island Constructor, in addition to some positions at the Island Wellserver and the Island Frontier.

Vessel	Position	Company
Island Constructor	Operations Manager	Statoil
	Operations Manager	Island Offshore Subsea
	Well Intervention Superintendent (WIS)	Island Offshore Subsea
	Well Manager	Statoil
	WOCS Operator	FMC Technologies
	Tower Operator	Island Offshore Subsea
	Wireline Operator	Aker Well Service
Island Wellserver	Well Superintendent	Statoil
	Supervisor	FMC Technologies
Island Frontier	Operations Manager	FMC Technologies

3.1.2 Error causation paradigms - RLWI operations

One way to identify the challenges that can affect decision making and work performance at the RLWI vessel are the error causation paradigms, presented in the project task number four and five. The human performance model is used as a basis when identifying the challenges.

The paradigms identify and seek to answer what are the challenges and influencing factors in the given working situations and thereby contribute to achieve the objectives of this thesis. The paradigms are classified into the engineering, individual, cognitive, organizational and work sociological paradigm. The error causation paradigms are used to get an instructive overview of the complex work settings and to elaborate complex interactions (Redmill, 1997).

Presentation of the identified challenges based on the error causation paradigms

First, the challenges identified will be presented shortly through the error causation paradigms in table 4 to provide an overview. Second, using the same paradigms the challenges will be described in a short presentation, and a more detailed description of the individual challenges will be given later in the chapter when presenting the PIFs for the RLWI concept.

Table 4: Presenting the identified RLWI challenges shortly, through the error causation paradigms.

RLWI	**Error causation paradigms**				
	Engineering	**Individual**	**Cognitive**	**Organizational**	**Work Sociological**
Identified Challenges	- Large amounts of information - Complex GUI and HMI system - Tower Control design challenges (space, noise and vision)	- Demotivation, frustration and less “alertness” due to periods with a lot of waiting - “Corner cuttings”	- Complex information processing - The correct amount of information is not presented to the managers and operators - “Information overload” - Routine and sedentary work tasks -Lack of operational training among managers - Too little sharing of experience	- Difficult to reach the right resources - Too many procedures which causes coordination challenges - Slow procedural updating system - Communication and information transfer challenges - Poor planning -Split up management and complex management practices - Unclear “command lines” - Need for clearer defined operator responsibilities	- Many additional personnel board the vessel during mobilization, operation and demobilization causing uncertainties and confusions - Several shifts do things differently with lack of task standardization

The engineering error causation paradigm covers the personnel challenges related to large amount of information to handle and also challenges related to the automated part of the system. Information from the automated part of the system is presented to the operators at the monitors, and is continuously being updated during RLWI operations. The operators also receive information through radio, telephone, cameras and visually by looking at the operations performed on deck. This leads to large amounts of information to be processed during periods with high workload. Challenges were identified due to the automation complexity with too many alarms and too many "nice to know" alarms. It could sometimes be difficult for the operator to locate the error during work activity. The GUI (Graphical User Interface) - and HMI (Human Machine Interface) systems is complex with large amount of information to handle, coordinate, analyze and communicate, together with operation tasks and extensive use of various communication and monitoring devices. The Tower Control design challenges were also identified, with space, noise and vision ranked as the main context concerns. This will be further described when presenting the PIFs.

The individual error causation paradigm considers the human's motivation, attitude and "corner cuttings". It appears to be a challenge keeping people motivated with a lot of waiting due to weather conditions, downtime, flawless periods and other causes. This may cause frustration, demotivation, less "alertness" and the feeling of being "left over". Challenges concerning human body "resting modus" were also identified, and will be presented in the PIFs section. "Corner cuttings" attributed to motivational and attitude factors have happened.

The cognitive error causation paradigm covers the information processing, mental and physical experience, training and sharing of experience. The survey identified some challenges for the managers and operators related the information processing and the amount of information provided in RLWI operations, and especially during hectic mobilization and demobilization. There is a lot of information and documentation to be processed during such periods leading to "information overload". It may be difficult to identify what information is important for the activity within the given time frame. The operators and managers also receive information both visually, written, and through radio- and telephone. The personnel felt that the correct amount of information was not presented to the managers and operators. A mismatch between the mental and physical capabilities of personnel and the demand of the job performed for new personnel during work and training has happened, but is not frequent.

The operator monitoring tasks may be characterized by routine and is sedentary, and can easily lead to lack of focus. The personnel training was ranked as good, but according to the crew it was always room for improvements. The operators felt that the managers lacked operational training suitable for their increasingly complex work tasks and responsibility. The crew also felt a need for better sharing of experience and “lessons learned”.

The organizational error causation paradigm considers the personnel competence level, procedures, communication and management. Today, it is difficult for the companies to provide sufficient personnel with adequate competence and experience due to the competitive market. Also, right resource availability during weekends, holidays, and even during the night can be challenging if operational difficulties occur and important decisions must be made. There are challenges related to the sheer number of comprehensive procedures, which causes coordination challenges. It was also presence of a slow procedural updating system. The survey identified challenges regarding communication and information transfer between the different companies, and between the different levels of competency and experience at the vessel, potentially leading to errors when combined with the comprehensiveness of the procedures and coordination challenges. The survey also identified limitations in the planning process during mobilization and demobilization. It was sometimes a mismatch between the plans being executed at the onshore facility and the corresponding action at the vessel. The management practices are complex and the challenges concerning a split up management due to the joint venture between Island Offshore, FMC and AWS, gray areas in the reporting path, unclear “command lines” and lack of standardization were identified, and will be further described later as PIFs. The operator’s responsibilities could also have been clearer defined.

The work sociological error causation paradigm focuses on the team and group dynamics in this thesis. The team work and group dynamics during RLWI are very good, and all of the managers and operators reported a good working environment with a great culture. A team challenge mentioned by the crew is related to the challenges that occur when different companies provide people to the vessel during mobilization, operations and demobilization. The personnel are usually not the same between each boarding, causing uncertainties and confusions when it comes to who belongs to which company, and who is responsible for which tasks. Also, several shifts conduct tasks differently, which was defined as a challenge by some personnel who asked for a more standardized way of performing activities.

3.1.3 Identified Performance Influencing factors (PIFs) at the RLWI vessel

PIFs are those factors which determine the likelihood of error or effective human performance (Ember, 2000). A wide range of PIFs are often the reason behind human errors and can contribute to incorrect decisions, reduced performance and critical operational situations if not handled correctly. The operational managers, Well Intervention Superintendent, Well Intervention Supervisor and operators at the vessels operate technical complex equipment, with continuously problem solving, analyzing, discussions and monitoring. They are performing complex tasks and are dependent of effective cooperation and team work to gain a safe and cost effective production, this combined with extensive use of monitoring programs and cameras, and communications through telephone and radio. This shows the importance of identifying the PIFs which in turn can contribute to identifying the challenges during such complex situations. These factors can increase the understanding, reduce human error and improve the decision making and the work performance. The PIFs method is, from my point of view, seen as the right way to reach the objectives in this thesis, and is presented as project task number six. The human performance model, with the human, activity and context components, was used as a basis when identifying the challenges. Figure 30 illustrated earlier in this thesis, showed how Redmill (1997) views the PIFs as Work-related factors and Human-related factors. This division will be used when presenting the PIFs.

I: Work-related factors

A: Environment

Space and Ergonomics

There is a lack of workspace at the vessels, especially in the Tower Control at the Island Constructor and the Island Wellserver since both managers, operators and service personnel are located in this part of the vessel, as described earlier. The Island Frontier is an older boat, also with a lack of space in the Tower Control, but fewer personnel are located here compared to the other two vessels. The Tower Control is small and it is difficult to provide workstations following today's requirement, and the fact that there is too little space is a general challenge at all the vessels. The space around the operator's chairs at the Island Constructor, especially the WOCS station, is not physically suited for holding and storing of the necessary paper-procedures and to maintain a good overview. The operators must hold the procedures in their laps during operations due to the lack of space, and the space challenges also contribute to cluttering. The personnel stated that there is room for improvements in this area to achieve a better work performance and decision making. According to the operators the ergonomically design of the desks and chairs are good, as the chairs are comfortable and adjustable.

Noise

The survey showed that the personnel at the Island Constructor and Island Wellserver are satisfied with the fact that the necessary personnel are gathered in the Tower Control since this improves the communication and shortens the information path. The surveys also showed that the operators in the Tower Control experienced problems with noise, due to the fact that it is sometimes very crowded with a lot of people coming and going causing distortion and noise. The Tower Control is a “gathering point” or “center at the deck” for discussions, conversations and questions. Some personnel must also visit the Tower Control to “sign in and out” to be able to access higher floors in the tower which also causes traffic and noise. The heavy doors are opening and closing, and cause disturbance. Signs are in place at the doors to remind people to take the situation in account before entering, but the noise challenge still persist. The tower operator is positioned in the middle, as shown earlier, and gets the noise from both sides. For some personnel this contributes to errors. Some felt that the tower operator should have had their own Tower Control arrangement, such as the one found at the Island Frontier. There is also cabinets and computer equipment placed in the Tower Control at the Island Contractor contributing to disturbing noise. The operators suggested that this could have been placed in another room. The air condition makes a disturbing noise, affecting some of the personnel, and a number of telephone calls are also disturbing for the personnel.

The fact that there is much noise and disturbance in the Tower Control worries some of the operators at the Island Constructor when it comes to the risk, safety and performance. Unfortunately, noise may contribute to tiredness, fatigue and also stress, without the operator being fully aware of it. The noise in the Tower Control may cause decision making and work performance challenges due to the “visits”, presence or “walk through” from other personnel that might cause disturbance. At the Island Wellserver and Island Constructor the Schlumberger logging personnel are located in the Tower Control. The personnel at the Island Constructor informed that Schlumberger has conducted a study concluding with that they want to move to another room next to the operational room, and not be located in the Tower Control.

Vision

The tower operator at the Island Constructor does not have an optimal view out the windows due to beams in the tower construction which limits the view. The wireline operator also experience vision challenges and has difficulties getting a good overview when monitoring the deck operations, due to small windows placed in a too high position compared to the operator chair, monitors and sticks. It was then difficult to monitor the screens, using the sticks and looking at the deck simultaneously because the operator had to switch between sitting and standing position to be able to look out of the window and get a proper overview. Sometimes a second person was needed during wireline operations to look out the window and inform the wireline operator of what was happening at the deck, while the wireline operator monitored the screen and steered the sticks to perform the operations.

B: Displays and Controls

Panels and Alarms

There are many alarms at the panels, and at times too many. From some personnel's point of view many alarms are "nice to know" alarms and are often unnecessary. Measures have been performed to remove redundant alarms, but it is difficult to assess the importance of the alarms. The many alarms did not give guidance to the actions the operator should take in the situation. According to some personnel monitoring programs and alarms might not function optimally in a given critical situation and in the end this may eventually influence the decision making and work performance.

The WOCS operator has an important position where he/she controls the RLWI operation with keystrokes and one mistake may cause serious consequences. Therefore it is important to optimize the WOCS operators working conditions to reduce those types of risks. The WOCS control program is very complex, and it can be difficult to find the error if one occurs. It is a lack of a clear early alarm when something is abnormal to help the operator to prioritize the alarms in situations which may be critical. The indication on what is wrong may not be clear enough, and the WOCS operator can sometimes have difficulties discovering developing situations in the well/stack due to the large amount of information presented at the monitors together with "disturbing" factors "hiding" the developing situation. There may be uncertainties to where and when to focus the attention in the automated part of the system, and this especially applies for new personnel. Long time personnel training are required. The survey showed that the panel's functional characteristics, clarity of signals and user friendliness were ranked as acceptable, but there is room for improvements as those mentioned above.

Complexity

The challenge with the GUI- and HMI systems relates to the complexity and there have been situations where the "wrong" things have been done due to this. Factors that may challenge work performance when it comes to the degree of automation of work tasks are that the personnel may blindly follow the procedures, without understanding the whole complex "operational picture". It is also difficult to maintain a complete overview of the procedures, monitors and the situation on deck, while communicating and contribute to decision making during hectically periods. It is important to have a good understanding of the whole situation, and not only the automation and procedural part, to achieve an optimal work performance and safe operation.

C: Task demands

Information and communication

The managers and operators have reported some challenges related the amount of information provided to the personnel together with periodically high workload and time pressure. "Information overload" has happened, which have led to reduced work performance and poor decision making. The experienced operators feel that they can handle the large amounts of information to a certain extent, but new personnel may struggle with "information overload". There is a lot of information provided to the personnel during RLWI operations, and it is a lot of documentation to keep track on. It can be difficult to go through all of the information and identify what is important or not. The personnel also have to deal with the individual companies' operational procedures, and additional procedures. The Statoil program contains a lot of information, maybe too much.

During RLWI mobilization and demobilization it is quite hectic. The information processing and communication is complex during these periods with information transfer between different levels.

Some felt that the amount of information presented to the managers and operators during RLWI operation was not optimal. There were also some communication and information handover challenges, where new information that occurred during the shift was not passed on to some of the crew or to the next shift. Information can thereby be “blocked” between boundaries, but this was not very frequent when important information occurred during a shift. One example of communication failures was when performing lift from the template to the vessel without closing in the neighboring well, this due to lack of communication between day and night shift and wrong risk assessment during the night shift according to the personnel. Errors have also occurred due to communication failure between the management and operators and because the procedures were not completely followed as they should. This led to a serious incident, but this is not frequent and it is zero tolerance for this at the vessel.

The personnel normally work with the same team members within their working area during the shifts. It can be a challenge that many other companies provide different people to the vessel, and the people are usually not the same between each boarding. Many additional personnel increase the communication complexity. This can be service personnel and personnel boarding to perform tasks during mobilization and demobilization. Then it can be uncertainties of who belongs to which company, who is responsible for which tasks, who one can ask, and who is going to receive important information and pass it on. It takes time to get to know people which may be a challenge in such situations.

Monitoring tasks

Problems with too many unilateral tasks over a period of time may also be a challenge. The operators in the Tower Control have only a monitoring task, working 12 hours shifts monitor the screens and deck. It is great variations from one shift group to another for how long an operator sits in the Tower Control during one shift, and when somebody can “take over the helm” for the operator to take a break. Usually it is after 6 hours, but this varies. It lies in the human nature that it is easy to lose focus in such situations, and it has happened at the vessels. For example, the WOCS operator work with 12 hours surveillance, and depends on a 100% focus sitting in an environment with sometimes heavy traffic. The WOCS operator has an important key role and need a lot of training to be able to perform the tasks. A weak point is that few can perform the WOCS task if he/she needs a break or replacement. During lunch “WOCS II” step in, but is only trained to perform simple operations. In a crisis situation, the

WOCS operator on the opposite shift has to help. As mentioned earlier, the operators can easily become distracted and they are only a few keystrokes away from doing something that might be dangerous.

Unfamiliar situations

When unfamiliar situations occur, mistakes happen, but this is not frequent. In fact, challenge arises more often during known operations rather than unknown. Routines and little variations in the work tasks cause errors and the crew can unintentionally ignore known signals and signs. When unexpected situations occurred, the personnel sometimes had to "go around" procedures. Decisions have then been taken too quickly and consequences occurred. No one thought of the effect the action would cause. The personnel try to focus on people getting familiar when starting on duty, i.e. handovers, SJA and toolbox meetings.

Mental and physical capabilities

A mismatch between mental and physical capabilities of human and the demand of the job performed has sometimes happened among new personnel during training, but is not frequent. New personnel sometimes say that they know the task and can perform it, but it has happened that they cannot perform the task after all. The employees have had the wrong capabilities and competency.

The system is very complex, extensive and difficult to operate without years of experience. The WOCS operator is a human barrier to the operation and this is a lot of responsibility with great competence requirements. Some mentioned that this might be too much responsibility if critical incidents occur in relation to what is expected from one person. Some were also afraid that the WOCS operator easily could become a target if a serious incident happens since he/she controls the operation with keystrokes, and is a human barrier.

D: Instructions and procedures

Coordination

The RLWI procedures are accurate, clear, detailed and easy to use, but it still remains some changes to be made. Some felt that a relatively slow system led to that it took a too long time before the procedures got updated if some procedural changes had to be made. The survey showed that the overall number of procedures is a challenge, rather than their contents. FMC has their detailed procedures, Statoil has their well program, and IOS has their project manuals. This cause coordination challenges of the procedures which can be demanding to keep track on. The personnel have to “jump” between different procedures during operation due to the number. There are also many additional procedures that must be implemented and coordinated at the appropriate time in the process. Also, the crew members were not satisfied with the number of forms, and they uttered that it often was an overlap between forms. Procedures or procedural steps have been skipped due to the high number of procedures. Some procedural tasks have also been duplicated, or some tasks have been differently described in different procedures. The procedures are necessary equipment, but operators have also experienced that three procedures told three different things, which confused the operator. There is then a risk of human errors, but the procedures are updated when wrong information is detected, though the updating system can be slow. When performing a “buddy check”, where you get a colleague to verify that you are doing things right after a task is performed, they have detected slips, and serious errors rarely occur due to this double checking.

Violation of procedures

Some personnel felt that the procedures, forms and the management documentation were too comprehensive, which gave rise to situations where some personnel took shortcuts, but such actions were seen very rarely. Despite this, a dangerous potential for making shortcuts or mistakes are present. Violations of procedures and “risk taking” behavior that challenges the decision making and work performance have happened due to communication failure and the number of procedures. It has happened that the procedure has not been complied with, or routine failure has led to operational errors, but this is very rare. In these cases, the human factors were present, including "absence" to a certain extent. It is common to have an internal investigation after such cases. Personnel have experienced pressure from different clients and personnel to skip steps in the procedures, or to do things in a different order. Mistakes have happened due to this. One operator said “my job is to do what I’m told”, but also says that it is important to be critical to the management/client decisions, take responsibility, and to think the situation through before taking action.

E: Socio-Technical

Manning and competence

The RLWI operation is very weather- and shutdown dependent, and some personnel mentioned that in such quiet periods it was almost too many people at the vessel, and they could go for days without having much to do. Also, when everything was going very well, it was generally little to do and they were therefore sometimes bored. The survey also showed that the availability of the correct personnel with the right competence may challenge or affect decision making. The personnel felt that the resource availability is currently low, due to a competitive market and lack of the right educated resources. Another challenge was the availability of resources located onshore during the weekends and holidays. It is then difficult to reach the right resources during important decision making. There is a great interdependence and when key personnel takes their weekends, holiday or even are at home sleeping through the night, it may be difficult to make the right decision. In such situation with a lack of key personnel, the employees at the vessel feel that they must be critical to the decision that returns from onshore and offshore facilities and focus on the importance of quality assuring the decision.

The personnel training was ranked as good, but according to the crew it was always room for improvements. The personnel stated a need for a better sharing of experience and that the personnel where given a fair chance to familiarize themselves with positive and negative events that had occurred while they were at home. Also, sharing of "lessons learned" from previous operation could have contributed to save a lot of time and money in today's operation, and could have contributed to a better and more streamlined decision making. The personnel will always learn as long as they go, and errors have occurred due to lack of know-how, but they have avoided the big incidents.

Planning and cooperation

During the mobilization and demobilization phase there are many tasks to be performed, and it is sometimes an "anthill" at the deck and dock. The personnel felt that nobody holds the record of everything that happens and/or will happen. This may cause deviations from the plan due to both anticipated and unforeseen things. During mobilization and demobilization there is a problem with concurrent plans, and time pressure with a tight schedule may be a challenge if not handled professionally. They experience limitations in the planning to achieve a continuous process. Due to poor planning and wrong decisions, performance degradation has occurred. Performance reduction has happened associated with large mobilizations where a lot of equipment is to be loaded of and on the vessel in the right place at the right time. Due to the limited space at the vessels deck, the placement of equipment must be well planned to hinder loss of time if the equipment has to be removed again to make space for other things. The personnel on board makes a good job when planning, but there may be some mismatch between the plans being performed by personnel located onshore in relation to what is done on board during mobilizations and demobilizations. The survey shows that the planners believe that they have planned for everything, but are hindered by entry and access limitations at the vessel due to too many simultaneous work tasks. This could have been better planned for. There are also tendencies to use plans or rules which have worked before during RLWI, but which may not be useful in the present situation. Side effect not considered when it comes to decision making during RLWI has happened when the team made an evaluation which was not well enough thought through. No one predicted the side effects which caused a potential for serious consequences.

The survey showed that the group dynamics, relationships, cooperation and team work during RLWI are very good due to incorporation focus during the many years of operation. But to further improve the team cooperation, some of the personnel at Island Wellserver stated a desire to mix work tasks among the different companies (IOS, FMC and AWS), due to sometimes uneven work distribution and workload. This could increase efficiency and thereby contribute to save both time and money. They suggest that the three companies can perform tasks for each other which can streamline collaboration by erasing some invisible boundaries. The challenge is the alliance within these three companies. It may at times be difficult to get personnel from the different companies to perform work not within their own industry and company. The crew at Island Constructor stated the opposite, and told that the different companies in the alliance helped each other when somebody had little to do. They had a great focus on working as “one organization and one team”. This may indicate team- and cooperation culture differences.

Some personnel mentioned that it should only have been one company on board as one organization, since it often is more difficult for several organizations to work as one. Another cooperation challenge is due to several different shifts doing things differently which can contribute to losing both time and money. New ideas and explanations occur at different shifts. The personnel want more incorporation and standardization of how thing shall be performed to improve the cooperation. It is irritating to go through the same situation many times due to new shift arriving. Also, many clients have different demands, which can cause collaboration challenges between the alliance and the client when it comes to how things should be done.

Management

The management practices in the decision making processes during RLWI are complex where decision making often goes through the onshore facility. The survey showed that the managers felt that the allocation and distribution of responsibilities at the vessel was clear, but that is was room for improvements. They felt that the allocation was complex, but they knew whom to contact. Some might feel that they should have been informed and involved in a decision, and somebody felt that there was some gray areas in the reporting path knowing who should be involved and not. The management level could sometimes be ineffective because of the split up management level, due to the joint venture between IOS, FMC and AWS. Also, the marine part of Island Offshore is controlled from Ulsteinvik, and the operational part is controlled from Stavanger, causing even more split up management.

The operators sometimes felt that the allocation of responsibility quality varied from which leader where in charge. Some leaders are very clear, while others are not, and some leaders "micro manages" the personnel, while others does not. The operators ask for a more clear, standardized and consequent management. They often experience to have four different supervisors during their two weeks offshore trip. This was annoying for some of the operators. One operator said that "We do not make many mistakes, but we use too much time". The key to save time, from the operator point of view, is clearer "command lines". Another challenge mentioned by the crew was too much swapping of crew constellations. This is organizational and management factors that can reduce or hinder the humans work performance.

The operator's responsibilities could also have been clearer defined, since the operators responsibility varies from one shift group to another and from one vessel to another. If an operator moves over to another shift group, he/she can get new areas of responsibilities, although he/she has the same position as before, and works at the same vessel. The fact that the responsibilities are not standardized from shift to shift and from vessel to vessel can quickly make disturbances in the system when everybody does it “their way”. According to the personnel there should have been more dedicated responsibilities to the individuals onboard with clearer guidelines from the onshore organizations.

Some personnel feel that some managers and supervisors are afraid of taking necessary decisions, thereby using an unnecessary amount of time. The survey also showed that the operators feel that the leaders do not listen to them when decisions are going to be made. They feel that the managers do not trust their decision and knowledge, and that the management maybe lacks the right knowledge to make effective, safe and correct operational decisions. One operator said that he sometimes felt that “the wrong man was hired in the wrong managerial position”. The leaders have very complex work tasks, and from the operator point of view, they need more operational training and courses to understand the “whole operational picture” when making decisions, and to increase their performance. Such training programs are not frequent for “experienced” managers.

The long-term goals of the organization are mentioned by some personnel as a challenge. Long-term decisions are very difficult to make when the future is unknown. Personnel at the vessel felt that no one took the hold of this challenge, and thinks that the organization needed a decision on which direction they will choose in the future with other innovative and competing SWI concepts emerging with time. They felt that nobody uses resources on innovation and development in this area, or that “future thoughts” were not visible to the employees.

II: Human-related factors

F: Individual

Motivation and attitude

The attitude and motivation among the personnel at the vessel are good, but it may be a challenge to keep people motivated with a lot of waiting due to weather conditions, downtime, and other causes. The personnel then have little to do, and for somebody it is frustrating and demotivating. Human failures, work performance reduction or unsatisfying decision making attributed to attitude and motivational causes has happened, but is not frequent. Automation combined with long periods of flawless operation or waiting due to bad weather conditions or shutdown might take the "edge" away from people, and they may be less on "alert". Sometimes people feel "left over". In such quiet periods a normal human body reaction is to put itself in a "resting modus". When the work processes starts up again it is sometimes difficult for the person to instantly switch the body from "off" to "on". Some personnel mentioned that their bodies could use hours to reconnect to fully active performance. This is a challenge, where the human body has to be switched "on" quickly. The survey showed that some personnel felt that the leaders must accept that this is a challenge, and that some "arrogant" leaders did not accept this fact.

"Absentminded behavior" leading to slips of action or memory lapses during RLWI has also happened, but is very rare. The behavior has been caused by a combination of motivational causes, abnormal situation causes and mental causes. An "I don't care" attitude, wrong emotional state of mind or mental state affecting decision making and work performance has also happened, but is very rare. Situations at home and sickness has caused this attitude.

Slips, lapses and "corner cuttings"

Slips and lapses types of errors occurring when a skilled person is performing a familiar task during RLWI has happened, but this is very rare. The personnel can make slips and lapses if it is too much routine work when performing their tasks. The person might do the familiar task without double-checking what he or she has done, or one can forget "buddy check".

There has been decision making and work performance "corner cuttings" attributed to safety attitudes, beliefs, risk-taking behavior, conflict or motivation, but this is very rare. "Corner cuttings" can be done in agreement among the team, but can be poorly thought through. Misunderstandings, such as confusion of information have happened. This is a well-known challenge, but seldom due to good procedures and so-called "buddy check".

Issues like taking "familiar short-cut", information not received, misinterpretation or assumption when it comes to decision making during RLWI has happened, for example during maintenance. Personnel may "check off" that maintenance has been done to equipment, although it has not, because the equipment has not been used since last maintenance check round. The person therefore makes his/her own assumption and checks it off in the forms, without discussing it with the rest of the team. This causes wrong historical data logging of the equipment. In different situations one can also choose a shortcut based on own experience, and can thereby make mistakes due to one trust itself too much.

G: Stresses

The survey showed stress levels among some crew members when it comes to information processing and performance during RLWI, but this is not seen as a challenge since the stress level was not rated as abnormally high by the personnel.

3.2 AX-S

3.2.1 Personnel Interviewed

Representatives from the company Expro working at the Havila Phoenix vessel have been interviewed to map the challenges that may affect decision making and work performance when operating AX-S. The interviewed personnel are listed in table 5. In addition, the results are also based on conversations with the Technical Manager which is responsible for sales and marketing. This thesis mainly focuses on the Deployment- and the Intervention Cabin and the personnel working there, but some studies are conducted of the Bridge where the shift supervisor has his/her workstation. The deployment- and intervention supervisors report to the shifts supervisor.

Table 5: The following hierarchical positions were interviewed at the Havila Phoenix.

Vessel	Position	Company
Havila Phoenix	Shifts Supervisor	Expro
	Deployment Supervisor	Expro
	Well Intervention Supervisor	Expro

3.2.2 Error causation paradigms - AX-S operations

The five different paradigms look at the decision making and work performance challenges at the Havila Phoenix vessel from an engineering, cognitive, individual, organizational and work sociological point of view, presented as the project task four and five earlier in the thesis. The human performance model is used as a basis when identifying the challenges. As mentioned earlier the paradigms identify what are the challenges and influencing factors in the given working situations and thereby contribute to achieve the objectives of this thesis.

Presentation of the identified challenges based on the error causation paradigms

First, the challenges identified through the error causation paradigms will be presented shortly in table 6 to provide an overview. Second, the challenges will be further described from the paradigms different points of view. A more detailed description of the challenges will be given later in the chapter when presenting the PIFs for the AX-S concept.

Table 6: Presenting the identified AX-S challenges shortly, through the error causation paradigms.

AX-S	**Error causation paradigms**				
	Engineering	**Individual**	**Cognitive**	**Organizational**	**Work Sociological**
Identified Challenges	- Large amounts of information - Operators still in the learning and familiarization phase - Automation system in the early stages, and relatively outdated computer system - Too much manual handling - Complex GUI and HMI systems - Deployment- and Intervention Cabin, and Bridge design challenges (space, noise, vision, air quality and lightning)	-Demotivation, frustration and less "alertness" due to periods with a lot of waiting - Wide scope of work - "Corner cuttings"	- Complex information processing - The correct amount of information is not presented to the managers and operators - Too much information is going back and forth. - Routine and sedentary/ stationary work tasks - "Information overload"	- Do not have the right amount of correct personnel yet - Lack of resource availability - Not produced enough procedures yet - Communication and information transfer are not streamlined - Poor planning - Complex management practices - Allocation of responsibility is unclear for some of the personnel - Uncertainties as to individual responsibilities	- Immature team still undergoing "storming" phase of the team dynamics - Complex team work tasks - New team -The relationships and group dynamics are not yet optimal

The engineering error causation paradigm focuses on challenges related to the large amount of information when it comes to automated part of the system, and also Deployment- and Intervention Cabin, and Bridge design challenges. The totality with operation tasks, extensive use of procedures, documentation, telephones, radio, panels, and cameras makes the whole picture complex, especially for new personnel. The automated side of the system is in the early stages and is not operating to its full potential with a relatively outdated computer system according to some personnel, since it has been in development for some years now. The GUI- and HMI system is complex with a quite comprehensive computer system. It may be difficult for the humans to detect the reason behind an error alarm. The operators are still in learning and familiarization phase, and the possibility for making mistakes when performing an activity is high since it is a brand new concept. Today, it is also a reasonable amount of manual handling required, which should be reduced in later stages from the operators point of view. Deployment- and Intervention Cabin, and Bridge design challenges were also identified, with space, noise, vision, air quality and lightning ranked as the main context concerns, described later when presenting the PIFs.

The Individual error causation paradigm considers motivation, attitude and "corner cuttings" among the personnel at the Havila Phoenix. With an engineering project such as AX-S the personnel sometimes become frustrated and demotivated due to waiting, uncertainties and unknown areas. Personnel are required to work for longer periods offshore during the commissioning phase, resulting in a lack of motivation. Human failures with work performance reduction attributed to motivational causes have happened, due to the wide scope of work and amount of information personnel are currently dealing with together with repetitive work does which becomes mundane. "Corner cuttings" attributed to safety attitudes, conflict or motivation has happened, but is not frequent.

This Cognitive error causation paradigm covers the information processing, mental and physical experience and training. The survey showed that the managers and operator sometimes had information processing challenges due to a large amount of information to handle, coordinate, analyze, and communicate. Some managers and operators feel that the amount of information presented to them is not optimal. Some mentioned that it feels like too much information is going back and forth and this could have been streamlined. There are tendencies of "information overload", but this is most frequent among new personnel. There have been personnel that have lacked the technical ability required to perform activities that is so technologically advanced, showing a mismatch between mental and physical capabilities. The survey also identified challenges related to too many repetitive tasks and monitoring task for 12 hours. Doing this in standing position in the Deployment Cabin is tiring. The training program is too early to evaluate since the concept is in an early stage.

The organizational error causation paradigm considers the personnel competence level, procedures, communication and management in this thesis. Due to the commercial phase, they do not have the right amount or the correct personnel yet. Also, the resource availability is not optimal, due to the fact that the AX-S is a new concept. The procedures are currently still being developed and are being issued in “draft” format, and it is therefore too early to comment on the procedures other that it is not produced enough procedures at this time. The communication between the managers and operators is not streamlined yet. Poor planning and communication before or during AX-S operational testing has happened, and sometimes happens too often due to a combination of factors which will be presented later in the PIFs section. Organizational and management factors that may reduce or hinder the humans work performance may be politics, power struggles, perceptions of performance, attitude differences between contractors and staff, complexity, new operation, newly formed operational team and a new system. The allocation of responsibility is quite balanced and clear for some, while unclear for others. There is also an uncertainty as to individual responsibilities.

The work sociological error causation paradigm focuses on the team and group dynamics at the Havila Phoenix. The teams have complex work tasks and they are new with unfamiliar structures. Right now the existing team structures are not ranked as optimal to execute safe and acceptable decision making and work performance. The group dynamics and team work are still at the “storming” phase. The team works very well together, but the relationships and cooperation is not yet optimal.

3.2.3 Identified Performance Influencing factors (PIFs) at the AX-S vessel

As mentioned earlier, a wide range of PIFs can contribute to incorrect decisions, reduced work performance and critical operational situations, and an identification of PIFs can contribute to better the decision making and to improve the work performance. The supervisors, operators and other crew members at the Havila Phoenix operate technical complex equipment, with problem solving, team work, communication, discussions and monitoring as daily events during their shift. This shows the importance of identifying the PIFs since they can provide a better situational overview, understanding and knowledge. The way to reach the objectives in this thesis is to identify the PIFs, defined in the project tasks number six.

I: Work-related factors

A: Environment

Space and Ergonomics

The Deployment- and Intervention Cabin workplace arrangement is ranked fairly satisfactory by the crew, but with room for improvements. Some personnel felt that the cabins layout was fairly spacious with good placement of screens, chairs, desks, etc. Others felt that the cabins were small and that they could have been bigger since it is actually room for this at the deck when the cabins are placed on top of each other. When visiting the vessel I felt that the cabins were small, especially when several people were gathered in the cabin. The ROV Shacks was from the personnel's point of view extremely well ergonomically designed.

The ergonomic design of the Deployment Cabin could have been better. The stations are easy to use but they are better worked in standing position, which is tiring after 12 hours. Some personnel felt that the existing chairs have not been afforded the adequate amount of design. The chairs do not fit very well under the station and there is room for improvements here. As this system is the 1st and is a prototype, there are lessons to be learned in this area, and they are working on improving the chairs. The ergonomically design of the Intervention Cabin is better, with a better adaption of the screens, desks and chairs, but it is also room for improvements here.

Noise

The climate control adjustment in the Deployments- and Intervention Cabins is distracting and uncomfortable making loud whistling and humming noises. It is also much noise from the computer cooling system in the Deployment Cabin. The Deployment- and Intervention Cabin can be isolated in terms of distraction, and the doors can be shut to prevent outside influence from unauthorized personnel. There is considerable noise from one of the power conversion systems located in the Intervention Cabin. It is possible to shut the doors between the power distribution side and the monitoring side, but it is still noisy.

Vision, lightning and air quality

The Deployment Cabin where supposed to be positioned lower than it is today, and the cabin was actually designed for such low-level location. Due to the lack of space at the vessels deck, the Intervention Cabin had to be placed underneath the Deployment Cabin. This resulted in the high stationing of the Deployment Cabin. The cabins where supposed to be placed next to each other, but the company had to change their plans due to the fact that their original vessel never got produced. Therefore they chose the Havila Phoenix vessel, which was smaller, resulting in the rearranged placement of the cabins. Therefore the Deployment Cabin affords a limited view of the back deck area due to the fact the cabin was not designed for this. It is therefore difficult to look out the windows while monitoring the panels and touch the screens. There are cameras showing the deck area, but due to safety and efficiency it is important to be able to look out the windows while performing operational tasks and monitoring. The floors in the Deployment Cabin were actually raised for the operators to be able to look out the windows, but it is still difficult to get a good overview. A stool is placed by the panels which the operators can step on to. The design could hinder the performance by the location of the cabin or rather design of the cabin, but some personnel felt that this is overcome by a very good camera on the deck which provides CCTV (Closed-Circuit Television Camera) for almost everywhere on the back deck and tower. Despite the cameras, it would have been safer to be able to watch the entire deck while monitoring the screens and camera views, and not be fully dependent on the cameras. They can potentially fail during critical operations, and then it is important to have the opportunity to have an appropriate view out the windows.

Some personnel located at the Bridge are bothered with bright lightning from the windows, blinding them when looking at the screens. This is tiring for 12 hours. Also, from my point of view, when visiting the vessel it was dark in the Intervention Cabin, which had no windows. This cabin had no windows because no deck overview where needed for the personnel in the Intervention Cabin to perform their operations. A working desk in the middle of the monitoring stations had very little lightning possibilities at the time I visited the vessel. I was told that it was supposed to be dark in the cabin so that the operators were not tired when looking at the bright screens. Despite this I felt that it was too little lightning possibilities to achieve healthy working conditions, although I know that HES personnel recommend the use of low light in such environments.

The climate control adjustment in the Deployments- and Intervention Cabins is limited causing bad air quality. When several people where located in the Intervention Cabin at the same time watching the screens during operations, the small square emergency door had to be opened to provide some fresh air, and to cool down the temperature.

B: Displays and Controls

Panels and Alarms

The GUI- and HMI systems are complex, but ranked as relatively user friendly. The functional characteristics and clarity of signals is good, but it is room for improvements. Some mentioned that it was sometimes difficult to detect the error when something happened during operations. As the system is in early stages the automated side is not operating to its full potential. Some mentioned that the control cabins computer system hardware is relatively outdated as the system has been in development for some time.

The relationship between automated and non-automated tasks in the cabins could have been better. Some personnel said that much of the system has been designed to reduce manual handling via automation, although presently there is still a reasonable amount of manual handling required. This should be reduced once the system becomes operational and best practices and procedures are developed, according to the personnel.

The possibility of making mistakes is high as this is a brand new concept and personnel are learning and gaining experience. At present, it is sometimes uncertainties where and when to focus the attention in the automated part of the system, as the system is quite comprehensive and the operators of the system are still in a learning and familiarization phase. This also applies to the high possibility that mistakes happen due to a person is faced with an environment for which no “know-how” or “rules for control” are available from previous experience. As the experience and knowledge of the system and enhanced procedures develop, this will most likely become less of an issue but although it is important to have a focus on this challenge. All activities are given full attention until they gain trust and confidence in the system, but even once this is gained every operation must be monitored.

Complexity

There is a diverse range of tasks to be performed both physical and mental, some tedious or repetitive others unique and requiring considerable thought and research. There are a lot of cross department interaction and assistance which provides additional diversity of tasks performed through the automated part of the system, contributing to increased complexity.

The different personnel’s knowledge about the automated part of the system was ranked as low, and many operators do not understand the whole picture yet. It is still too early to be able to accurately quantify the human-machine match effectiveness of the system, though one would expect that once personnel are more experienced and the system optimized, it is likely to be a more functional and efficient system.

C: Task demands

Information and communication

The right amount of information is not presented to the managers or to the operators in the cabins performing AX-S operations according to the personnel. Important information is communicated to the key-personnel through pre-shift supervisors meetings, shift task planning, priority meeting, shift handovers and toolbox talks, and by way of email, reports, procedures and training. There are sometimes tendencies of “information overload”, which have led to reduced human performance and poor/confusing decision making. As personnel have been on the project for a long period and through the build phase, information has been easy to take onboard as it has been put together bit by bit and information has been at a steady flow. Although for new personnel it is not easy, but this is understood and is the reason why personnel new to the project are put in the correct role and given the appropriate tasks for their skill set and degree of knowledge. Still it is important to focus on the fact that the new personnel struggle with the information amount.

The communication and cooperation between the managers are good, but there is room for improvements. The same applies to the cooperation between managers and operators, but it is ranked slightly lower. There are some team communication challenges between the Intervention Cabin personnel, Deployment Cabin personnel and the shift supervisor when the operations are performed. The processes are not fully streamlined yet. Some mentioned that it feels like too much information is going back and forth between too many reporting levels. According to the personnel, it would be better if the communication, command and reporting path were streamlined. When the shift supervisor communicates over the radio or telephone to the supervisors, located in the cabins, to perform an operational task with for example placement of subsea modules or stacks, the vessel may have moved its location during that time due to communication delay, hindering the correct placement of the stacks. Therefore the process takes time. To save time and to streamline the work processes, the shift supervisor delegates the responsibility to the cabin supervisors, and takes the responsibility back after the task is performed. Such measures could also help to streamline other communication paths in other situations too.

Monitoring tasks

Problems with too many repetitive tasks over a period of time may be a challenge. The operators in the Deployment- and Intervention Cabin have a monitoring task, and this also applies to the shift supervisor and DP personnel. They are working 12 hours shifts monitoring the screens and deck, and it lays in the human nature the risk of losing focus in such situations.

Unfamiliar situations

Memory lapses or attention errors due to human information processing issues of great amounts of information provided at the same time happens typically when dealing with unknown areas of the system and during operations of equipment. As the AX-S system, technology and concept is new and unique this is to be expected according to the personnel.

At present the possibility that mistakes may happen when a person is operating the automated part of the system and is faced with an unfamiliar situation during AX-S operations at the vessel is reasonably high as the system is in a pre-commercial commissioning phase, thus many of the operational situations are at present unfamiliar and untested. The system does have considerable safety interlocks to minimize potential mistakes.

Mental and physical capabilities

A mismatch between mental and physical capabilities of the human and the demand of the job performed has occurred. There have been personnel that have lacked the technical ability required to support a system that is so technologically advanced.

The operators in the Deployment Cabin must be able to stand a lot during their 12 hours shift when monitoring the operations, which normally require both solid mental and physical capabilities.

D: Instructions and procedures

Coordination

The procedures are currently still being developed and are being issued in “draft” format. They are being reviewed during first time conduct, and it is not produced enough procedures yet. The personnel knowledge about the content and requirements of the procedures are not satisfying at this time, and must and will be improved. The personal behavior of the teams with regards to procedures, rules and procedures seem to be proactive and openly accepted. Some mentioned that there is a concern that management will implement rules and safety requirement purely to satisfy clients rather than considering the practical benefits and aspects, though this is more a product of the industry sector than AX-S.

E: Socio-Technical

Manning and competence

Due to the commercial phase, they do not have the right amount of personnel yet, and it is also difficult to find the right people with relevant experience to a new concept such as AX-S. Today, they have only two shifts, but they need more people with time. It is difficult to reach and hire the right personnel due to the fact that nobody has earlier experiences from such a concept to relate to. As they are yet to go commercial, the staffing levels are engineering rather than operations focused, but this is said to change in the future. Some feel that the right skilled and experienced personnel are hired, while others feel that this is not completely true. Right now the training is not optimal due to the commercial phase, but at present it is too early to accurately comment on training, since training is planned in the near term. The sharing of experience is quite good, but it is always room for improvements. The working environment is sometimes characterized by openness an dialog, but not as much as it should be according to the personnel.

Planning and cooperation

Decisions errors or performance reduction due to poor planning and communication before or during AX-S operations testing has happened, and sometimes happens too often. This is the result of combination of factors according to the personnel; contractual complexities between Havila Phoenix/AX-S/Salt Subsea/Fugro, an immature team still undergoing a "storming" phase of the team dynamics, and a level of manning below that which is needed to effectively operate the AX-S system during full operations. Sometimes it may also be a problem with concurrent plans during AX-S operations and there is a tendency to use plans or rules which have worked before, but which may not be useful in the present situation.

There are planning and cooperative challenges due to the new team and unfamiliar structures. The existing team structures are not ranked as optimal to execute safe and acceptable decision making and work performance. The work tasks of the teams are also quite complex. The dynamics of the team will change as they are new and still in the early stages of forming one team. The existing team works very well together with a great working environment and this has been proven when contingency plans have come into action, and they come up with ideas and solutions to overcome problems. Still, the relationships and cooperation is not optimal yet. They also solve problems and conflicts in a good manner and it is quite easy for the teams to share the same situation awareness during operations, but it is room for improvements. The personnel normally work with the same team members, and they work with almost all due to split shift pattern. There are currently only two crews, and changes are only due to agency personnel brought in to cover.

Management

Organizational and management factors that may reduce or hinder the work performance may be politics, power struggles and perceptions of performance and attitude differences between contractors and staff. The managers work tasks are quite complex. There are challenges associated with the management practices and decision making related to a new operation, newly formed operational team and a new system. There have been many recent and ongoing improvements to find the most efficient and effective system for the team. There are challenges on the daily basis with this being a brand new design and engineering concept, and as the system is a prototype everyone has to work very hard to overcome problems. The allocation of responsibility is quite balanced and clear for some, while unclear for others. There is an uncertainty within certain team members as to individual responsibilities. The management structure has been modified several times to improve operations and due to changes to the company. One of the challenges is ensuring that personnel understand and use the correct chain of command, this to ensure that coherent, clear and consistent decisions can be made. The organizational diagram is not yet finished and the allocation is still in the early stages. There are areas that need changing. The allocation has been improved by the addition of an offshore project engineer between the shift supervisor and the operations manager in the hierarchy. Another allocation of responsibility can improve the decision making and make human performance more optimal, but others also feel that they have a fairly good system that will get optimized in as operations progress. This is organizational and management factors that may affect decision making and work performance

II: Human-related factors

F: Individual

Motivation and attitude

The managers and operators work tasks are complex, and they have high demands of concentration and knowledge. The time pressure can also be high, followed by periodically high work load. Human failures, work performance reduction or unsatisfying decision making attributed to motivational causes has happened. With a unique engineering project such as this there are times where personnel become frustrated and/or demoralized, however there is a good team oriented work ethic. As there are no back to back crews with the system not being commercial and in the commissioning phase, a lot of personnel are required to work for longer periods offshore, this sometimes results in lack of enthusiasm and drive and ultimately leads to mistakes or bad decisions. Also, AX-S does not earn money yet, which can be demotivating for some personnel. An "I don't care" attitude, wrong emotional state of mind or mental state affecting decision making and work performance has also happened, usually due to short term frustrations. "Absentminded behavior" leading to slips of action or memory has also happened, but is not frequent.

Slips, lapses and "corner cuttings"

Slips and lapses types of errors occurring when a skilled person are performing a familiar task happens, but is not frequent. This is attributed to the wide scope of work and amount of information personnel are currently dealing with, and repetitive work does become mundane. These types of errors have occurred during the mobilization phase with 24 hour work with multiple concurrent activities and a deadline to meet. It has also happened if there have been long period between operations i.e. the vessel has been alongside for a technical issue. It takes personnel a few shifts to get familiar again with operations. If individuals have a personal problem then this can also affect the concentration. This can also happen when a person thinks a task is below them and is not giving 100%, or if a task is repetitive.

Decision making and work performance "corner cuttings" attributed to safety attitudes, beliefs, risk-taking behavior, conflict or motivation has happened, but is not frequent. The team has an open and proactive approach to safety. It is fairly common for them all to assist and remind each other when they forget "best practice". This is why supervision is in place to observe and to instruct correct/safe working practices. Issues like taking "familiar short-cut", information not received, misinterpretation or assumption when it comes to decision making has happened, but very rarely. They take great care in ensuring everyone is aware of the job scope and not to go ahead and assume that what they are doing is correct. It has been a few occasions where personnel have done their own thing, but this was rectified.

G: Stresses

The stress level among the personnel when it comes to information processing and important decision making during operations is sometimes high, but is not ranked beyond what is normal in a commissioning phase.

4. Improvement Opportunities

The identified challenges needs to be discussed related to opportunities to improve the working situations. The improvement opportunities, for the identified RLWI and AX-S challenges presented above, will be suggested with the SRK-framework as a basis in this section, but various solutions from other stand points will also be proposed. This is defined as the project task number seven. As mentioned earlier, the SKR-framework consists of three behavioral levels of cognitive control which are related to a decreasing familiarity with task and environment (Redmill and Rajan, 1997). Figure 36, presented earlier, will be used as background information for the solutions proposed in table 7. It illustrates that humans can control their actions through various combinations of two control modes - conscious and automatic (Reason, 1997). It also illustrates the second dimension where one has familiar everyday situations and routines, trained-for problems and entirely novel problems. The SRK-framework is a good conceptual and structured framework which can be used to suggest solutions to the identified challenges and to increase the understanding, and are therefore, from my point of view the correct method to reach this thesis' objectives.

Some suggestions to solutions to the identified environmental and workplace design challenges presented above (space, ergonomics, noise, vision, lightning and air quality) will be presented when discussing these factors for both the RLWI- and AX-S concept in chapter 5 "Discussion and Recommendations".

4.1 Solutions from different perspectives

The proposed solutions to the challenges will be presented in table 7. As mentioned earlier the SRK-framework is used as background, but solutions from other perspectives will also be suggested.

Table 7: Proposed solutions, divided into common challenges between RLWI and AX-S concepts, and challenges the concepts experience individually.

Identified Challenges	Proposed Solutions
Common Challenges	
➢ **Large amounts of information to handle** ➢ **Complex information processing** ➢ **"Information overload"** ➢ **Ineffective Communication and information transfer**	- Learn to handle the large amount of information and complex information processing through customized training to hinder "information overload" and increase the focus and awareness on this kind of issues through the training. - Communication and information transfer-based training can contribute to understanding and streamlining the processes. - Improve the procedures and rules with focus on decreasing/balance information amount to hinder mistakes, streamline communication and to make the processes more effective. - Hire the correct and right trained people able to think "out of the box" when novel situations occur and when there is a lot of information to handle with the need of effective communication. - Investing in more sophisticated information processing mechanisms. - Evaluate the existing organizational design and allocation of responsibility to see if it is adapted to the mentioned issues. To improve information processing and the ability to handle large amount of information, one can develop rules for a higher control of the organizational environment, utilization of more resources and create self-contained tasks through higher integration, or reduced division of labor. - Develop a team of operators or task force (and cut across the lines of authority) who can jointly resolve the outstanding and non-routine issues that might need higher levels of problem-solving and information processing abilities. - Make job aids such as a storage medium for keeping vital information available and easily accessible. This can be done by for example implement rules and routines for external information storage to be able to search and "go back" to critical information, to hinder loads of information in paper-formats and to loose information. For example focus on storage of lessons learned to increase knowledge, understanding and effectiveness. - Focus on hindering selectivity, working memory overload and memory cueing. This can be achieved through training specific adapted activities.
➢ **Complex GUI and HMI system**	- Increase the operators knowledge and understanding through proper training - Focus on that the personnel have the correct mindset and availability to follow the procedures and rules, and that they are not too overconfident and oversimplify the challenges or tasks they face.

	- Develop properly formatted job aids to the systems. This can reduce training time and enhance productivity, accuracy and effective work performance. - Use clear symbols in the interphase design which can help the operator to deal with the system's complexity. - Focus on and provide high-level information GUI at the panels to enable accurate decision making and monitoring. - More extensive use of graphs instead of tables and other ways of presenting data. By clicking on the graph, the operator can reach more low level information and see the hundreds of alarms/statuses one by one if necessary, while the graph itself provides high-level information and an overview. - Use the operator's knowledge and input when optimizing the GUI and HMI.
➢ **Routine and sedentary/ stationary work tasks**	- Hinder strong habit intrusions trough training and by increasing the awareness of the routine work tasks effects on the human. - Facilitate variation of work tasks, for example by standardizing how and when the operators can take a break or do some other work for a short period of time, this to "to break the routine pattern". - Facilitating and improving the workplace to hinder errors due to routine and sedentary/stationary work tasks. - Increase the awareness of consequences of losing focus due to routine and sedentary/stationary work tasks.
➢ **Demotivation, frustration and less "alertness" due to periods with a lot of waiting**	- Performing training, operational activities, social activities, planning, team-buildings etc. to keep people motivated, on "alert" and updated during such periods to hinder the body to "fall into a resting modus" with the danger of slips, lapses and human errors when the operation starts up again. - Perform procedural training. - Provide the possibility (maybe through a board) where the personnel can suggest general improvement opportunities and possible solutions to the challenges. It is important to use personnel knowledge and viewpoints.
➢ **Poor planning and concurrent plans**	- It is necessary to consciously formulate a goal and to develop a plan to achieve the goal. To better the planning process, training can be conducted to increase the ability to keep an overview. - Have a person or group of people that are interacting and keeping the record of everything that happens and will happen during operation, mobilizations or demobilizations, and that make sure that things are being performed according to the plan, hindering deviations from the intended plan and concurrent plans. - Develop rules, or improve existing rules to streamline planning and to hinder concurrent plans. - Implement proper planning problem solving abilities and increase the ability to use reasoning and using analogies when planning through courses.
➢ **Complex management practices**	- Increase and improve management training with focus on operational understanding and decision making. - Clearly define each leader's individual responsibility, and focus on training within each area. - Standardize how managers shall control and define how the management processes can be standardized.
➢ **Uncertainties as to individual responsibilities**	- Clearly define each positions individual responsibility, and focus on training within each the area. Focus on how important it is that each and everyone know their own responsibility. - Make rules for standardization of individual responsibility for each position at each shift, insuring that every shift perform tasks in a similar manner.

RLWI	
➢ **Too many procedures which causes coordination challenges and give rise to situations where some personnel indicated that they sometimes took shortcuts** ➢ **Slow procedural updating system**	- If possible, reduce the number of procedures by merging two or more related procedures to decrease the number. This may reduce the dangerous potential for making mistakes, which are present. It can also contribute to hindering violation of procedures, and intentional or unintentional skipping of procedural steps. - Focus on using few words, use action verbs, precise language, together with a user friendly layout, presentation and graphics whenever possible. - Focus on procedural training and increase the focus on the importance of following the procedures, and also the importance of taking their time when performing tasks and not to take procedural shortcuts. - Streamline the procedural updating system through proper training of the personnel responsible for the updating and progress. - Place higher demands to the procedural updating system, and put focus to the importance of effective procedural updating. - A team or group of people should have been responsible for reducing the number of procedures and better the procedural updating system, and to implement measures to do this.
➢ **Human body "resting modus" and managers not accepting this**	- Performing training, operational activities, social activities, planning, team-buildings during quiet periods where "resting modus" can be a challenge. - Develop a team responsible for keeping people "on alert" ready to face familiar and novel problems. - Perform management training to make managers focused on this challenge, and increase their ability to understand the situation and to make proper measures.
➢ **Split up management** ➢ **Unclear "command lines"**	- This can be overcome by ensuring competency is achieved with cooperation and coordination training and taking time to analyze areas for improvement - Implement rules for standardization of how to get the organizations and its personnel to fully work as "one" unit. - Focus on "grey areas" in the reporting path and remove these areas by defining clear reporting paths. - Develop a team or a group responsible for keeping focus on the humans and organization, and the value of working as one unit, and how this can be done. Maybe a clear and user friendly scheme or diagram can be made to show the "one" organization and its "command lines" which can be displayed or posted readily available to the personnel at the walls or intranet.
➢ **Several shifts do things differently with lack of task standardization**	- Focus on standardized task training. - Focus on an incorporation and standardization of rules of how thing are going to be performed. - Standardization of when and how often to "take over the helm" for the operator to take a break. - Develop a team across the "shift boundaries" which has the responsibility of insuring that tasks are conducted in a standardized manner.
➢ **Difficult to reach the right resources during holydays, weekends etc.**	- Develop an onshore teams that can be "on watch", with the correct competency. - Conduct specialized training.

AX-S	
➢ **Operators are still in the learning and familiarization phase**	- Implement standardized and adapted training in as early stages as possible. - Log "lessons learned" along the way to not "forget" important experiences. Develop job aids, for example a system reporting "lessons learned" which can be readily available for the personnel. - Implement standardized and adapted rules and procedures of how tasks shall be performed, and define individual responsibilities and focus on streamlining the HMI systems and optimizing the GUI. - Study other SWI concepts and learn from their mistakes, miscalculation and misdiagnosis to improve the AX-S concept, but also focus on learning from what they do well.
➢ **Automation system in the early stages, and is a relatively outdated computer system**	- Update the system through research of new computer systems, and study other SWI concepts computer systems to learn from their pros/cons. - Develop a group of people responsible for updating the system with an extensive use of clear symbols and high-level information, and the possibility to easily access the low-level information.
➢ **Too much manual handling vs. automation handling**	- Identify which manual tasks should be automatic and implement measures to make the proper amount of tasks automatic vs. manual. - Implement a team responsible for identifying the optimal amount of manual handling vs. automation handling.
➢ **Not produced enough procedures yet**	- Here AX-S has the opposite challenge compared to the RLWI, but this is due to the fact that the concept is still in the commercial phase. It is important to put a focus on making the proper and balanced amount of procedures, but not too many which may result in slip, lapses, mistakes and shortcuts. - Use few words, use action verbs, precise language, user friendly layout with presentations, graphics whenever possible. - Perform procedural review and courses to increase the understanding of the contents. - Implement proper demands and routines to the procedural updating system. - Hinder "out of sight out of mind" issues by implementing a team or group responsible for effective and continually updating of procedures.
➢ **Allocation of responsibility is unclear for some of the personnel**	- Training and courses explaining and defining the allocation of responsibilities and reporting paths. Focus on how important it is that each and everyone know the allocation of responsibility. - Maybe a clear visually scheme or diagram which is easy to understand can be made to show the organization and its allocation of responsibilities which can be displayed or posted readily available to the personnel at the walls or intranet. - Develop a team or a group responsible for keeping focus on the humans and organization, and the value of knowing the allocation of responsibility and how this can be done.
➢ **New, immature team still undergoing "storming" phase of the team dynamics**	- Sufficient time allocated for standardized and adapted training. - Team-buildings/activities for the new teams to get to know each other - Standardize the way tasks will be performed at each shift. - Continuous constructive feedback from the management to improve the cooperation and team dynamics, and to improve the working environment and insure that each individual know that they are doing a correct and good job and that they are being corrected when they can do something better.

5. Discussion and Recommendations

Now as the challenges and improvement opportunities have been presented, this chapter will discuss the RLWI- and AX-S concepts similarities and differences based on the identified challenges, together with some further improvement recommendations and suggestions to further studies.

The RLWI- and AX-S concepts certainly have one thing in common, the complexity. According to Rossnes, Guttormsen, Steiro Tinmannsvik and Herrera (2004) many activities take place in parallel in complex systems and these parallel activities may interact in non-obvious manners if the system is characterized by high interactive complexity. For the personnel at the RLWI- and AX-S vessels it is challenging to maintain a complete overview over parallel activities, procedures, monitors and the situation on deck, while communicating, cooperating and contributing to decision making between the different levels of authority and at the same time have an acceptable work performance. There is a diverse range of tasks characterized by high interactive complexity to be performed both physical and mental, some tedious or repetitive while others are unique. By streamlining the decision, reporting, information, communication and cooperation processes, and by increasing the personnel's understanding and knowledge of their individual tasks and of the entire concept through proper training, one can contribute to an improved decision making and work performance.

The fact that there is some lack of space in the cabins is more or less a general challenge at all the vessels. To contribute to optimize decision making and work performance at the RLWI vessel, there should have been made a workstation in the Tower Cabin for the holding of the many necessary paper-procedures to contribute to improve the context the activities are performed in. This will better the possibility to maintain a good procedural and situational overview since the space around the operator's chairs, especially the WOCS operator, is not physically suited for paper work at this time. It may also contribute to reduce some cluttering at the workplace in the Tower Cabin. The ergonomically design of the desks and chairs are good according to the operators at the RLWI vessel. The Deployment- and Intervention Cabin at the AX-S vessel have, like the Tower Cabin, room for improvements. Some personnel felt that the cabins could have been bigger. By improving the space and design the work performance can be increased which again can contribute to success and higher income due to more streamlined activities in an optimized context. The stations in the Deployment Cabin are better worked in standing position, which is tiring after 12 hours. The existing chairs in this cabin are designed as “bar” chairs with no back support, and the material is quite hard with no pillow or soft material in the seat. There should have been designed comfortable chairs where the personnel could sit down and rest his/her legs and back, and which fits under the panel station. Measures can be made to enable the work system to function better by improving the interactions between the human component and other components at the vessels.

The condition under which decisions are made, strongly influence the outcomes and decision processes (Rossnes, 2001), and according to Hollnagel (1984) the decisions the person makes can shape the performance. The noise is a part of the physical context in the Tower Control at the RLWI vessel and is mainly caused by crowding and walk-throughs, which is a part of the social context. The “sign in and out” registration process could have been changed or moved to a less critical location to reduce some of the traffic. The heavy doors which are opening and closing could be improved by putting better “breaks” on the doors causing them to be closed more gently, or by making stricter access restrictions to hinder crowning. By making clearer signs at the doors and by putting more focus on not to disturb the operators in the Tower Control together with an underlining of the importance of this, can increase personnel performance and decrease the risks of making slips, lapses and mistakes. The cabinets and computer equipment can be moved to reduce noise, which was suggested by the operators. Measures could also have been made to reduce the noise from the air condition. Working conditions must be provided to enable the operators to function efficiently without distraction to ensure a safe operation of the system (Wong, 2002). According to Bailey (1996) the designer or engineer should understand the human qualities, characteristics and deficiencies, and in the best possible way take them into account when producing the system and making decisions. The AX-S personnel in the Deployments- and Intervention Cabins were not bothered with noise due to crowding and walk-throughs to the same extent as the RLWI personnel, but during some periods of the commissioning and training phase there were some crowding in the cabins since many people are involved. Measures can be done here to hinder that the cabins become the “center at the deck” for discussions and questions in the future. Like the RLWI personnel in the Tower Control they are bothered with noise disturbances from the climate control adjustment. Also, the computer cooling system in the Deployment Cabin makes disturbing noises. Measures could be made here to reduce the noise by changing or adjusting the system. It is also considerable noise from one of the power conversion systems located in the Intervention Cabin and noise insulation would benefit here.

At the RLWI vessel the tower- and wireline operator's view out the windows can be improved to increase work performance and to contribute to safer decision making. The operator's chair, monitors and sticks can be moved or adjusted, the windows can be adjusted or maybe some arrangements and modifications can be done to the disturbing beams to improve the context. In the AX-S Deployment Cabin, measures like raising the floor have already been made due to lack of adequate vision out the windows. Still, the cabin affords a limited view of the back deck area. More measures should be made to improve the view out the windows by "redesigning" the cabin. A stool is placed by the panels which the operators can step on to, but this is not satisfying from my point of view. There are cameras monitoring the deck area, but due to safety reasons it is important to be able to look out the windows while performing the activities. It can be quite dangerous to depend on the technology and the cameras monitoring, since a "worst case scenario" can be that critical camera monitoring fails during critical operations.

The personnel at the RLWI vessel did not mention challenges due to too bright lightning, or due to dark work stations, and they did not mention bad air quality. Some personnel at the AX-S vessel's Bridge were bothered with bright lightning from the windows which are a part of the physical context. The light blinded them when looking at the screens, but this can easily be fixed by using blinds or curtains. From my point of view, when visiting the vessel it was dark in the Intervention Cabin, which had no windows since no deck monitoring was needed during operation. I felt that the room was too dark to achieve healthy working conditions. From my point of view, a window with blinds could have been mounted in the cabin providing the possibility to let in some daylight, together with some extra lamps at the working desks to be able to read procedures under correct lightning conditions. The climate control adjustment in the Deployments- and Intervention Cabins is limited causing bad air quality, especially in the Intervention Cabin. Measures should be made here to increase the quality of the air provided to the personnel. The lightning and air quality can be measured by professionals to adapt them to the humans and to the HSE requirements.

From a human-machine interaction view errors often occurs as a result of a human-machine mismatch between the demands of the task, the characteristics of the interface provided to enable the person to carry out the task and the physical capabilities of the person (Redmill and Rajan, 1997). At the RLWI vessel some personnel mentioned that there are at times too many alarms at the panels, where many of the alarms are “nice to know” alarms. Measures have been performed to remove redundant alarms, but it is difficult to assess the importance of them. Also, the many alarms did not give guidance to the actions the operator should take in the situation when performing the activities. Especially the WOCS control program is very complex, and it can be difficult to identify the error when one occurs due to a lack of a clear early alarm when something is abnormal to help the operator to prioritize the alarms. More measures should be performed to remove redundant alarms, and to improve the clarity of alarms and action guidance. The operator knowledge should be used in the process to assess the importance of the alarms. Also, more extensive use of symbols and graphs could contribute to clear early warnings, where thousands of parameters can be plotted in the graph to provide an overview. If the operator needs more detailed information, he/she can click on the graph that provides low-level and detailed information. The WOCS operator, which will sit in the AX-S Interventions Cabin, is not yet hired due to the fact that the concept is still in the commissioning phase, and therefore not all of the positions and shifts are filled yet. Therefore, it is not possible to compare the RLWI and AX-S WOCS operators working conditions. The operators GUI- and HMI- systems in the Deployment- and Intervention Cabins are, just like at the RLWI vessel, ranked as complex and comprehensive. The AX-S panel’s functional characteristics and clarity of signals was ranked as fairly good, but it was sometimes difficult to detect the error when something happens during operation. In contrast to the RLWI systems, the AX-S systems are in the early stages and the automated side is not operating to its full potential. Some personnel mentioned that the AX-S computer system hardware was relatively outdated since the system has been in development for some time. Newer implementations of the computer system could be simpler, more efficient and could have contributed to increased work performance.

Presently there is still a reasonable amount of manual handling required and this should be changed to automation handling once the system becomes operational. According to Bailey (1996) it is important to know which types of work can be performed by people and what can best be performed by computer- or automation systems. Compared to the RLWI concept the possibility for making mistakes is high as the AX-S is a brand new concept and everyday personnel are learning and gaining experience, but it is still too early to be able to accurately quantify the human-machine match effectiveness of the system. The AX-S personnel knowledge about the automated part of the system was ranked as low compared to the RLWI concept, since many operators do not understand the whole picture yet and is still in the learning phase.

Common for both of the concepts are challenges related to too many routine and repetitive tasks. The personnel in the Tower Control, Deployment- and Intervention Cabins and Bridge have a monitoring task, working 12 hours shifts monitor the screens and deck, and it lays in the human nature the risk of losing focus in such situations. Some personnel at the RLWI vessel said that it varied for how long an operator sat in the Tower Control during one shift, and when somebody “took over the helm”. This should be standardized. The AX-S personnel did not mention any experienced challenges so far of great variations from one shift group to another when it comes this, due to the early stages of the concept. Also, the “weak point” where that few people can perform the WOCS task as the RLWI vessel if he/she needs a break or replacement should be improved. For both of the concepts there have been registered a mismatch between mental and physical capabilities of humans and the demand of the job performed, but is not frequent. There have been personnel that have lacked the technical ability and competence required to support systems that is so technologically advanced. For the AX-S concept it can be difficult to find people with the right competence, due to the fact that it is many completely new aspects of the concept. Training has to be prioritized in the future.

The petroleum industry comprises a growing number of Integrated Operation (IO), based on information and communication technology (ICT) advances (PSA, 2011), and systems become more complex and opaque to the people who manage and operate them (Reason, 1997). The managers and operators at the RLWI vessel reported some challenges related the amount of information and documentation provided to the personnel and “Information overload” was sometimes a challenge leading to reduced work performance and poor decision making. This especially applies to the mobilization and demobilization which is quite hectic. Also, communication and information transfer challenges where identified at the vessel. Many additional personnel are boarding when the vessel reaches the dock, increasing the communication and information transfer complexity. The crew felt that the amount of information presented to the managers and operators during RLWI operation was not optimal. Since the AX-S concept is not commercialized yet, they do not have the same mobilization and demobilization information and communication challenges as the personnel at the RLWI vessel. But, today they feel that the amount of information presented to the managers or to the operators in the cabins performing AX-S operations is not optimal, just like for the RLWI-concept, and there are sometimes tendencies of "information overload" which have led to reduced human performance and poor/confusing decision making. Also, measures could have been made to improve the communication and cooperation between the managers and between the managers and operators. The processes are not fully streamlined yet and some feel that too much information is going back and forth between too many reporting levels. The experienced operators at the RLWI vessel feel that they can handle the large amounts of information quite well to a certain extent, but new personnel may struggle with "information overload". The AX-S personnel have been on the project for a long period and through the build phase, therefore information has been easier to take onboard as information has been at a steady flow. Although for new personnel it is not easy. The great amount of information is a challenge, and the organizations must adopt mechanisms to process this large amount of information and focus on structure and training within this area.

The RLWI procedures are accurate, clear, detailed and easy to use, but some personnel experienced challenges related to the number of procedures and a relatively slow procedural updating system. Measures like combining two or more procedures can contribute to reduce the number and thereby contribute to hinder violation of procedures, and intentional or unintentional skipping of procedural steps. This may reduce the dangerous potential for making mistakes, which are present. Also, if measures like implementing the "Step-ladder" model described earlier are conducted, one of the advantages according to Hollnagel (1984) is that it specifies the correct and complete way to execute the task/procedure and it also accounts for the various ways in which shortcuts may be made. Such an implementation can contribute to streamline the decision process, improving work performance and map various ways in which shortcuts can be made. A high number of procedures can, together with other information- and documentation complexities, lead to "information overload" and "absence" to a certain extent according to the personnel. They have also experienced pressure from different clients and personnel to skip steps in the procedures, or to do it in a different order.

Therefore it is important to further develop an open culture in the psychological context and show the importance of being critical to the management decisions, and other decisions, and to think the situation through before taking action. It is important to have the attention on developing a safety culture, including training and education related to the work performed. The slow procedural updating system should have been streamlined to increase the speed of the procedural updating. The AX-S procedures are currently still being developed and are being issued in "draft" format and it is not produced enough procedures yet. Therefore it is natural that the personnel knowledge about the content and requirements of the procedures are not satisfying at this time, and therefore training and courses is important in the future. Some mentioned that there is a concern that the management will implement rules and safety requirement purely to satisfy clients rather than considering the practical benefits and aspects, but this can be hindered by putting focus on this concern both among the crew and the specific people responsible for making the rules and procedures.

Both the RLWI- and AX-S concepts have challenges with the availability of the correct personnel with the right competence. The RLWI personnel felt that the resource availability was currently low due to a competitive market, and this is a challenge many companies in the industry experience at this time. They also experienced challenges with the availability of onshore resources during the weekends and holidays and the personnel felt that it was important to be critical to decisions in such situations. This should have been put more focus to and measures should have been made. Also, somebody mentioned that in quiet periods it was almost too many persons at the RLWI vessel, and they could go for days without having much to do. During quiet periods measures like performing training, activities, planning, team-buildings etc. could keep people motivated, on "alert" and updated, which can contribute to decrease the possibility of making slips, lapses and mistakes when the operation starts up again. Due to the commercial phase, the AX-S concept does not have the right amount of personnel yet, and it is also difficult to find the correct people with relevant experience to the new concept. Nobody has similar experiences from such a concept to relate to. Therefore it is important that they have a great focus on training in the future. The RLWI personnel training was ranked as good, but according to the crew it was always room for improvements. They wished for a better sharing of experience and "lessons learned" from previous operation which could have contributed to better decision making and improved work performance. This can be put focus to through training, to make all of the personnel aware of the importance of this. At present it is too early to accurately comment on the AX-S training, though training is planned in the near term. The sharing of experience is quite good at this stage, but it is always room for improvements such as for the RLWI concept.

Due to poor planning and concurrent plans, wrong decisions and performance degradation has occurred at the RLWI vessel. Also, the personnel felt that nobody holds the record of everything that happens and will happen during mobilization and demobilization, which may cause plan deviations. There should have been one group of people responsible for keeping track of the processes and tasks. The AX-S concept does not have the same challenges since it is still in the commercial phase, but decisions errors or work performance reduction due to poor planning, concurrent plans and communication before or during testing of the AX-S operations have happened, and sometimes happens too often. This is the result of combination of factors according to the personnel; contractual complexities between Havila Phoenix/AX-S/Salt Subsea/Fugro, an immature team still undergoing “storming” phase of the team dynamics, and a level of manning below that which is needed to effectively operate the AX-S system during full operations. The survey showed that the group dynamics, relationships, cooperation and team work during RLWI are very good due to incorporation focus during the many years of operation, but as mentioned earlier some improvement opportunities were identified at the Island Wellserver. A cooperation challenge at the RLWI vessels are due to several different shifts doing things differently and the personnel ask for more incorporation and standardization of how activities and tasks should be performed. Measures should have been performed here with focus on standardization and training. At the AX-S vessel the existing team structures are not ranked as optimal to execute safe and acceptable decision making and work performance and the relationships and cooperation is not optimal yet since they are still in the early phases, but the existing team works very well together. Further incorporation, optimization and training should be in focus.

When it comes to the organization and management, both RLWI and AX-S have challenges. The personnel at the RLWI vessel experience organizational and management challenges like too much swapping of crew constellations, complex decision making going through the onshore facility, for some unclear allocation and distribution of responsibilities, grey areas in the reporting path, a sometimes ineffective management level due to the split up management level between IOS, FMC and AWS, and unclear “command lines” and individual responsibility. These challenges can quickly contribute to disturbances in the system. It should have been made more dedicated responsibilities to the individuals onboard with clearer standardized guidelines from the onshore organizations. Also, some personnel felt that some managers and supervisors were afraid of taking necessary decisions, thereby using an unnecessary amount of time. The operators felt that the managers did not trust their decision and knowledge, and that the management maybe lacked the right knowledge to make effective, safe and right operational decisions. From the operator point of view, they need more operational training and courses to understand the "whole operational picture". Today, such management training are not frequent and could have contributed to saving time and leading to a more effective decision making and work performance, but it can also contribute to increasing the safety. AX-S experience some of the same organizational and management challenges like complex decision making, and unclear allocation of responsibility and a definition of individual responsibilities, but they also experience some challenges related to politics, power struggles, perceptions of performance and attitude differences between contractors and staff, new operation and a newly formed operational team combined with the development of a new concept. Also, one of the challenges is ensuring that the personnel understand and use the correct chain of command, to ensure that coherent, clear and consistent decisions can be made. As mentioned earlier, the AX-S the organizational diagram is not yet finished and the allocation is still in the early stages, but training and focus on these challenges can contribute to increase the awareness and to improve the situation.

Both the RLWI- and AX-S personnel experience some attitude and motivation challenges. According to Bailey (1996) the human is the most complex of the three elements in the human performance model. At the RLWI vessel it may be a challenge to keep people motivated with a lot of waiting due to weather conditions, downtime, flawless periods, and other causes, leading to frustration and demotivation for some. A normal human body reaction is to put themselves in a "resting modus" during such periods. The survey showed that some personnel felt that the leaders must accept that this is a challenge, and that some "arrogant" leaders did not accept this fact. Measures could be conducted to put focus on this fact, to achieve that all the leaders accept that this is a challenge, and to insure that they contribute to increased motivation and earn the right skills to implement the correct measures. AX-S also experiences some attitude and motivation challenges where personnel becomes frustrated and/or demoralized as the system is not yet commercial and a lot of personnel are required to work for longer periods offshore resulting in lack of enthusiasm and drive. This is due to the commercial phase, and is expected to improve when new shifts arrive and the concept becomes commercial. It is still important to keep focus on the attitude and motivational factors in the future and to implement this in the personnel training.

Another challenge the RLWI concept faces from some personnel's point of view is the long-term goals of the organization. Personnel at the vessel felt that no one took the hold of this, and felt that the organizations needed a decision on which direction they will choose in the future to maintain and increase performance. Nobody uses resources on innovation and development from some RLWI personnel's point of view. Maybe a specialized team, consisting of all types of personnel and experiences can come together and suggest future directions by using the operators and managers' knowledge and suggestions, and make the personnel aware of that the long-term goals are in progress. AX-S is a new and innovative concept taking the risk of developing something which has not been tested before. The AX-S organization has taken a decision on which direction they will choose, and are taking chances and risking money to succeed with their concept.

It would have been interesting to perform a closer and deeper study of the situations at the RLWI- and the AX-S vessels, not only from a human perspective but also from a technological- and organizational perspective. I will suggest that the challenges identified from a human perspective should be further studied for both the RLWI- and AX-S concepts, combined with a deep study of the technology- and organization elements, together with a study of the HTO interactions. A further mapping of the concepts, from a HTO- and HTO interactions perspective can, from my point of view, contribute to a trustworthy and accurate human, technological and organizational focused best practice formulation. I also suggest that other colleges and universities should increase the HTO focus and implement the HTO area as a subject in their bachelor or Master's degrees, with the University of Stavanger as an example. This will, from my point of view, give the students a valuable knowledge and understanding of the human-technology-organization aspects and complexity, which will be useful both for the students and the industry they will enter in the future.

6. Conclusion

As presented in this thesis, SWI operations have several sensitive work settings which can affect decision making and work performance, and it exists many measures that can contribute to better the situation. In order to improve the decision making and work performance at the vessels, an understanding and identifications of the challenges that may have a critical effect is required. An incorporation of a human perspective can contribute to a better understanding of these effects. The challenges can be identified and presented by using the PIFs and error causation paradigms with reference to the human performance model. Based on the collected data from the interviewed personnel, the challenges within the thesis' scope were identified and showed that a wide range of factors can introduce different effects.

A proper knowledge and analysis of the complex work settings from a human perspective, can give the personnel a better working environment and an opportunity to improve the decision making, work performance and work situation. It is important to identify and underline the challenges to provide a good overview and to achieve a safe, optimal and productive operation. As Niccolo Machiavelli once wrote "*a common failing of mankind is to never to anticipate a storm when the sea is calm".* By providing the challenges presented in this thesis, I believe that the identification can contribute to improve the decision making and work performance situation at the SWI vessels, and that it can help to insure that the personnel can be "prepared for a storm" or hinder "a storm".

I wish to take Charles Percy Snow's quotation from year 1971 a bit further by adapting it to the views and system's complexity in today's industry. One can from my point of view say that: *The human, technology and organization elements are a queer thing. They bring you great gifts with one hand, but they can stab you in the back with the other if not handled correctly.* Let us avoid that the settings within the HTO elements and the HTO interactions stabs us in the back. To be able to avoid such situations and to implement the correct measures, one has to study the elements both separately and combined. Therefore, my recommendations are further studies of the identified challenges presented in this thesis from a human perspective, combined with studies of the technology- and organization elements and the HTO interactions at the vessels. Combining the studies with relevant solutions and implementations of proactive measures can result in a complete "best practice".

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Appendix

Appendix 1 – Interview guide

Interview:

- *Mapping of decision making and work performance during complex SWI-operations*

1. Mapping of the workplace design and work situation

1. Can you shortly describe the existing SWI operating teams and what their tasks are at the vessel? (WOCS-, Tower -, Wireline- and ROV operators etc.)
2. Where do the different operators (WOCS-, Tower -, Wireline- and ROV operators etc.) and managers have their "work base" at the vessel?
3. How is the ergonomic design of the "control room" (concerned with human anatomy with placement of screens, chairs and panels, and disturbance, noise, mental processes like memory, mental workload, work stress, working hours etc.) adapted to the humans?
4. How does the design of the "control room" affect human work performance and decision making? (Does the design hinder or reduce human performance effectiveness, or the opposite?)

A. How happy are you with the control center and cabins workplace arrangement?

Very bad ☐1 ☐2 ☐3 ☐4 ☐5 Very good

B. How does noise, vibration, temperature, air quality, lighting, space or other environmental disturbing factors affect the decision making processes at the vessel?

Very much ☐1 ☐2 ☐3 ☐4 ☐5 Very little

C. How does noise, vibration, temperature, air quality, lighting, space or other environmental disturbing factors affect the human work performance at the vessel?

Very much ☐1 ☐2 ☐3 ☐4 ☐5 Very little

2. Automation and human capabilities

1. Which factors challenge or affect decision making and human performance when it comes to the degree of automation (of work tasks for example of the tasks in the control room monitoring programs? Is too much automated, and too little amount of tasks left to humans to perform, or the opposite?) in the “control room”?
2. How frequent does mistakes happened when a person is faced with an unfamiliar situation during SWI operations at the vessel?
3. Is it sometimes uncertainties where and when to focus your attention in the automated part of the system in control center?
4. Have mistakes ever happened due to a person is faced with an environment for which no “know-how” or “rules for control” are available from previous experience?
5. How is the relationship between the demands of the tasks in the “control room”, and the physical and psychological capabilities of the operator?

A. Is the relationship between automated and non-automated tasks in the control center optimal?

Not optimal ☐1 ☐2 ☐3 ☐4 ☐5 Optimal

B. How is the personnel knowledge about the automated part of the system?

Very bad ☐1 ☐2 ☐3 ☐4 ☐5 Very good

C. How do you classify the human-machine (in the “control room”) match/mismatch?

Mismatch ☐1 ☐2 ☐3 ☐4 ☐5 Match

D. Are the control panel functional characteristics, clarity of signals and user friendliness satisfying?

Unsatisfying ☐1 ☐2 ☐3 ☐4 ☐5 Satisfying

3. Procedures, forms and personnel training

1. Are the procedures accurate, clear, detailed and easy enough to use?
2. Have you experienced violation of procedures and rules, or other "risk-taking" personnel behavior which have challenged safe and effective decision making and human performance at the vessel?

A. How satisfying are the number of procedures? Too many vs. too few?

Too many ☐1 ☐2 ☐3 ☐4 ☐5 Too few

B. How is the personnel knowledge about the content and requirements of the procedures?

Very bad ☐1 ☐2 ☐3 ☐4 ☐5 Very good

C. What is the frequency of use of forms when performing a work task?

Too often ☐1 ☐2 ☐3 ☐4 ☐5 Too rare

D. Is there often an overlap between forms/procedures when performing a work task?

Very often ☐1 ☐2 ☐3 ☐4 ☐5 Very rare

E. How satisfying is the personnel training?

Unsatisfying ☐1 ☐2 ☐3 ☐4 ☐5 Satisfying

F. How is the personnel knowledge about the SWI technology and equipment?

Very bad ☐1 ☐2 ☐3 ☐4 ☐5 Very good

G. Are the right skilled and experienced personnel hired?

Shortcomings ☐1 ☐2 ☐3 ☐4 ☐5 Professionals

H. Is the number of employees satisfying?

Unsatisfying ☐1 ☐2 ☐3 ☐4 ☐5 Satisfying

I. How is the resource availability?

Very bad ☐1 ☐2 ☐3 ☐4 ☐5 Very good

J. How is the sharing of experience and knowledge among the personnel at the vessel?

Unsatisfying ☐1 ☐2 ☐3 ☐4 ☐5 Satisfying

4. Management, allocation of responsibility and planning

1. How are the management practices in the decision making processes during SWI? Any challenges?
2. How is the allocation of responsibility at the vessel, and do you see any challenges here?
3. Could another allocation of responsibility between the RLWI personnel at the vessel improve the decision making processes and make human performance more optimal?
4. What organizational and management factors reduce or hinder the humans performance? What are the challenges here?
5. Have you ever experienced decision errors or performance reduction due to poor planning and communication before or during SWI operations? If yes, explain shortly.

A. In the day-to-day work there is no doubt about who is responsible for the different tasks.

Disagree ☐1 ☐2 ☐3 ☐4 ☐5 Agree

B. Is there a problem with concurrent plans (the holding of more than one plan or intention at once) during RLWI?

Very often ☐1 ☐2 ☐3 ☐4 ☐5 Very rare

C. Are there ever tendencies to use plans or rules which have worked before during RLWI, but which may not be useful in the present situation?

Very often ☐1 ☐2 ☐3 ☐4 ☐5 Very rare

D. How do you evaluate the complexity of the managers work tasks?

Too complex ☐1 ☐2 ☐3 ☐4 ☐5 Too simple

E. How effective are the communication and cooperation between the managers?

Ineffective ☐1 ☐2 ☐3 ☐4 ☐5 Effective

F. How effective are the communication and cooperation between the operators?

Ineffective ☐1 ☐2 ☐3 ☐4 ☐5 Effective

G. How effective are the communication and cooperation between the managers and operators?

Ineffective ☐1 ☐2 ☐3 ☐4 ☐5 Effective

5. Personnel behavior and safety

1. Have you experienced human failures, work performance reduction or unsatisfying decision making attributed to attitude and motivational causes? If yes, explain shortly.
2. Have you ever experienced intentional violations or routine violations attributed to attitude and motivational causes? If yes, explain shortly.
3. Have you ever experienced mismatch between mental and physical capabilities of people and the demand of the job performed? If yes, explain shortly.
4. Is there a frequency of slips and lapses types of errors occurring when a skilled person are performing a familiar task during SWI? If yes, explain shortly.
5. Have you ever experienced "absentminded behavior" leading to slips of action or memory lapses during SWI? If yes, explain shortly.
6. Have you ever experienced any decision making and work performance "corner cuttings" attributed to safety attitudes, beliefs, risk-taking behavior, conflict or motivation? If yes, explain shortly.

A. How do you evaluate the complexity of the operators work tasks at the control panel?

Too complex ☐1 ☐2 ☐3 ☐4 ☐5 Too simple

B. How do you evaluate the complexity of the operators work tasks performing SWI operations?

Too complex ☐1 ☐2 ☐3 ☐4 ☐5 Too simple

C. How is the time pressure during SWI operations?

Very often ☐1 ☐2 ☐3 ☐4 ☐5 Very rare

D. How is the workload level during SWI operations?

Too much ☐1 ☐2 ☐3 ☐4 ☐5 Too little

6. Information processing

1. Is there sometimes a tendency of "information overload", which have led to reduced human performance or poor/confusing decision making?
2. Have you ever experienced attention errors due to human information processing issues of great amounts of information provided at the same time?

A. Is the right amount of information presented to the managers during SWI?

Too much ☐1 ☐2 ☐3 ☐4 ☐5 Too little

B. Is the right amount of information presented to the operators in the control center during SWI?

Too much ☐1 ☐2 ☐3 ☐4 ☐5 Too little

C. Has there been a tendency to use familiar solutions when performing a task even when these are not the most convenient or efficient?

Very often ☐1 ☐2 ☐3 ☐4 ☐5 Very rare

7. Team work

1. How is the group dynamics, relationships, cooperation and team work at the vessel during SWI?
2. How do the decision makers communicate any operational decision to the rest of the SWI team?
3. Do you normally work with the same team members within your working area / working group, or does it vary?
4. Is the working environment on board characterized by openness and dialog?

A. How are the relationships and cooperation among different “social groups” or teams?

Very bad ☐1 ☐2 ☐3 ☐4 ☐5 Very good

B. How do you evaluate the complexity of the teams work tasks?

Too complex ☐1 ☐2 ☐3 ☐4 ☐5 Too simple

C. Do the teams solve problems and conflicts in a good manner?

Very bad ☐1 ☐2 ☐3 ☐4 ☐5 Very good

D. Are the existing team structures optimal to execute safe and acceptable decision making?

Not optimal ☐1 ☐2 ☐3 ☐4 ☐5 Optimal

E. Are the existing team structures optimal to achieve acceptable work performance?

Not optimal ☐1 ☐2 ☐3 ☐4 ☐5 Optimal

F. Is it difficult for the teams to share the same situation awareness during RLWI-operations?

Difficult ☐1 ☐2 ☐3 ☐4 ☐5 Easy

Other Suggestions or Comments____