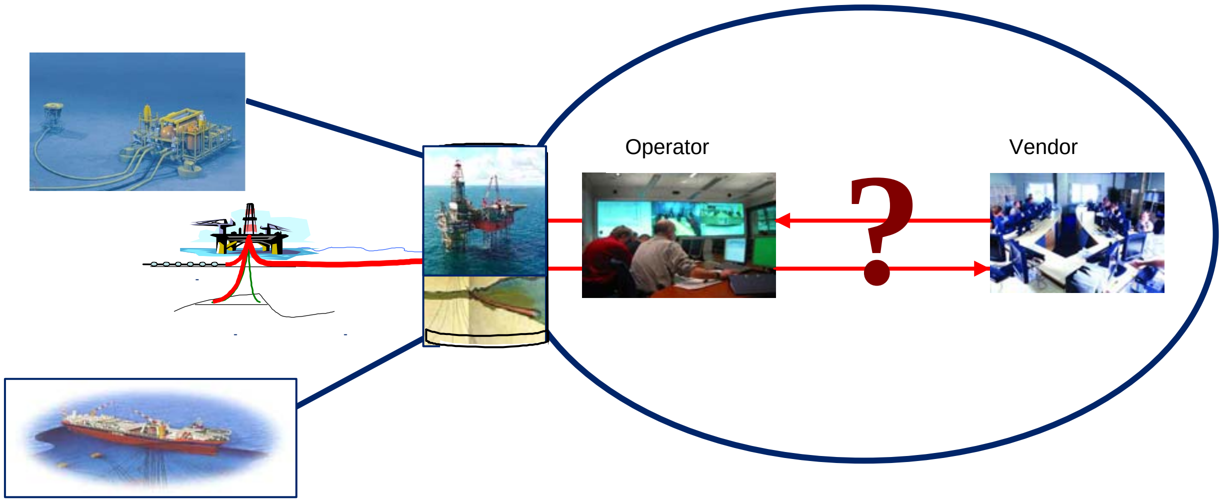

Improving Safety through Integrated Operations

MSc thesis in Safety, Health and Environment (HSE)

Spring 2006

Written in co-operation with Statoil

By

stud. techn. Siri Andersen

NTNU

Faculty of Social Sciences and Technology Management
Department of Industrial Economics and Technology Management

STATOIL

Illustration on front cover inspired by OLF (shown in Hepsø 2006)

Norges teknisk-naturvitenskapelige universitet
NTNU

Fakultet for samfunnsvitenskap og teknologiledelse

Institutt for industriell økonomi og teknologiledelse

MASTEROPPGAVE

for

STUD.TECHN. Siri Andersen

Fagområde	Helse, miljø og sikkerhet (Health, Safety and Environment)
Utleveringsdato	15.januar 2006 9. juni 2006
Tittel	Økt sikkerhet ved Integrerte Operasjoner (Leveraging safety through Integrated Operations)
Formål	Overgang til bruk av integrerte operasjoner (IO) innebærer nye måter å organisere og utføre arbeidet på, både offshore og onshore. Denne oppgaven har til hensikt å undersøke hvordan bruk av integrerte operasjoner virker inn på sikkerhetsmessige forhold i olje og gassektoren.

Følgende hovedpunkter skal behandles:

1. Kartlegge status/erfaringer med bruk av IO så langt i olje og gassindustrien.
2. Undersøke om det er områder som er spesielt utsatte ut fra et sikkerhetsperspektiv ved innføring av IO.
3. Undersøke om bruk av tjenesteutsetting kan ha positive sikkerhetsmessige effekter ved bruk av IO.
4. Identifisere områder det i dag er mangler ved eller som trenger ekstra oppmerksomhet.
5. Komme med anbefalinger og innspill for bruk av IO, deriblant mot CRIOP.

Organisering:

Masteroppgaven utføres i samarbeid med Statoil.
Veileder er Stig Ole Johnsen, SINTEF Teknologiledelse, Sikkerhet og Pålitelighet
Kontaktpersoner hos Statoil er Dag Sjong og Vidar Hepsø

Olav Fagerlid
prodekan

Jan Hovden
faglærer

DECLARATION

Stud.techn. Siri Andersen
Institute of Industrial Economy and Technology Management

I hereby declare that I have written the above mentioned
thesis without any kind of illegal assistance

Trondheim — Place

16.06.2006 — Date

Siri Andersen
Signature

Preface

This master thesis is written at the Department of Industrial Economics and Technology Management at NTNU and concludes my masters degree with specialization in health, safety and environment, HSE. It has been written in co-operation with Statoil which have provided access to necessary resources. The main objective with this thesis has been to explore how use of integrated operations (IO) affects safety related conditions in the oil and gas industry and how to improve safety in IO. The thesis' objective and delimitations is based on my own interests and made in cooperation with my supervisors at Statoil, Sintef and NTNU.

Several persons have been involved in this project with guidance, advice and professional knowledge, and I am very grateful for all help and support given. I would like to thank my teaching supervisor Stig Ole Johnsen at SINTEF for contributing with professional guidance, motivation and feedback. I would also like to thank my supervisors at Statoil, Dag Sjong and Vidar Hepsø, for support and advice on the thesis, as well as help with getting in contact with persons in Statoil. I would also like to thank my tutor, Professor Jan Hovden, who has contributed to the thesis with professional knowledge and constructive criticism.

Last I would like to thank all the informants which have contributed to the interviews. Without their involvement and contribution it would not have been possible to carry out this project.

I would also like to credit Statoil for their open-minded approach to my research problem, my choice of research methods, to my discussions and to my findings.

Trondheim, June 23, 2006

Siri Andersen

Abstract

The purpose of this study is to investigate how use of integrated operations (IO) affects safety related conditions in the oil and gas industry. IO has several meanings and covers many aspects in the industry. In this thesis IO is related to cooperation in and between control rooms. The focus is on cooperation across distance involving vendors. A case study is made about Snøhvit and cooperation with ABBs control room ARMOR (ABB Remote Monitoring & Operations Room). The main focus of the thesis is on safety aspects related to cooperation and collaboration between STATOIL and ABB, but general findings for the industry regarding cooperation and safety in IO are also given. The methodology used is qualitative literature studies and in-depth interviews.

The first research question is 'how does use of IO affect the level of safety?' This question is complex to answer. Many aspects related to man, technology, and organisation (MTO), has to be addressed. The focus area in this thesis i.e. cooperation with vendors, is just a small part of the total picture.

An interesting topic is that safety has not been stated as an initial specified goal in IO. It has rather been seen as an added benefit of IO. If possibilities to improve safety when implementing IO are not integrated in all activities from the start, IO may not influence safety or influence safety negatively. Increased safety should be one of the main goals of IO implementation. A mapping of threats and possibilities to safety in IO i.e. vendor cooperation, is not done and at present most focus is placed on technological aspects. My assessment is that the level of safety is dependent on the how much the industry is focusing on safety. A focus on safety would lead to increased safety while an implementation process without due focus on safety would led to decreased safety. Because of low focus in man and organisation it is probable that IO will affect safety negatively according to these, and I therefore recommend that much effort is devoted to them.

An interesting question is how to improve safety in IO. This is answered in the second research question, 'how can IO improve the level of safety in the oil and gas industry?' First of all elements in High Reliability Organisations (HRO) is lacking in STATOIL related to the implementation of IO, both in general and at Snøhvit. HRO is a designation of organisations which manage to stay stabile and avoid major accidents even though they operate in a

complex environment where deviations can crate serious consequences. They have organisational redundancy and are able to spontaneously reconfigure the organisation. In IO there are weaknesses both in organisational redundancy and in ability to spontaneously reconfigure the organisation. IO in the oil and gas industry is characterized by complex processes and operations. Trying to establish some sort of an HRO would be an important step to be able to avoid accidents and gaining safety in operation. To correct shortcomings in HRO I recommend focusing on aspects in worker involvement, cooperation and interfaces and aspects in routines and procedures.

From an MTO perspective, safety aspects in technology (T) are well taken care of, while safety aspects to man and organisation (MO) is lacking, especially for Snøhvit and cooperation with ARMOR. Accidents however happen because of shortages in all three elements, and aspects to M and O should therefore be analysed as soon as possible. Also important mutual influences between the elements in MTO should be mapped, e.g. solutions for communicating may not be utilized fully because of lack in trust. This would help in understanding and take care of the most critical threats to safety. Aspects to all elements of MTO were considered through a Human Factors (HF) analysis and one CRIOP (Crisis Intervention in Offshore Production) analysis of the control room *at* Snøhvit, but cooperation with ARMOR was not considered. One highly important part of IO i.e cooperation with vendors, was therefore left out. CRIOP is an important tool for validating and verifying that safety is taken care of in control rooms according to all elements in MTO. It is recommended that another CRIOP analysis is made as soon as possible. This CRIOP analysis should consider both control rooms (ARMOR and at Snøhvit) and the e-operation checklist should be used. Statoil should also notify and recommend ABB to use CRIOP in ARMOR.
CRIOP is an important analysis tool in assuring safety in IO. CRIOP and the e-operation checklist may have some shortcomings in ability to handle every aspect of cooperation but it also has a lot of positive and good elements, making it important that the industry start using it. Also the timing of CRIOP is important. CRIOP analyses should be made both early in the process to be able to correct faults and later in the process to verify that the end design actually are good.

In general HF analyses need to be performed earlier in projects. It is often observed that these analyses are made to late in the design process and that it therefore is difficult to get acceptance for changes in control room design. By doing such analyses late in the process it is costly to make changes and it may be difficult to get understanding of why the changes are necessary although the changes may be important to safety and reliability. Making such analyses early in the process is therefore recommended, to be able to get optimal design regarding all aspects of MTO.

A general shortage was found in lack of practice to report incidents caused by errors in work and cooperation in control rooms. Because of this shortcoming in reporting culture, the control room operators are missing an important possibility to evaluate consequences, learn by experience and make improvements of their actions. Therefore experience transfer and organisational learning in IO is insufficient. Organisational learning is more characterized as single loop learning while it should be characterized as double loop learning. Another similar aspect is that experience transfer from project to operation and between projects was found insufficient and should be improved. Experience transfer, as prescribed in PROMIS (Project Model in Statoil), were usually not accomplished. With this shortage important possibilities for continuous improvement are lost.

Experiences from other fields in Statoil showed that it is essential to implement work processes early and in parallel with technological solutions to gain good results in cooperation and use of control rooms. Still there is low focus on developing work processes early and across control rooms, also at Snøhvit. It is therefore highly recommended that work procedures and work practice for ARMOR and Snøhvit is developed now. Early development (and change) of work processes should be part of all control room projects in Statoil.

Sammendrag

Oppgavens formal har vært å undersøke hvordan bruk av integrerte operasjoner (IO) påvirker sikkerhetsmessige forhold i olje- og gassektoren. IO har mange betydninger og dekker mange aspekter i industrien. I denne oppgaven er IO relatert til samhandling mellom kontrollrom, og fokuset er på samhandling over avstand der leverandører er involverer. Et case studium ble gjennomført av Snøhvit og samhandling med ABBs kontrollrom ARMOR (ABB Remote Monitoring & Operations Room). De to kontrollrommene ligger henholdsvis i Hammerfest og Bergen. Hovedfokus ligger på sikkerhetsaspekter relatert til samhandling og samarbeid mellom Statoil og ABB, men generelle funn for industrien om samhandling og sikkerhet i IO blir også gitt.

Det første forskningsspørsmålet er ”hvordan påvirker bruk av IO sikkerheten?” Dette spørsmålet er kompleks å svare på. Mange aspekter relatert til menneske, teknologi og organisasjon (MTO) må identifiseres og undersøkes. Fokusområdet i denne oppgaven, samhandling over avstand, er bare en liten del av det totale bildet.

Et interessant funn i rapporten er at sikkerhet ikke har vært et spesifisert mål i IO. Økt sikkerhet blir heller betraktet som et tilleggsresultat av IO. Dersom muligheter til å forbedre sikkerheten i IO ikke er en integrert aktivitet fra starten av, vil sannsynligvis ikke IO påvirke sikkerheten i det hele tatt, eller påvirke sikkerheten negativt. Økt sikkerhet må være et av målene i arbeidet med IO. Kartlegging av sikkerhetsmessige trusler og muligheter i IO (leverandørsamarbeid) er ikke gjort, og på nåværende tidspunkt er det mest fokus plassert på teknologiske aspekter. Min vurdering er at sikkerhetsnivået er avhengig av hvor mye industrien fokuserer på sikkerhet. Et fokus på sikkerhet vil føre til økt sikkerhet, mens en prosess uten nok fokus på sikkerhet vil føre til redusert sikkerhet. På grunn av lavt fokus på menneske og organisasjon er det sannsynlig at IO vil påvirke sikkerheten negativt i disse, og jeg anbefaler derfor at mer ressurser blir plassert på barrierer relatert til disse to.

Et interessant spørsmål er hvordan IO kan forbedre sikkerheten. Dette blir besvart i det andre forskningsspørsmålet “Hvordan kan IO forbedre sikkerheten I olje- og gassindustrien?” For det første er det mangler ved alle elementer i High Reliability Organisations (HRO) relatert til innføringen av IO, både generelt og på Snøhvit. HRO er en beskrivelse av organisasjoner som klarer å opprettholde nesten feilfri drift selv om de operer i svært kompliserte omgivelser der det benyttes krevende teknologi. Slike organisasjoner er karakterisert ved organisatorisk

redundans og tilpasningsdyktighet i uventede situasjoner. I IO er det svakheter i både organisatorisk redundans og tilpasningsdyktighet, samtidig som IO i olje- og gassektoren er karakterisert av komplekse prosesser og operasjoner. Å etablere forutsetninger for HRO i IO vil derfor være et viktig steg til å kunne unngå ulykker og oppnå sikkerhet i driften.

Fra et MTO perspektiv er sikkerhetsaspekter til teknologi (T) godt tatt vare på, mens aspekter til menneske og organisasjon (MO) er manglende. Spesielt for Snøhvit og samarbeid med ARMOR. Ulykker oppstår likevel på grunn av alle de tre elementene, og de bør derfor bli analysert så snart som mulig. Dette gjelder også gjensidig påvirkning mellom alle elementene i MTO, for eksempel kan løsninger for kommunikasjon bli dårlig utnyttet på grunn av dårlig tillit. En kartlegging av slike avhengigheter ville hjelpe til med å forstå og håndtere kritiske trusler for sikkerheten. Aspekter til alle elementene i MTO ble vurdert gjennom en Human Factors (HF) analyse og en CRIOP (Crisis Intervention in Offshore Production) analyse av kontrollrommet på Snøhvit, men samarbeidet med ARMOR ble ikke tatt med. Et viktig aspekt ved IO, samarbeid med leverandører, ble derfor utelatt. CRIOP er et viktig verktøy for å verifisere og validere at sikkerheten i kontrollrom, i henhold til alle elementene i MTO, er ivaretatt. Det anbefales derfor at en ny CRIOP blir gjennomført så snart som mulig. Denne CRIOPen må inkludere begge kontrollrommene, bade ARMOR og Snøhvit. Det er også viktig at e-driftsjekklista blir brukt. Statoil bør også anbefale ABB og bruke CRIOP i ARMOR.

CRIOP er et viktig verktøy for å vurdere sikkerhet IO. Den kan ha noen mangler med tanke på å håndtere alle aspekter ved samhandling, men den har også mange gode elementer. Det er derfor viktig at industrien bruker den i IO sammenheng. Tidspunkt for utførelse av CRIOP er sentralt. Metodikken bør brukes tidlig i designprosessen at det er mulig å forbedre mangler, men også senere i prosessen slik at sluttdesignet med alle elementer blir vurdert.

Generelt må HF analyser utføres tidligere i prosjekter enn det som er vanlig i dag. Det er ofte observert at disse analysene blir gjennomført så sent i prosessen at det er vanskelig å få aksept for endringer i designet. Ved å gjennomføre slike analyser sent i prosessen er det kostbart å gjennomføre endringer og det kan være vanskelig å få forståelse for hvorfor endringene er nødvendige, selv om endringene er viktige for sikkerhet og pålitelighet. For å få optimalt design med tanke på alle aspekter i MTO anbefales det derfor at slike analyser gjennomføres tidlig i designprosessen.

En generell mangel ble funnet i mangel på praksis med å registrere og rapportere hendelser der arbeid i kontrollsentralen eller kontrollromsoperatøren er involvert. På grunn av denne mangelen i rapporteringskultur mister kontrollromsoperatøren en viktig mulighet til å reflektere over konsekvenser, lære og forbedre handlinger. Dermed blir også erfaringsoverføring og organisatorisk læring i IO mangelfull. Organisatorisk læring er mer karakterisert som single-loop lærning, mens den bør være kjennetegnet av double-loop lærning. Et annet liknende aspekt var at erfaringsoverføring fra prosjekt til drift og mellom prosjekter ofte var dårlig. Disse funnene tilsier at viktige muligheter for kontinuerlig forbedring uteblir.

Erfaringer fra andre felt i Statoil viste at det er viktig å implementere arbeidsprosedyrer tidlig og i parallell med teknologiske løsninger for å oppnå gode resultater i bruk av kontrollrom og samhandling. Likevel er det ofte lavt fokus på å utvikle arbeidsprosedyrer tidlig, også på Snøhvit. Det er derfor en sterk anbefaling at arbeidsprosedyrer og praksis for ARMOR og Snøhvit blir utviklet nå. Tidlig utvikling (og endring) av arbeidsprosedyrer bør inkluderes i alle kontrollromsprosjekt i Statoil.

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Abbreviations and Definitions

Abbreviations

ARMOR	ABB Remote Monitoring & Operations Room
CRM	Crew Resource Management
HF	Human Factors
HNO	Halten Nordland
HRO	High reliability organisations
ICT	Information and Communication Technology
IO	Integrated Operations
IWC	Integrated Work Processes
LNG	Liquid Natural Gas
MTO	Man, Technology and Organisation
NCS	Norwegian Continental Shelf
NPD	Norwegian Petroleum Directorate
OLF	Norwegian Oil Industry Association
PROMIS	Project Model in Statoil
PSA	Petroleum Safety Authority Norway
PUFF	Planlegge, Utføre, Følge opp, Forbedre
R&D	Research and Development
RIR	Recordable Incident Rate
RUH	Rapport Uønsket Hendelse
SJA	Safety Job Analysis

Definitions

Verification:	To satisfy stated requirements. Confirmation by examination and provision of objective evidence, that the requirements have been fulfilled. (ISO 8402, IEC 61508). Requirements can be statutory, company defined, in relation to standards and/or contractual (Johnsen et.al 2004).
Validation:	To satisfy implied needs, i.e. that the control room is usable. Confirmation by examination and provision of objective evidence, that the particular requirements for a specific intended use are fulfilled (ISO 8402, IEC 61508).
Safety Culture:	The safety culture of an organisation is the product of individual and group values, attitudes, perceptions, competencies and patterns of behaviour that determine commitment to, and the style and proficiency of, an organisation's health and safety management'. (From Advisory Committee for Safety on Nuclear Installations-93)
Concurrent design/ Engineering:	Working and developing products in parallel processes. Concurrent engineering replaces the traditional development process with one in which tasks are done in parallel. It embodies team values of co-operation, trust and sharing of information and efforts. Decisions in are made in consensus and involving all perspectives in parallel. Operators are part of a collaborative, collective and simultaneous environment.
IO:	Integrated operations are about making effective use of new technology, ICT solutions and real time data to optimize operation. It is also about making use of new work processes and practices to achieve higher efficiency. This development make people in organisations or companies, even though they are separated physically and/or geographically, able to work closer, cooperate and use each others knowledge more effective in solving problems and doing their daily work.

Part one: Introduction

1 Objective

This chapter describes the research problem with goals and questions to be answered in the study. It also describes the scope and delimitations, mainly through a case study description and a definition of IO. Last some background material is given. The background is described through present perspectives of IO in the oil and gas industry, how IO is used and expected development of IO.

1.1 Research Problem

The technological development has important impact on the oil and gas industry. The traditional split of work tasks between people onshore and offshore is not quite as obvious anymore. New technological solutions, especially in information and communication technology (ICT) and real time data, make it possible to restructure the operation of oil and gas fields. It is these possibilities that give the foundation for integrated operations (IO). Use of integrated operations in the oil and gas industry can be implemented in various ways. In short, integrated operations make it possible to have better utilization of the cooperation between the oil and gas fields offshore and the organisations onshore. Technological solutions make planning and operations more effective. It is also possible to monitor, run or control the processes offshore from a central place onshore. Thereby new aspects when it comes to challenges with safety arise. It is with these elements in mind the work with this report is structured.

The purpose of the task, given in the task specification, is as follows:

Transition to use of integrated operations (IO) imply new ways of organizing and carry out work, both offshore and onshore. The purpose of this task is to investigate how use of integrated operations affects safety related conditions in the oil and gas industry.

As the title of the report, ‘Improving Safety through Integrated Operations’, says, it is also a goal to explore if integrated operations can enhance the level of safety in the oil and gas industry.

The task is covering the following main points:

1. Map the status/experiences with use of IO this far in the oil and gas industry.
2. Investigate if there are areas that are negatively exposed from a safety related perspective when IO is introduced.
3. Investigate if outsourcing to vendors can have positive effect on safety when IO is used.
4. Identify areas that have shortcomings or needs extra attention.
5. Give suggestions and recommendations for improvement when IO is used, among other things towards CRIOP.

1.1.1 Research Questions

To specify and structure the work the following research questions are made:

R1. How does use of IO affect the level of safety?

R2. How can IO improve the level of safety in the oil and gas industry?

Research question two is partly based on the results in research question one. The answers to question one therefore has to be given before answering question two.

In the previous section some main points about elements to be covered in the report were given. These elements are covered by the two research questions the following way: Element 1 ‘Map the status/experiences with use of IO this far in the oil and gas industry’ is covered in the thesis background material. Element 2 ‘Investigate if there are areas that are negatively exposed from a safety related perspective when IO is introduced’ is answered both in R1 and R2. Element 3 ‘Investigate if outsourcing to vendors may have positive effect on safety when IO is used’ is answered in R2. Element 4 ‘Identify areas that have shortcomings or needs extra attention’ is answered both in R1 and R2. And last, element 5 ‘Give suggestions and recommendations for improvement when IO is used, among other things towards CRIOP’ is answered in R2. Chapter 6.4 gives a discussion about how the thesis answers the main elements above.

1.2 Scope and Delimitation

This chapter describes what to be included in the study and what the delimitations are. Because the concept of IO has several meanings in the industry, an important delimitation in is a description of the interpretation of IO in this thesis. Then a description of the focus area in the thesis is given, telling both about the thesis scope but also about delimitations in the study. Case studies is a way of delimiting research projects (Tjora, 2005), and in this thesis a case study about Snøhvit is made. The case study description in this chapter describes important areas of IO to be included in the research, and also what is left out. Another thesis about safety in IO was made in parallel with this thesis. A description of the relations and differences between them is therefore given. Last, elements used in recommendations and suggestions are described to explain important prerequisites for making improvement suggestions.

1.2.1 The Term Integrated Operations

The data acquisition shows that the term integrated operation (IO) actually has several definitions and meanings in the industry. IO is defined differently by many actors and reports, but the most interesting is what people in the industry actually *think* it means. During the interviews several meanings were found. The most often found elements in the term were:

- IO represents a focus on technology and how technology can be used to operate oil and gas fields in new and more effective ways.
- How personnel work and make decisions more integrated, both personnel in the same company but also personnel from different companies. This integration implies better cooperation.
- Integration of people by use of ICT solutions. ICT is used to make it possible for people geographically dispersed to cooperate.
- To bring technology and work processes together independent of time and place.
- People with diverse backgrounds located at different geographical places who work together in solving problems.

- New ways of doing maintenance and operation. Integration of work processes between offshore and onshore and between organisations.
- New technological solutions and new ICT solutions which make it possible to share real time data.
- Remote controlling of installations, either by persons, technology or a combination of both.

The above points are focusing on quite different elements in IO. An interesting observation was that people normally were focusing on only one of them and not a mix of views. This shows that there are many ways of defining and thinking about IO in the oil and gas industry. It is not the scope of this thesis to define the term IO, but a definition of the meaning in this report is necessary. To make a common understanding of the meaning of IO in this report an explanation of the term is given as follows:

Integrated operations are about making effective use of new technology, ICT solutions and real time data to optimize operation. It is also about making use of new work processes and practices to achieve higher efficiency. This development makes people in organisations or companies, even though they are separated physically and/or geographically, able to work closer, cooperate and use each others knowledge more effective in solving problems and doing their daily work.

IO is a complex concept and more than ‘just’ technology. Independent of geography, IO implies sharing of real time data, use of appropriate resources, faster and better decisions, good technological solutions, integration of people, development of new competencies, development of data and tools, adjusted work processes, good practices etcetera.

1.2.2 Focus Area

To delimit the research a specific case study is chosen. The purpose of the case study is to gain insight into the general problem, safety perspectives in IO, but the particular case and its characteristics are also of interest. This is a combination of what Stake (1994) calls instrumental and intrinsic cases studies[1]. A further delimitation is that focus is placed on operation and maintenance.

Case Study: Vendor cooperation at Snøhvit

The case study is based on the cooperation between Statoil and ABB towards the installations at Snøhvit, located on Melkøya outside Hammerfest. Snøhvit is landing, producing and exporting Liquid Natural Gas (LNG) from the fields Snøhvit, Albatross and Askeladd, see figure1.

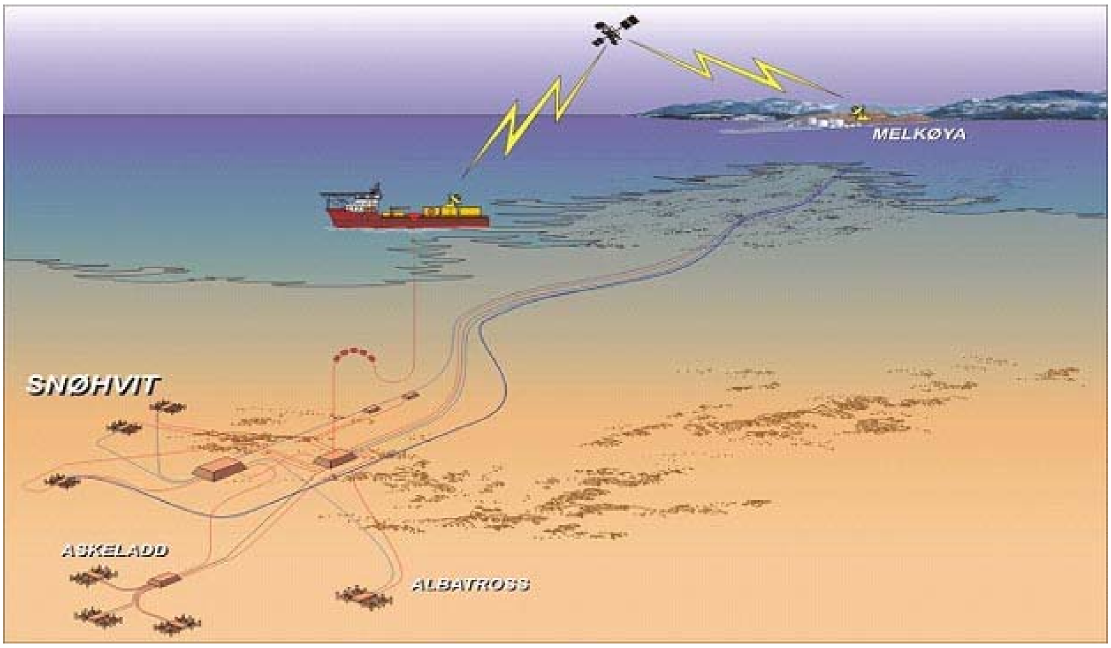

Figure 1: The Snøhvit fields and installations (retrieved from www.statoil.com)

Snøhvit is Europe's first export facility for LNG and it is the first major development on the Norwegian continental shelf with no surface installations and no floating units at sea. Instead sub sea production facilities will stand on the seabed, and gas transported to shore through pipelines. All installations at the Snøhvit field are subsea, which means that no part of the development is visible at the surface.

[1] Intrinsic case study: a study is undertaken because one wants better understanding of this particular case. The case in it self is of interest. Instrumental case study: a particular case is examined to provide insight into an issue or theory. The case plays a supportive role, facilitating our understanding of something else.

The control room is located onshore on Melkøya. From this room operators will control and operate the offshore installations. The control room are handling remotely-operated subsea installations and pipeline transport to shore. Remote communication with the subsea installations is by fibre optic cables.
Snøhvit is still in the project phase. Construction started in the first half of 2002, and operation and delivery is supposed to start in second half of 2007.

To support daily operations at Snøhvit, ABB is building their own control room, the ABB Remote Monitoring & Operations Room (ARMOR), at Kårstø close to Bergen. From this room they can monitor and work on the installations at Snøhvit. Many tasks and responsibilities are supposed to be placed on the contractor (ABB). New to this situation is that the contractor, the same time as being located geographically far away and not in the same building as the operator (Statoil), still has direct access to the systems and installations at Snøhvit. ***This is a new way of collaborating with vendors, and it is this collaboration that is the scope of the study. The study is delimited to a focus on integration of people in different companies and control rooms that may be geographically dispersed. This integration is made possible through technological solutions, suitable organisational structures and human factors***.

Figure 2 gives an overview of the focus area:

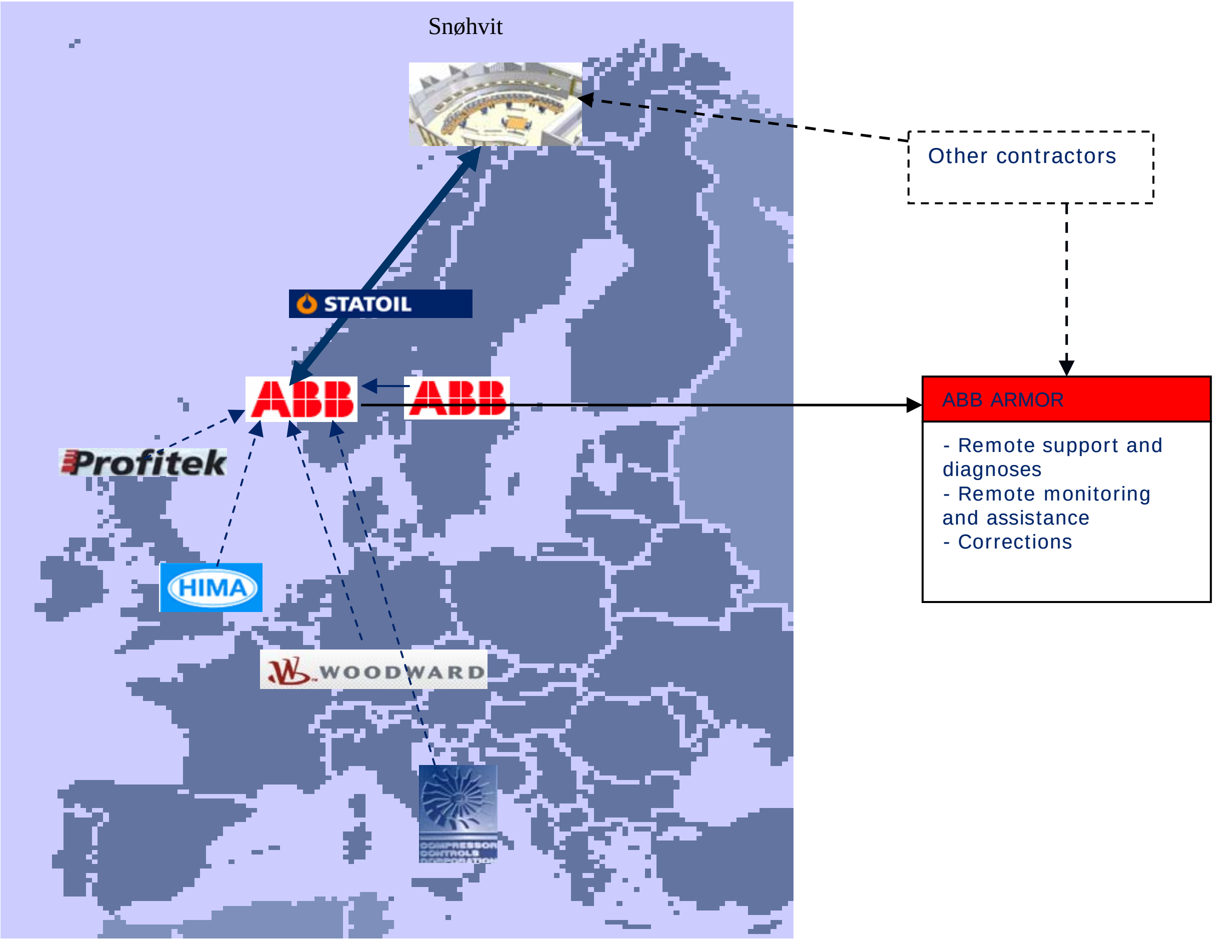

Figure 2: Focus area (adapted from internal Statoil presentation about IO)

The thick arrow in the figure represents the collaboration between Statoil and ABB. As the figure indicates other contractors may be connected to ABB and work towards Snøhvit through ARMOR. Up to this point there are however no such contractors. ABB is the only actor using ARMOR and Statoil is the only client served by it. However ABB sees this as an opportunity in the future. With Statoils approval ABB would like to take full responsibility for some contractors and let them work towards Snøhvit through ARMOR. The safety and security are then taken care of by ABB. This would bring even new perspectives into the picture of safety in IO. Since this is not yet an actual situation, real data can not be collected and this is not a topic in the study.

Figure 2 also shows ABBs tasks and responsibilities. They are supposed to:

- Give remote support and make diagnoses.
- Do remote monitoring and assistance
- Make corrections

- Handle everything related to the control systems/network (servers, controllers, I/O-cards etc.)
- Make updates on the control network (patching, updates, virus protection, backup routines etc.)

From ARMOR ABB is able to communicate directly into the systems they are responsible for at Snøhvit. Figure 3 gives an overview of these systems.

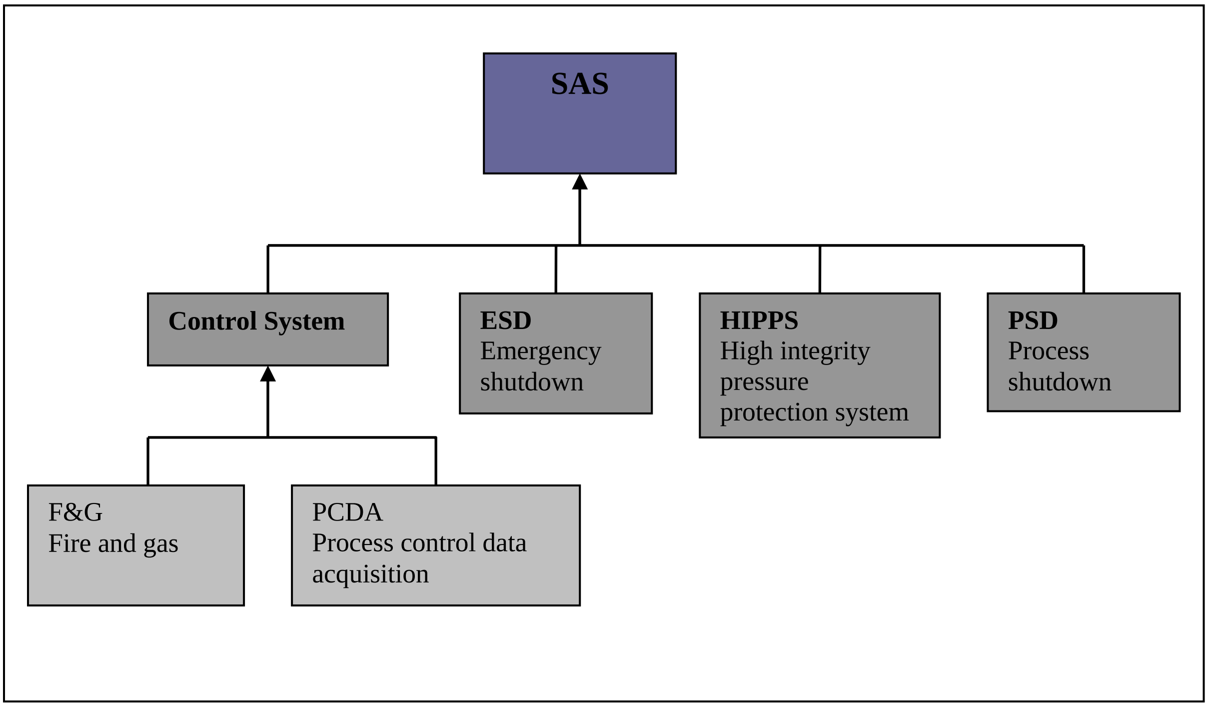

Figure 3: The systems ABB is responsible for

ABB is delivering and is responsible for the control systems whitch is the system controlling the processes. It consists of Process Control Data Acquisition (PCDA) and Fire and Gas (F&G). In addition they are responsible for the Emergency Shutdown (ESD), Process Shutdown (PSD) and High Integrity Pressure Protection System (HIPPS). These systems together make the total SAS for which ABB is responsible.

Even though it is possible to update and make changes on the control system from ARMOR it is ABB personnel at site who is responsible for what is actually done. Before ABB can work on the systems, either from ARMOR or Snøhvit, ABB needs a work permit from Statoil. ABB also needs a check on the work permit and a Safety Job Analysis (SJA) from Snøhvit before they can enter and work on the systems at Snøhvit. Time schedule for doing routine work is also predefined by Statoil (Snøhvit).

In ARMOR integrated team work is possible. Video conference and video session is on and available at all time. It will be direct and real time contact between ARMOR and the control room at Snøhvit.

One of the delimitations of this report is to investigate IO in operation and maintenance. In the case of Snøhvit these phases are however not yet started. To be able to make evaluations and suggestions about IO in the operation and maintenance phases another field, Halten Nordland (HNO), is chosen as reference point.

Integrated operations in Halten Nordland (HNO):

As mentioned, HNO is used as a refrence point. The land organizations of the fields at HNO are mostly located at Stjørdal. Here IO is used daily and the centers at Stjørdal work towards the platforms Åsgard, Heidrun, Kristin and Norne. At Stjørdal there are several centers, both Operation Support Rooms (OPS) and one Onshore Support Centre (OSC). There are OPS for all the mentioned platforms, Heidrun, Åsgard, Kristin and Norne. They are all in daily use but have some differences in solutions and extension of use. Kristin and Åsgard have regular support from their onshore centers while the personnel at Heidrun use the room and equipment only when needed. At Kristin the personnel offshore are located in a room similar to the one onshore. The OSC are only used in the area of drilling. There are no personnel from vendors located in the rooms at Stjørdal.

Case Study Relations between HNO and Snøhvit:

Even though IO is used at HNO, it is not used the same way as on Snøhvit. The main difference between HNO and Snøhvit is that HNO are having manned offshore installations and cooperation is between control rooms *in* Statoil. At Snøhvit on the other hand, there are unmanned subsea installations, and cooperation is between control rooms in Statoil and the vendor (ABB). Vendors are given more direct responsibility for tasks and they are a more direct part of the collaboration and operation. Even though IO is used at HNO it is not used the same way as on Snøhvit. Adjustments to the findings in HNO therefore have to be made.

The similarities between HNO and Snøhvit are that they both use some sort of control rooms and personnel in different locations are collaborating in finding solutions to daily operation and problems. Interesting IO elements for Snøhvit that can be found in HNO are:

- Elements in the project of implementing IO at Stjørdal that have resulted in problems in the operation phase
- Experience transfer between projects
- Problems and safety critical elements with work in control room

The two first points can be illustrated as in figure 4:

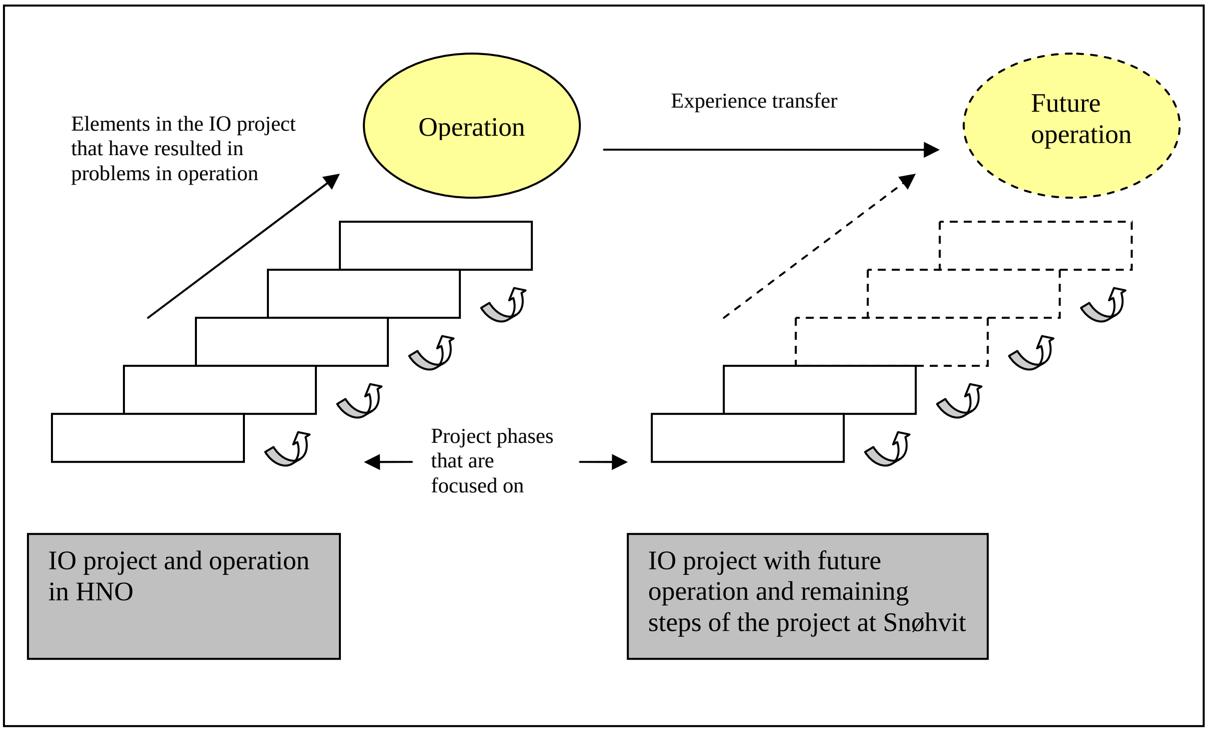

Figure 4: Relevant relations in the study between HNO and Snøhvit

The figure illustrates the projects of implementing IO at Snøhvit and HNO. At Stjørdal the project phase is finished and operation has started. At Snøhvit the project phase is still going on. It is interesting to explore if there are elements in the project phases at HNO that have resulted in problems in operation, elements important for Snøhvit too. Experience transfers between projects are also interesting, and examples of safety critical incidents related to the control rooms at Stjørdal. The project phases illustrated in figure 4 are given in a standard model for all projects in Statoil called Project Model in Statoil (PROMIS). This model is illustrated in figure 5:

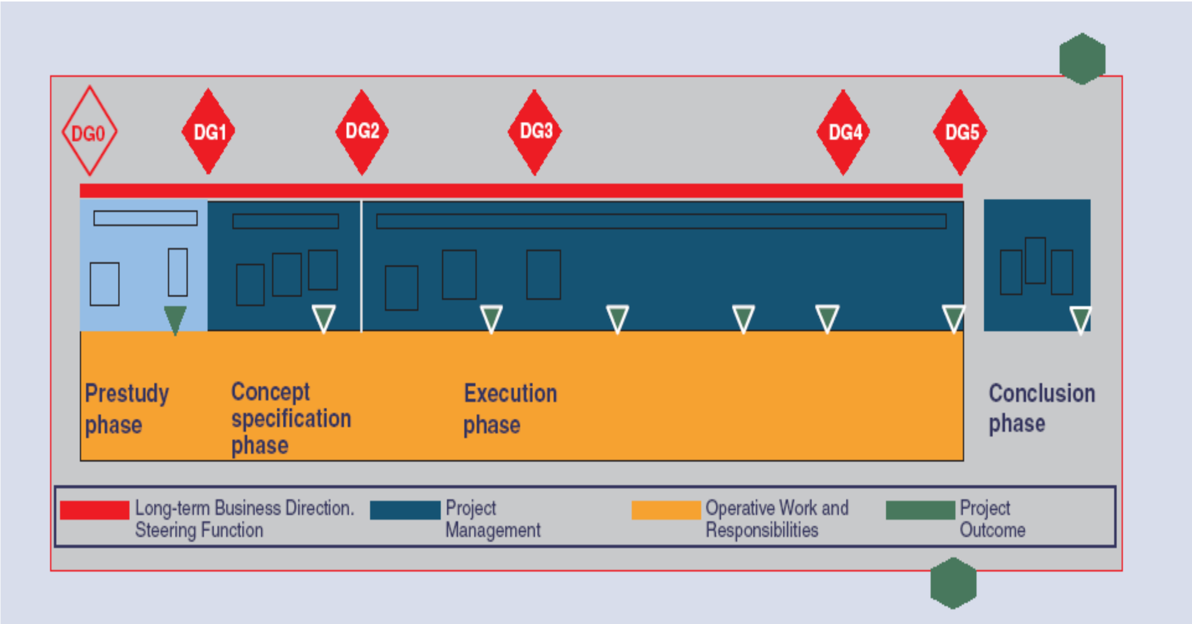

Figure 5: PROMIS -Project Model in Statoil. (Retrieved from Statoil's internal web pages)

<u>The decision gates represent the following</u>:

DG0: Start of pre-study

DG1: Start of project concept and specification study

DG2: Start execution of the project

DG3: Continued execution according to original or revised plan

DG4: Start of hand over of the project outcome to the receiver and the customer

DG5: Project outcome accepted, start of project conclusion

1.2.3 Relations with a similar master thesis

In parallel with this thesis another similar thesis ‘New Work Processes through IO in Statoil – Function Allocation by Trial and Error?’ was developed. The two theses are both exploring safety perspectives in IO and are developed in cooperation with the same supervisor in Statoil. Other similarities are a common case study of Snøhvit, and cooperation in making and accomplishing some interviews. The two theses are also similar in an organisational perspective to improve safety, but the broadness and level of detail is different. ‘New Work Processes through IO in Statoil – Function Allocation by Trial and Error?’ takes a broad perspective and explores strategies for accomplishing IO changes in oil and gas organisations. ‘Improving Safety through Integrated Operations’ has a more detailed focus and explores collaboration geographically dispersed across companies. Another difference is that CORD is used in ‘New Work Processes through IO in Statoil – Function Allocation by Trial and Error?’ and CRIOP is used in ‘Improving Safety through Integrated Operations’.

1.2.4 Recommendations and Suggestions

Recommendations and suggestions are given in research question two ‘How can IO improve the level of safety in the oil and gas industry?’ In general the recommendations and suggestion are given according to the scope of this task, i.e. vendor cooperation in control rooms, and situations where vendors are given more responsibility for tasks. Areas found to be important for taking care of safety in IO is considered. These are areas identified in research question one ‘How does use of IO affect the level of safety?’, but also other areas found during the data acquisition are considered. The recommendations are closely related to identifications of areas that have shortcomings or need extra attention. The recommendations are linked to the chosen theory, described in next chapter, chapter two. Recommendations are limited to problems identified in interviews and documents.

In the thesis the CRIOP (Crisis Intervention in Offshore Production) methodology is evaluated according to its applicability in IO and how it can help developing and implement IO. The study of CRIOP is not an in depth analysis of the methodology’s parts and questions. A detailed study of each check list and their advantages and shortcomings are not done. It is the methodology’s main purpose and focus that are examined.

1.3 Background - Integrated Operations in the Oil and Gas Industry

According to the report '*Integrated Work Processes: future work on the Norwegian Continental Shelf*' (OLF, 2005), the rapid maturation of the Norwegian Continental Shelf (NCS) mean that the window of opportunity for implementing IO is limited. Implementation of integrated work processes therefore has to be accelerated to realize its full potential. To do this special attention should be paid to development of common data standards, required technologies, competencies, MTO concepts and organisational models. Some of these areas are partly developed in the industry and some hardly considered.

The implementation of IO in the Oil and Gas industry is thought to take place during two major steps called generation one (G1) and generation two (G2). When both G1 and G2 processes are implemented the total impact on production, recovery rates, cost and safety are thought to be profound. Figure 6 illustrates G1 and G2 processes:

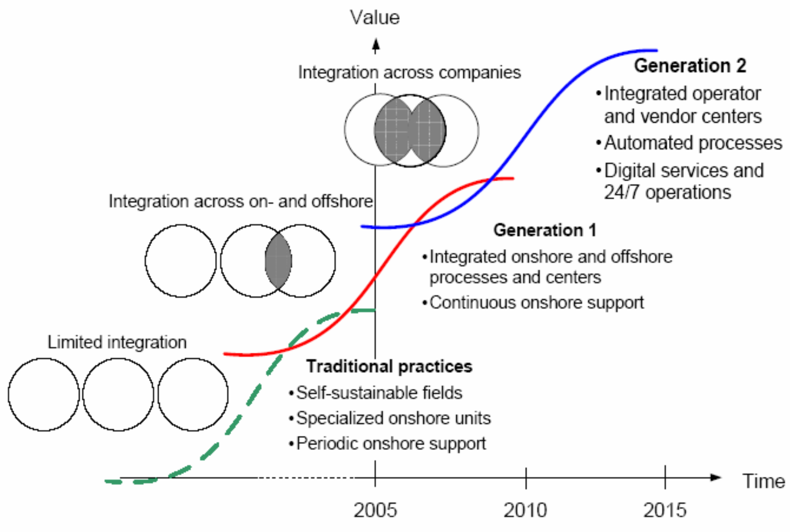

Figure 6: G1 and G2 processes (from '*Integrated Work Processes: future work on the Norwegian Continental Shelf*' (OLF, 2005))

Generation one processes (G1):

With G1 processes integration of onshore and offshore support/control centres will take place. More detailed G1 processes will represent an integration of personnel and processes in *onshore support* and *offshore control* centres, i.e., offshore gets support from onshore. G1 also imply that offshore gets continuous support from onshore when onshore centres are manned. Some onshore support centres are available 24/7 while other is available beyond normal work hours. This integration will take place using ICT solutions and facilities that improve onshore ability to support offshore operationally. Decisions are made in real time collaboration arenas through collaboration facilities and solutions which give personnel onshore and offshore access to each other and the same information at the same time. Communication between personnel in the two locations is facilitated via high-fidelity audio and video systems. The centres onshore are integrated real time collaboration rooms where many disciplines are located, i.e., production, drilling and maintenance. The centres are staffed by professionals who have the competencies necessary to manage and take the necessary decisions for the field in question. Personnel both onshore and offshore can monitor operations in real-time, compare actual data with simulations and identify operational and safety-related problems. Both locations cooperate in finding out how to optimize operations further and avoid or solve problems affecting production, cost and safety. In the onshore centres decisions and related consequences can be discussed and integrated activity plans made.

Generation two processes (G2):

The major characteristic in G2 processes will be integration of vendors and operators and their delivery chains. It will help operators utilize vendors' core competencies, services and products more efficiently. Personnel belonging to vendors and operators will be located in onshore control centres that may be geographically dispersed and team members will have full access to required information, tools, services and each other, through advanced decision support and collaboration tools. The centres will be operational 24/7. Personnel in vendors and operators onshore centres are closely integrated and collaborate digitally over the net. A large portion of the services required to operate a field will be delivered over the net and vendors will participate actively in this operation i.e., thorough drilling, well, production and maintenance services. Bases on this collaboration operators will be able to update reservoir models, drilling targets and well trajectories as wells are drilled, manage well completions remotely, optimize production from reservoir to export lines, and implement condition-based maintenance concepts. This means that fields will be operated by personnel in centres belonging to both operators and vendors and vendors will take care of some of the daily work and decision making processes that earlier were carried out by the operators. The operators will be informed and advised when anomalies or alarms are registered but operators will still have the overall responsibility for the operation of the fields. They will therefore still be responsible for taking the decisions necessary to handle anomalies or alarms. This development means that a lot of information will be provided digitally and the amount of information will increase drastically. To make these changes possible and avoid information overload the centres and processes will make extensive use of tools for automatic filtering of information and automation of processes and decisions. Offshore there will be intelligent equipment and roving teams and onshore vendors and operators use advanced filters, models and optimizers to solve problems and operate offshore installations form onshore centres. The G2 processes are more demanding to implement because roles and responsibilities of operators and vendors have to be redefined and new competencies as well as services and technologies developed. This means that G2 processes will require significant organisational changes.

Use of IO in the oil and gas industry:
According to the report '*Integrated Work Processes: Future work processes on the NCS*' (OLF, 2005) the present situation in G1 processes are that most companies on the NCS have built onshore operation drilling centres. Some of the companies have onshore operation centres that integrate onshore and offshore drilling, completion, production, maintenance and logistics functions. Onshore centres have access to the same information as personnel offshore. Some centres are manned 24/7. The centres facilitate real-time collaboration and use high-fidelity audio and video systems and portable computers. Personnel both onshore and offshore can monitor operations in real-time and identify problems. At onshore centres "what-if' analyses and discussions about decisions and consequences are carried out. Integration of activity plans are preformed from onshore. Discussions about the operation and problems are solved in cooperation with personnel onshore and offshore. Regarding G2 processes some operators have started piloting these processes but they are not tested and implemented to a broad degree[2].

The report '*eDrift på norsk sokkel – det tredje effektivitetsspranget'* (OLF, 2002) tells about the development in IO. ConocoPhilips have made several platforms remotely operated and unmanned. They have built an onshore operation centre which coordinates and operates several platforms and one onshore drilling centre. BP has established one onshore centre for

[2] More information about G1 and G2 processes related to the areas well planning and well execution, well completion, production optimization and maintenance management are found in the report "Integrated Work Processes: Future work processes on the NCS (OLF, 2005)

drilling activities. They are using real time data for simulations and to optimise operation. Norsk Hydro is building an operation centre with real time data and advanced ICT solutions for onshore and offshore cooperation, but also cooperation with vendors. At Statoil the Tampen area is mentioned. Here Statoil are installing modern control systems at several platforms and also connecting them to the computer network onshore. It is therefore possible for onshore personnel to more effectively support offshore operations. See also chapter 1.2.2 which tells about IO in HNO. Several of these companies are also using new technology and real time data to perform condition based maintenance.

The interviews provided an insight into the present status of IO in the oil and gas industry. For operation of manned platforms most of the onshore centres are functioning as support centres only, and they are not doing remote operation from onshore. There is however examples of remote operations of unmanned platforms. In drilling and well activities some vendors have built their own support centres for directly contact with offshore or operators support centres. Vendors have possibilities to collaborate with operators support centres if personnel in the operator centre need advice or guidance. It is in drilling and well the development in IO has come furthest and it is in these areas most of the IO experience is found. The disciplines of drilling and production are also more integrated now while they earlier were separate disciplines. Daily operation and plans are made more in parallel. The technological development has mostly been focusing on solutions for fast access of data for personnel onshore and offshore. In close relation to this is the development of collaboration room offshore an onshore that can use this increased amount of data to collaborate in making better and faster decisions. Several companies are using these possibilities. Because of a technological development that gives possibilities to monitor equipment remotely and to do maintenance when needed, there has been a transition from traditional maintenance to conditioning based maintenance.

Characteristics of the 'Snøhvit' Case Study

The case study and collaboration between Statoil and ABB at Snøhvit can mostly be related to G1 processes but also elements of G2 processes are found. G1 processes are focusing on integration and collaboration between onshore and offshore, which really is not the case at Snøhvit. There are no personnel located offshore and the only integration and collaboration is of people onshore. However, ignoring this supposition, some similarities with G1 processes are found. G1 processes means integration of people and processes geographically dispersed, which is also the case for Snøhvit and ARMOR. The cooperation is based on continuous support, use of ICT solutions and facilities that improve ability to support the operation. Decisions are made in real time collaboration arenas through collaboration facilities and solutions which give personnel access to each other and the same information at the same time. There are also some similarities with G2 processes. The most important similarity with G2 processes is an integration of operator and vendor. Personnel in vendors' and operator's onshore centres are closely integrated and collaborate digitally over the net. Personnel belonging to vendors and operators are located in onshore control rooms that are geographically dispersed and collaborate through advanced decision support and collaboration tools. The case study of Snøhvit is therefore an interesting mix of elements from both G1 and G2 processes.

Part two: Theoretical Framework and Scientific Approach

2 Theoretical Framework

This chapter describes the theoretical framework of the study. The theoretical aspects are chosen to suit important elements in IO, and the research questions. First of all IO implies new ways of organising organisations, theoretical frameworks that consider safety in organisations are therefore chosen. IO entail that organisations are becoming more geographically independent and more tasks are performed digitally, therefore Virtual Organisations (VO) is chosen to examine aspects to safety. Besides the virtual and organisational aspects, the oil and gas industry is characterised by complex processes. The perspectives of High Reliability Organisations (HRO) are therefore chosen as a tool in exploring safety aspects. Theory about organisational learning is chosen to cover the aspect of improvement in IO. Because IO, in addition to organisational changes, also implies changes in technology and people, concepts of Man, Technology and Organisations (MTO) and Human Factors (HF) are chosen. Safety needs to be taken care of across all aspects of MTO and theories about barriers are therefore chosen as a way of discussing this.

2.1 Crisis Intervention in Offshore Production (CRIOP)

'*CRIOP is a methodology used to verify and validate the ability of a control centre to safely and efficiently handle all modes of operations including start up, normal operations, maintenance and revision maintenance, process disturbances, safety critical situations and shut down*' (Johnsen et.al, 2004).

The methodology consists of three parts, introduction and context of use, general analyses and scenario analysis, the last two being the main parts. The general analysis *verifies* that important requirements for the control centre design are fulfilled. This analysis contains checklists with questions related to the working environment in a control room and the ability to handle normal and abnormal situations. The check lists are divided into the following areas: 1.Layout, 2.Working environment, 3.Control and safety systems, 4.Job organisation, 5.Procedures, 6.Competence and training, 7.e-Operations. The scenario analyses *validates* that the control centre satisfies implied needs. Scenarios for new situations or accidents helps analyse and correct the way personnel in the control room handle situations that may happen. The general analyses represent a static assessment of the control centre. It takes into account situations that are not related to scenarios or situations that do not need to be related to a specific sequence of events. The scenario analysis on the other hand is a dynamic assessment made for interaction between factors and people in the control room.

CRIOP applies to several stages in the design process, and addresses elements in man, technology and organisation (MTO). In a design process consisting of the stages: clarification, analyses, conceptual design, detailed design and operation and feedback, the CRIOP methodology should be used in the three last stages. This is illustrated in figure7.

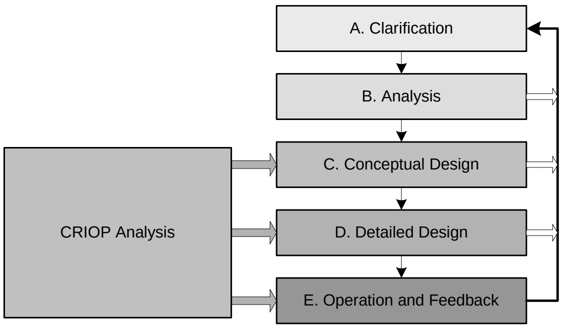

Figure 7: CRIOP in design process (from Johnsen et.al 2004)

In this report factors concerning fragmentation of responsibility and new organisational structures in use of IO are of particular interest. One of the check lists, the e-operation checklist in the general analysis, are in fact taking care of requirements related to IO. This check list is therefore important for the work with making suggestions and recommendations in the study.

2.2 High Reliability Organisations (HRO)

High Reliability Organisations (HRO) is a designation of organisations which manage to stay stabile and avoid major accidents even though they operate in a complex environment where deviations can give serious consequences (LaPorte, Consolini, 1991). These organisations are characterizes by what Perrow (1999) call complex interactions and tight couplings. Perrow claimed that organisations having these characteristics were most likely to have system accidents or major accident. His theory are not further described here, but it is noted that also Perrow (1999) identify oil and gas installations to have tight couplings and complex interactions. In most cases oil and gas installations are close to the source of energy, and also the systems are complex and difficult to gain full overview of. Whether the installation is a manned or unmanned platform or placed on the seafloor, there are many actors involved in the process of producing oil and gas. IO makes the interactions and collaboration between these actors tighter, and gives possibilities for more actors to have direct contact towards the same systems. In many ways this contributes to even more complexity in the systems. Thereby it is important to form systems, and organizations around the systems, in a way that prevent erroneous actions or fragmented responsibility among actors to result in accidents or unsafe systems.

There are especially two elements in the ideas of HRO that are important be able to avoid accidents and gain safe systems, organisational redundancy and spontaneous reconfiguration of the organisation (Rosness et.al 2004). There are two dimensions of organisational redundancy, structural/instrumental preconditions and cultural dimensions. The characteristics of these dimensions are listed in Figure 8. As the figure show HRO exists when both cultural and structural factors are excellent.

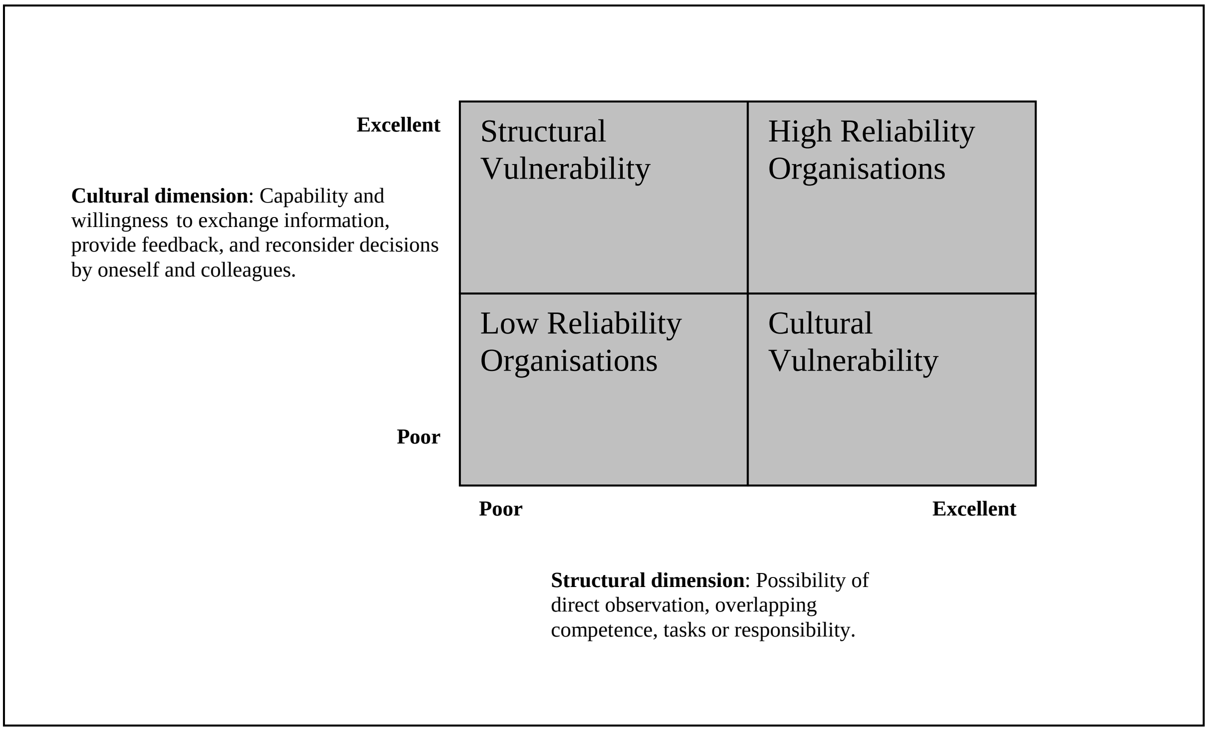

Figure 8: Two dimensions of organisational redundancy (Rosness et.al 2004)

Spontaneous reconfiguration of the organisation means that the organisation is able to reconfigure spontaneously during demanding operating situations and crisis (LaPorte and Consolini, 1991). They have resilience in the organisation.

2.3 Barriers

In the simplest form a barrier is something that separates a vulnerable target from a dangerous energy source. The barrier is placed between the hazard end the victim and prevent the energy form reaching the victim, as figure 4 illustrates:

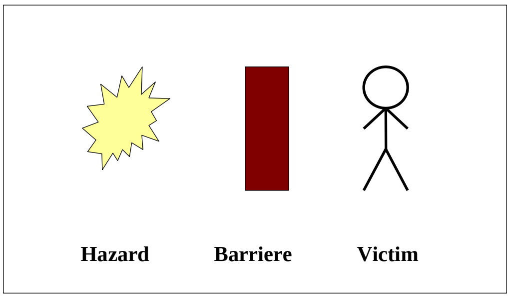

Figure 9: Barrier

In relation to figure 9 Haddon (1980) make accident prevention strategies related to al three elements, the hazard, barrier and victim. All three elements in figure 9 have to be considered when preventive measures are identified. First the energy source (hazard) should be reduced or if possible eliminated, then barriers which prevent the hazard from reaching the victim should be installed and last personal protective equipment is introduced. This presentation of barriers may give a perception of barriers as physical structures or devices. Barriers however may as well be routines, work processes, guidelines or culture. It is therefore convenient to talk about MTO barriers. For physical barriers it is convenient to talk about passive and active barriers (Kjellén, 2000). Passive barriers are embedded in the design and are independent of the operational control systems, but they still need maintenance and follow up, e.g. fire and explosion walls. Active barriers are dependent on human actions or technical control systems to function. Such systems may be both automatic and manual e.g. sprinkler systems in fire protection and the fire brigade. In a system it is important to think about all these kinds of barriers, both physical and non-physical and barriers to man, technology and organisation.

An expansion of the barrier model in figure 9 is the 'defence in depth' theory by Reason (1997). High hazard systems, as oil and gas installations, usually employ several levels of barriers and defence to bring the total risk to an acceptable level. Thereby an accident is usually not caused by a single failure. Reason also distinguishes between active and latent failures. Active failures trigger unwanted events, e.g., errors made by control room operators, while latent conditions lie dormant in system and may contribute to future accidents, e.g., poor design. Kjellén (2000) says that the rationale behind the philosophy of 'defence in depth' is to establish independent barriers between the hazard and the victim. By that a major accident can only occur when there is an improbable combination of barrier failures. Building 'defence in depth' is important for IO to reduce the possibility of experience major accidents.

Rosness et.al (2004) talks about building fault resistance in the oil and gas industry, meaning that we need to perform work in a way that wrong actions, wring decisions and technological faults normally do not result in accidents. Barriers are a way of making fault resistance, and such barriers include humans, equipment and systems.

Use of IO usually implies that more tasks and equipment are taken care of by contractors. With IO barriers then have to be taken care of by both the operator and contractor. This in turn means that contractors are given more responsibility for the work done. Based in this it is crucial to remember that the total system has to function and have a design that represents all necessary barriers, across actors.

2.4 Virtual Organisations (VO)

Virtual organisations are organisations comprised of multiple, distributed members, temporarily linked together for competitive advantage, that share value chains and business processes supported by distributed information technology (Grabwski, 2006).

As other networked organizations virtual organisations (VO) is organisations that transcend conventional organizational boundaries. The bonds among members are temporary. Virtual organizations are noted for forming and dissolving relationships with other members of the virtual. Advantages attributed to virtual organizations include:

- Adaptability and flexibility - the ability to respond quickly to market changes.
- Shared, interdependent business processes that are designed to achieve shared business objectives.

Features of virtuality:

- The creation of a common value chain among the distinct entities of the virtual organization
- Business processes supported by distributed information technology.
- Members are not co-located, can meet face-to-face as well as electronically
- Temporary linkages that tie together the distinct organizations

Members in traditional network organisations on the other hand generally don't have temporary linkages between members or share value chains and interdependent business processes.

Organisations using integrated operations, as the oil and gas industry, share several similarities with virtual organisations. Members, both in the same organisation and other organisations, are supposed to work together independent of geography. This cooperation is supported by information technology. A goal is to make it possible to change and connect to different contactors dependent on who is able to fulfil needed tasks best. This makes temporary linkages between the distinct organisations important to have.

2.5 Organisational learning

For organisations to be able to improve their results it is important that they are able to learn from mistakes and take corrective actions. Argysis (1992) makes the distinction between single-loop and double-loop learning.

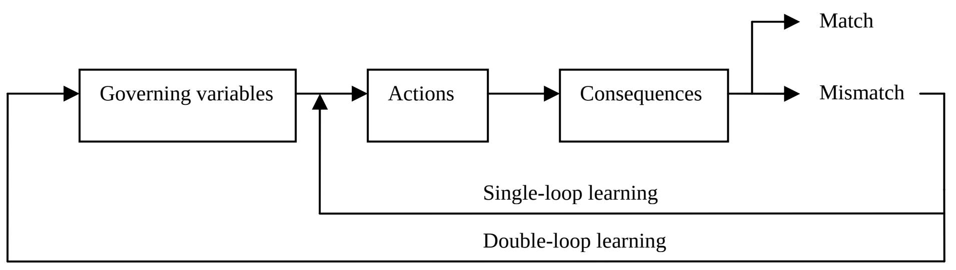

Figure 10: Single-loop and double-loop learning

Single-loop learning is appropriate in routine issues, where it is necessary to get the job done. Double-loop learning will affect the governing variables of the organization. This type of learning is necessary for long term effectiveness and ultimately for the survival of the organisation. In single-loop learning many opportunities for learning are lost and no long term effects are produced as a result of experience. Persons are learning from their mistakes and correct the faults in further work. The possibility for other workers that might face the same problem to also correct their actions is however missing. Corrections of deviations are also made in safety inspection, but no strategically or organizational changes are carried out. Organisational changes are on the other hand accomplished in double-loop learning. The whole organization is able to learn from faults. Based on accidents and incidents changes in routines, instructions or design are made.

One central goal in CRIOP is to achieve double-loop organisational learning by taking action to change the governing variables. This are variables like control room design, procedures or work organisation.

A similar concept to Argysis Organisational Learning is Van Court Hare's hierarchy of order of feedback. Van Court Hare distinguishes between different orders or levels of feedback control, characterizes as follows (Kjellén, 2000):

Level 0: Simple transformation without feedback. E.g. accidents are not followed up with remedial actions.
Level 1: Simple machine with direct feedback but without selective memory. E.g. corrections of deviations identified by accident investigations or safety inspections.
Level 2: Tactical systems with memory of organisation, conditional selection of pre-established plans and predictive feedback. E.g. starting a pre-planned eye-protection campaign following and increase in eye injuries.
Level 3: Strategic systems that learn from experience and have ability to correct plans and develop new plans. E.g. Change in routines, instructions, rules or design on the basis of accident experience.
Level 4: Goal-changing system that learns and consciously develops, selects and implement new plans. E.g. Change of safety policy and goals on the basis of accident experience.

The order of feedback is an indicator of the degree of learning from previous experiences. Van Court Hare's hierarchy of orders of feedback can be related to Argysis Organisational Learning. Single-loop learning is happening in level zero and level one. Corrections are made on an individual and incident level. Double-loop learning is happening in level three and four. Preventive actions that continuously reduce risks in the organisation are taken.

2.6 Theoretical Concepts

Often the literature use some concepts that are actually not defined anywhere. The concepts of Human Factors (HF) and Man, Technology and Organisation (MTO) are of particular interest for this thesis.

HF – Human Factors

This concept is closely related to MTO. According to Adam Balfour (2003) Human Factors is a scientific discipline using systematic methods and knowledge about humans to evaluate and improve interaction between man, technology and organisation. The goal is to make products or systems that are effective, safe and user friendly. The goal is also to make effective and reliable collaboration between man and technology. Design of suitable technology for human use is a central part of HF. Looking into the interactions of human and machines, systems and environment, HF tries to: improve safety, reduce the possibility for human errors, enhance operational activity, reduce costs and improve communication between experts. By that it is possible to design a work place that gives effective and safe operation and take care of the employee’s health.

MTO –Man, Technology and Organisation

These concepts of MTO are about focusing on all three elements in man, technology and organisation, and consider interactions between them. They are all affected by each other. A change or development in one of them will most likely affect the other two.

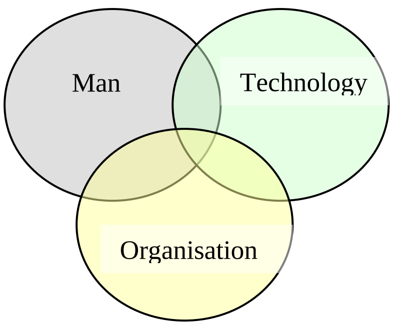

Figure 11: MTO – interacting elements.

According to (Kjellén, 2000) the following attributes belongs to the three elements:

Technology: The technology used is safe, there are good barriers and the technology is user friendly and supports a good working environment.
Organisation: There are organisational redundancy, room for flexibility, good training and how the management system is working.
Man: That right and good competence and knowledge is look after, the attitude and behaviour shown by people, and cultural aspects.

MTO may be considered as two perspectives; the soft and the structural perspectives.
The soft perspective is about safety culture, attitude, behaviour, knowledge, norms and so on. The soft is related to what is *actually done*. The structural is about technological solutions, organisational maps, organisational policy, guidelines, standards, laws and so on. The structural is about what *should be done.* It is important to focus on both soft and structural values. It is however often the case that structural elements are most focused on (Albrechtsen, 2004).

Closely related to MTO is the ISO 11064 standard, which gives guidance to ergonomic design of control rooms, and the CRIOP methodology. CRIOP is briefly described in chapter 2.1.

3 Scientific Methods

The description of the chosen method is based on Ringdal (2001) and her description of a research process. The steps in this process and relation with this thesis are illustrated in figure 12. The steps in the figure are explained in more detail in this chapter.

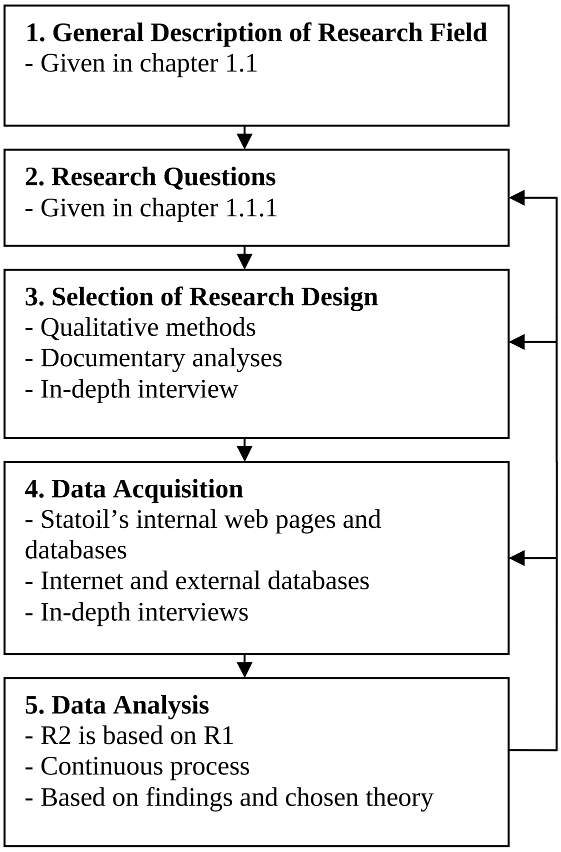

Figure 12: The research process and methodology

3.1 General Description of Research Field and Research Questions

Both the general description of research field and research questions is already explained in chapter 1.1, and is therefore not repeated here. The general description is based on own interest, work with the autumn project and wishes from Statoil and SINTEF.

While the general description of research field mostly was given through the project description, the work with the making the research question was a more iterative process. Findings in the data acquisition made it necessary to make some adjustments in the research questions.

3.2 Selection of Research Design

When selecting a suitable research design the main choice is between a qualitative and a quantitative approach. A qualitative research design is explorative. It starts out with general issues and then through research finds new theories and definitions. In this approach closeness to the object of study is important and the method seeks to understand rather explaining a phenomenon. Quantitative research design uses statistical methods to support existing theories and definitions. It often starts out with some hypothesis to be investigated. It is causal, has distance to the object or phenomenon and data is usually collected in numbers. Tjora (2005) makes a distinction between the types of knowledge gained from the two approaches. Qualitative research gives in-depth knowledge while quantitative research gives comprehensive knowledge about an issue.

Based on this thesis objective and its formulated research questions, a qualitative approach is chosen. The nature of the case study and research question makes it more appropriate to use qualitative methods. There is not much written information about safety implications in IO, and the collaboration between Statoil and ABB are still in the start phase (project phase). It is also a pilot project, being the first of its kind, which means that actual data are limited. Part of the thesis scope is also to look at operation and maintenance, phases that are not yet started at Snøhvit. To gather information about these phases it is necessary to look at other projects, not actually similar to Snøhvit and the collaboration with ABB. To compare two such different kinds of IO project it would be difficult to use quantitative methods. Quantitative analyses based on large amount of data from Snøhvit and sufficient surveys to give statistically correct results, would be difficult to accomplish. Not many people are in the position of having knowledge about this particular case. Qualitative methods based on some depth studies to understand the case, is thought to be more helpful. There are however several possible methods to gather data in qualitative methods, i.e. documentary analyses, interview, observation and survey. In this project documentary analysis and interviews are used.

3.3 Data Acquisition

As mentioned above documentary analysis and interviews are used as methods to collect data. Because there are not much available documentation and written information about how IO will affect safety, the study and results are mainly based on interviews.

Documentary analyses:

Documentary analyses are used in several parts of the report. Fist documentary analysis was used in answering how IO is used in Statoil and in the oil and gas industry, second in describing Snøhvit and collaboration with ABB. Documentary analysis was also important in finding information about the research questions, especially some parts of R1 in answering and how use of IO affect the level of safety and if there are areas that are especially exposed from a safety related perspective when IO is introduced.

Documents were gathered through Statoils internal web pages and from personnel working with the Snøhvit project, both in Statoil and ABB. Other important web pages were the pages of NPD, PSA, OLF and the CRIOP web page. My supervisors at both Statoil and SINTEF had a central role in suggesting important documents and where to find them. Also informants in the interviews, especially in SINTEF and IFE, had suggestion of documents.

Interviews:

As with the documentary analyses, the interviews served several roles in answering the questions in the report. Because of the lack of data about the operating and maintenance phases at Snøhvit, it was often necessary to rely on information from interviews, both in answering question R1 and R2. People from many sectors with experience in integrated operation were selected as informants. Another important factor was to include both ABB and Statoil regarding the collaboration at Snøhvit. The list of informants was constantly updated because of refers from informants about other relevant persons and because of informants' availability. Table 1 shows the final lists of informants. Names are not provided but the list illustrates in which sectors and companies interviews were made, and the roles of the informants selected.

Table 1: Sectors and companies in interviews

Sector/company	Position/role
Statoil	1. Head engineer in automation, works with safety and automation systems at Snøhvit. 2. Head engineer, project leader in an R&D project in operation and maintenance in IO. 3. Leader process, worked with operation, maintenance and modifications in IO at HNO, but also process and technical safety in HNO. 4. Leader process, responsible for delivering the process control systems at Snøhvit. 5. Head engineer, project manager in building a support centre at HNO. 6. Chief engineer, team member in Statoil responsible for CRIOP. 7. Head engineer, works with HF in the control room at Snøhvit. 8. Head engineer, works in a support central. Works as a process engineer.
ABB	9. Department leader, leader of an apartment for remote monitoring and system operations. Responsible for developing ARMOR
PSA	10. Project engineer, working with how to follow up IO in PSA
NPD	11. Chief engineer, worked with management and development of IO
SINTEF	12. Senior scientist, doing research in cooperation geographically dispersed. The research also considers e-operations. 13. Researcher/PhD student, worked with the CORD project and IO in this. 14. Researcher, works with HF in control rooms and organisational safety.
IFE	15. Senior scientist, responsible for MTO activities in IFE 16. (Position), work with HF and CRIOP analysis (?)
Scanpower	17. Senior Consultant in risk management, have worked with development of CRIOP and performed CRIOP in control rooms

According to Ringdal (2001) one can choose between a flexible or strict approach to the interviews, where the strict approach does not allow for changing the questions during the interviews or to substitute the selected informants. In this thesis a flexible approach and in-depth interviews are chosen. The flexible approach is an iterative process that gives room for changes as the interviews are carried out. In-depth interviews mean that it is possible to focus on topics especially relevant for the informant. A guiding questionnaire with predefined topics was used and the interviews were all carried out as partly structured, i.e. often the exact order of the questions was changed to allow the informants to talk free and flexible during the interviews. A wide questionnaire was developed to cover every interesting aspect if IO, but depending on the informant's role, a selection of questions in the interview guide were made. For people familiar with the CRIOP methodology some separate questions were made. Appendix A gives an overview of the questionnaires used in the industries.

As described in chapter 2.4, IO in the oil and gas industry often can be viewed as virtual organisations (VO). Martha Grabowski (2006) use leading indicators to be able to identify and benefit from alerts, signals and prior indicators, and therefore recognize potential accidents before they occur in virtual organisations. She also makes a model for leading indicators in VO. In the model she gives some areas that are important for the safety in VO. These areas are:

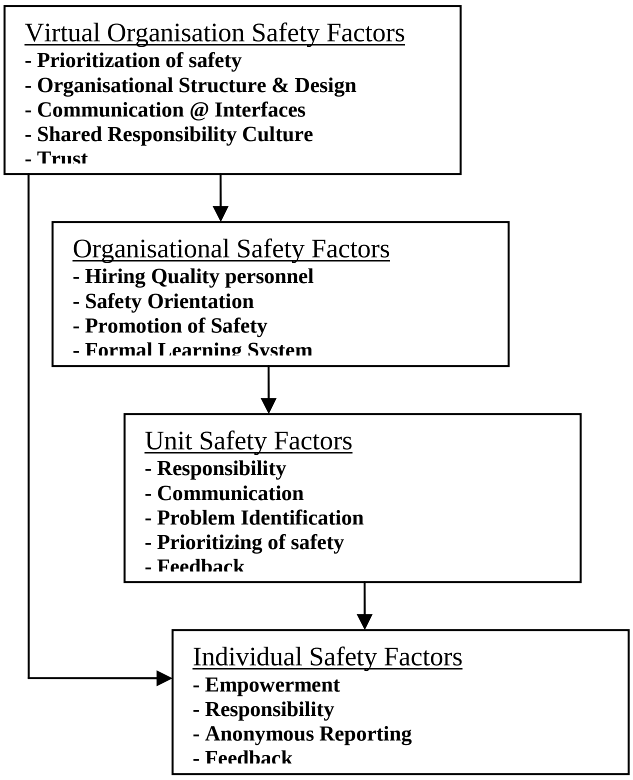

Figure 13: Research Model for Leading Indicators in Virtual Organisations (adapted from Grabowski, 2006)

As the figure show there is one box especially for virtual organisations. The other three boxes are important to virtual organisations as well as other organisations. This model is used when making questions for the interviews and by that help focusing on important factors for safety in VO and integrated operations.

3.4 Data Analysis

The phases of collection data and analysing data were not separated in the study. There were not much available documented information about safety in IO, and it was difficult to see all interesting perspectives in the beginning of the work. Documents and interviews were read and partly analysed as they were collected, and by doing this other relevant informants and documents were found. As new issues arose some new questions were added to the guiding questionnaire, which were then used in the next interviews. These made it possible to include aspects not considered in the beginning but that were of highly importance for the work.

First information form the interviews were analysed and categorised to get an overview of relevant findings. Appendix B summarises the results of this work. Second these findings, in addition to relevant literature and chosen theoretical aspects, were used to analyse the research questions. Given the nature of the research questions, research question one is mainly answered before research question two. During the analysis many findings in the data acquisition and interviews are repeated through the chapters discussing the research questions. To illustrate how findings can be used to enlighten several contexts, I have mainly chosen to divide the discussion into sections based on the chosen theoretical frameworks. This implies some repetitions of the findings, but is also makes it easier to understand how the chosen theory can enlighten safety perspectives based on the same findings. This structure is supposed to help enlighten how the thesis goes from collected information to analysis and at last to state results.

3.4.1 Credibility, Verification and Transferability in Results

It is important that the method assure credibility, verification and the ability to transfer results to similar cases. Credibility is related to the how the research process is executed, the way data have been collected and if these data are credible. The collection should be accomplished in a manner that gives confidence to the Study. It is also important to find and point out possible errors in the work. If the results and conclusions are to be credible it is important that they can be checked. A similar project should give the same results. Verification is related to the quality in data and the interpretations done. The interpretations should be relevant and show if the researchers own experiences and opinions have been used. One other important element is to show that the study actually answers the questions given.

Last it is important to make the results possible to transfer to similar cases. If the results are possible to transfer they may be used in other contexts. An evaluation of credibility, verification and transferability are given in chapter 6.3, Evaluation of study process.

Part three: Results and Discussions

4 How does use of IO affect the level of safety?

IO affects safety in several ways and it is complex to answer exact how IO will affect safety. Many aspects both in technology, man and organisation have to be addressed. The focus area in this thesis, cooperation with vendors, is just a small part of the total picture. The data acquisition indicates several safety aspects to IO. This chapter address how IO affects the level of safety and how the industry is dealing with this.

4.1 Safety is lacking as a driving force in IO

In Statoil's governing documents safety (in HMS) is proclaimed as important to consider in all activities, but safety was not found to be a initial specified goal in work with IO. As a guidance to work with IO, Statoil has identified some strategic corporate initiatives. These areas are divided into three categories 'Broad Implementation', 'Pilots' and 'Research and Development' (R&D). The three categories are telling what IO solutions are ready to be implemented (Broad Implementation), what IO solutions are being tested in projects (Pilots) and what IO solutions need more research to become ready for implementation (R&D). The three categories consist of several projects where experiences are collected, and in none of these are safety a specified theme.

The data acquisition showed that there are several driving forces towards IO. These are the main driving forces found in the interviews:

1. **Financial aspects**
    - Smarter ways to run processes and installations during operation will give more oil and gas from the reservoirs and therefore improve financial results.
    - Reduced cost of operation.
    - Higher profitability.
    - Increased income.

2. **Competitive advantages**
    - A wish to be the leading country in IO, and develop solutions that can be leading in IO implementation in other countries. A way of getting market shares in the future.
    - The need and wish to be a part of the development in IO. Some informants pointed out that the rationale behind this decision was not sufficiently assessed in all operator companies. Not all of them have made goals and plans for what to achieve with the new tools, technology and ways of working. It is more like buying equipment and building control rooms just to be part of the IO trend.

3. **Efficiency in operation**
    - A reduced need to make timely and costly transportations of people.
    - Enhanced availability on scarce human recourses which give reduced time to solve problems.
    - Better and more effective use of available technical solutions.
    - Better utilization of data and information.

4. **Decision making**
    - Possibilities to use the best people/knowledge to solve problems and therefore make better decisions.
    - Faster response because it is possible to communicate fast with vendors and experts located other geographical places.
    - Effective decisions because it is possible to solve problems remotely in multidisciplinary teams.
    - Utilization of technological solutions to make decisions faster.

The answers about driving forces varied to a small degree on the informants' role and company. It seemed to be quite random what aspects each informant focused on. Reduced costs and better efficiency seem to be the most important ones. Some of the informants said that the only reason why IO is being implemented is because of the anticipation that IO at some point in time will provide profit. To lower the operational costs is important for operators to be able to extend the life time of fields and better their results. Because IO will enhance efficiency and lover costs[3] IO is an important part of achieving this goal.

Different actors are having different driving forces. The perspective of society is found in Stortingsmelding 38 (Olje og energidepartementet, 2002) where improved profit by increased oil recovery and longer lifetime are important, but also competitive effects outside the NCS. A world leading development in IO for Norwegian companies will give the oil and gas industry in Norway a good competitive position in the world market, and increase the tax income to society.

A repeating factor in reports and articles is that IO will enhance the level of safety. There is however not much argumentation about why safety will increase, and also the interviews indicated that safety is not a driving force in IO. It is more thought to be an added benefit of IO. The industry identifies some possibilities for increased safety through IO but there are no plans in how to ensure these possibilities. It is therefore uncertain if IO will have this particular effect. Some multi industrial forums exist where safety are discusses but it seems to be a low specific focus on safety when actually implementing IO. The same elements as those above were also found at Snøhvit. Some informants mentioned that a more focused strategy in how to better HSE results with IO is necessary, and that HSE management has to focus on this.

The lack of focus on how to achieve better safety trough IO will probably be a factor affecting safety negatively. Increased safety must be one of the main goals of IO implementation. This would increase the possibility of actually getting good results. It would make it more certain that improved safety is actually achieved.

[3] According to the report '*Verdipotensialet for Integrerte Operasjoner på Norsk Sokkel*' (OLF, 2006) the value creation on the Norwegian Shelf can increase by at least NOK 250 billion until 2015 with use of IO, because of better opportunities for making good decision which will better production results.

4.2 Threats and possibilities to safety should be addressed

The actual effects on safety, positive or negative, are not yet documented by the oil and gas industry. During the interviews with NPD it was mentioned that collecting such experiences is something they are doing now.

It seems to be difficult to give an explicit answer to whether IO will reduce or improve safety. Some elements may give reduced the safety while other will improved it. The sum and total picture is not clear. However, during the interviews several elements in how IO will affect safety were found. These elements showed both possibilities to improve safety and threats to reduce safety. Both threats and possibilities are important factors in how IO may affect safety and what problems may arise. With a focus on vendor cooperation, these are the most important possibilities and threats found:

Threats that may reduce safety:

1. **Threats caused by geographically distance between operator and vendor:**
   - Distance to experts and physical installations can result in communication problems and poor understanding of problems.
   - The distance and separation of operator and vendor may lead to problems with trust.
   - Vendors separated from the installations or operator's organisation may lose feeling of ownership for the tasks they are performing.
   - Making decisions in critical incident and situations of readiness may be difficult.
   - Operator may lose control of which vendor is involved, especially if many vendors are involved or they are often changed. Lacks of trust in vendors can arise because of rapid changes in personnel at vendors.

2. **Threats related to use of new technological solutions:**
   - ICT technologies are becoming much more complex with IO and the operation is more dependent on it. Computer and network security are therefore more difficult.
   - Virtual intruders are more difficult to spot and access control to computer and technical systems can become a problem.

- With the new technological solutions it may be too much information and data available to control room personnel.

3. **Threats related to the new virtual organisation:**
    - IO implies more integrated organisations which may give new kind of problems in cooperation because of different cultures, language and expressions used.
    - Poor compliance of routines, procedures and work practice for companies involved in IO and working towards the same interface and systems may become a problem.
    - Poor information sharing because of reluctance to give other companies information.
    - Misunderstandings caused by the change processes in IO (especially for old installations). This may give changed roles and responsibilities that result in misunderstood practice.
    - High focus on operational perspectives and solving operational challenges (as the situation in many projects is today) will not guarantee that the risk level in operations is improved.

4. **Threats to shared responsibilities:**
    - Operators with poor knowledge can be responsible for giving ‘work permissions’. The operator giving ‘work permission’ may not be the operator having best knowledge about the case in question. The depth knowledge may be located at the vendors.
    - Fragmented knowledge to systems because of spread tasks and responsibilities between many actors (operator and vendors) may give poor understanding of the total picture.
    - If not sufficient focus is placed on responsibilities it may lead to unclear responsibilities to operator and vendors.

<u>Possibilities that may improve safety:</u>

1. **Possibilities caused by less people located offshore:**
    - Reduced transportation of personnel because of possibilities to get help from experts independent of geography, and located at both vendor and operator.

- Less people may be located offshore and therefore less people are exposed to the hazards.

2. **Possibilities caused by technological solutions:**
   - Technological solutions make it possible for personnel at different locations to see the same information and documentation about a problem which will make it easier to discuss problems.
   - Operators are working through one standardized and familiar interface in their control/rooms. They do not have to travel and work on several different installations, many of those they may not be familiar with.
   - Joint technological solutions and dedicated channels facilitate vendor and operator to share information which improves the cooperation and communication.

3. **Possibilities cause by cooperation:**
   - Better awareness on how work is done and that right people are making decisions (more involved vendors/experts).
   - Better cooperation, communication and follow-up because of closer cooperation with vendors.
   - More focus on cooperation which possibly improves the climate and barriers for making contact.
   - A possibility to build common and good culture both socially and technologically.
   - Possibility to evaluate and improve present routines. Continue with good elements and improve shortages.
   - An opportunity for vendors to handle safety according to the operator's requirements.
   - IO may be used to make safety (HSE) management better. It is a possibility to involve onshore operation centres in safety management. This can be done in having the same requirements for using and handling safety both offshore and onshore.

Possibilities are discussed more thoroughly in chapter 5.1.

The threats above shove several shortcomings to HRO. Examples of this are:

Lack of cultural aspects: Lacks of trust in vendors because of rapid changes in personnel at vendors. Lack of trust may restrict cooperation and communication.
Lack of structural aspects: Low awareness of vendors involved. Operator may loose control of which vendor is involved, especially if many vendors are involved or they are changed often.
Lack of ability for spontaneously reconfiguration of organisation: Fragmented knowledge of systems and tasks as a result of giving vendors more responsibility for tasks. This may lead to poor understanding of the total picture.

Such shortcomings are further addressed in chapter 5.4. In addition to the weaknesses in HRO given above, more such weaknesses is identified and improvement suggestions given.

Some reports have already addresses perspectives of threats and possibilities to safety, e.g. '*Trusler og Mulighet knyttet til e-drift*' (Johnsen, et.al, 2005) and '*eDrift på norsk sokkel – det tredje effektivitetsspranget*' (OLF, 2002). They are mostly taking a broad perspective in exploring IO. However '*Trusler og Mulighet knyttet til e-drift*' (Johnsen, et.al, 2005) is also giving more detailed considerations, and some of them are similar to the threats and possibilities found in this thesis. For example Johnsen et.al (2005) says that a split of tasks between several companies could lead to gaps in responsibility and reduced safety, and that the change process might lead to vague responsibilities. A similar possibility was also found i.e. easy access to experts and knowledge will have positive effect on decisions. The report *eDrift på norsk sokkel – det tredje effektivitetsspranget*' (OLF, 2002) questions safety aspects in fragmented organisations, like giving vendors more responsibility for tasks. However a more detailed discussion about this is not given. Most of the reports written are taking a broad perspective in IO.

As the points above shoves there are many aspects of threats and possibilities to safety in IO. This thesis is mainly focusing on aspects to cooperation across distance and cooperation with vendors. To get a more complete picture of safety aspects in IO similar lists should be made in all important parts of IO. Also a mapping of threats and possibilities in actual IO projects in the industry would be useful. There are usually unique elements in every project that should be addressed.

How IO will affect safety is depending on how threats and possibilities are taken care of. It is important to make plans in how to avoid threats and make sure possibilities are realized. For vendor cooperation and cooperation in control rooms this is usually not done, not at Snøhvit either. Because of this it is more likely that threats will occur and possibilities fail to appear, which means a negative effect on safety in IO.

4.3 MTO – IO is affecting safety in all three elements

When using integrated operations interaction between all elements in MTO are important. IO may imply remote monitoring, remote controlling and remote assistance, all of them implying increased use of technological solutions in daily operation, but also new ways of working and structuring the organisation. Therefore changes will come in all elements in MTO, and they are all important to consider in work with IO. This is however not the present picture seen in the industry. Results from the data acquisition shows that technological aspects have been most focused on until now, and there have been a low focus on aspects to man and organization. A balanced safety perspective should include all three aspects because accidents are known to happen because of all of them (Andersen, 2005). Even though most of the unsolved problems are in man and organisation, the interviews indicated that some challenges also will lie in technological aspects. These are the main elements (many of them are already briefly mentioned in the previous section):

Man (M):

1. **The main characteristics of IO, cooperation across distance, may give cultural threat to safety in several ways. Trust and culture was mentioned to be an important element in keeping safety in the interface between operator and vendors**.
    - By being located physically together trust was believed to develop faster than by being located geographically at different places. Different location of personnel would possibly decrease the trust. In worst case this may give a situation where operators don't trust vendors in doing tasks or vice versa. It is however possible to verify this with use of CRIOP scenario analyses.

- Other problems are lacks of trust in vendors because of rapid changes in personnel at vendors. This will mean many interruptions in the process of getting to know personnel at vendors, and trust their skills.
- Reluctance to share information because of problems with trust and culture may become a problem. Reluctance to share information may occur because of lack in trust or a culture for strict consideration of sensitive or competitive information. Even with faultless technological equipment for information sharing, information may not be shared if reluctance to share information exists in the organisation.
- The problem of organisations having their own language and expressions was mentioned. IO implies more integrated organisations which may give new kind of problems in cooperation because cultural aspects like different cultures, daily language and expressions used. If these differences are large there will most likely be problems in interpreting each other which may reduce the efficiency in performing tasks.

2. **Distance to experts and physical installations can also result in communication problems, problems in understanding each other and poor understanding of problems**. Problems with communication were the most mentioned element in affecting safety. Such problems would occur because of lack in trust and unequal cultures. Cooperating across distance means that some possibilities to interpret messages sent are lost e.g., body language, simultaneous use of all senses and direct view of incidents. Because of this the process of interpreting and considering alternative actions may be more difficult and time to solve problems may increase. But this picture is not unilateral. If the problems in trust and culture are solved it may be easier to solve problems because it is possible to reach the right vendor and person faster, and this person is available at all time. Operators do not have to start searching for the right person and use time calling around when critical incidents happens. The time to solve the problem may actually decrease.

3. **Making decisions in critical incidents may also become a problem. This area was in the interviews said to have a lot of challenges, especially if vendors are given direct access to the systems from a remote location**.

- Responsibility in critical situations need not be the same as in normal operation and practice in handling such incidents may be more complex when actors at different locations are involved. This may lead to wrong decisions.
- When personnel at are located far away from the installations or systems they are making decisions about, they may loose feeling of reality in the situation. While if vendors are located the same place as the operator and is able to observe and feel the consequences in problems more directly it may be easier to understand the severances in the incident, take action and make decisions. This situation applies as well to operator's control rooms.

Technology (T):

1. **Access control on computer and technical systems need to be improved**. Virtual intruders are more difficult to spot. If there are fragmented responsibilities for tasks and several vendors and actors are able to work on the installations, access control is said to be critical. Good and understood procedures are therefore important. It may however be difficult to make sure that everyone in the virtual organisations fully understands this.
2. **Challenges in information security.** There were examples of platforms with downtime because of fault in data transmission or viruses. The potential for situations like this are even higher with IO, a situation dependent on signals arriving through fibre optic networks for most of the operations.
3. **The design of user interfaces in control rooms need attention**. The PSA mentioned that they during supervisions of alarm systems had observed that control room operators understanding of alarms and functionality in the systems were often bad and varying. Being able to understand and handle the user interface is essential for operators to perform their work safely and be able to take care of critical or unfamiliar situation.
4. **There is a need for more work in standardisation of data and common standards in equipment and ICT security**.
5. **Making and difficult conditions in pressure, temperatures and chemicals used**. This is a threat to the possibility of transferring data to operators geographically dispersed.
6. **The technological development makes it possible to transfer large amount of data and it may be too much information and data available to personnel**. Focusing on

reducing the load of unnecessary information and make good models of to whom what information is relevant for is important.

Organisation (O):

1. **The present systems, routines and models for learning and, experience transfer and do not seem to be good enough for IO**. These models are made for one company only and it is difficult to make them usable across several companies. In addition reporting systems are usually not used to document incidents related to IO (more about this in chapter 5.6).

2. **Problems regarding decision making in readiness may occur**. With lowered amount of staff offshore there may become task conflicts in situations of readiness. The transaction from operation to readiness may not be smooth and a challenge to find good solution to. Another element regarding readiness were the location of responsibility for decision making in such situations. If there are staffs both offshore and onshore where should the operative responsibility be located in such a situation? Is it possible to have it both places or is it necessary to transfer it to just one place? This is important for onshore centres as well. How is readiness taken care of by operator and vendor, and are there any possible misunderstandings?

3. **Poor compliance of routines, procedures and work practice for companies involved in IO may become a problem**. In general the interviews showed that procedures and practice were not developed as well as technological aspects.
    - Today routines and procedures are an internal matter for each company and often not available outside the company. This may not be adequate anymore, and some informants said that routines and procedure have to apply across company borders. Especially when operator and vendor are working towards the same interface and systems it is difficult to spot mismatches that may lead to conflicts if procedures are different.
    - There is a need for cooperation to make routines and procedures more similar. With IO the complexity in systems will probably increase which will make more complexity in routines also, incising the amount of procedures and interactions between procedures. Making procedures common may lower the total amount and make it easier to se how they relate to each other. Such work

is however being done in the forum 'Samarbeid for sikkerhet[4]' (cooperation for safety). This work is highly important to continue.

- With IO and also more use of concurrent design it is possible that use of procedures will be done more in parallel now, while they earlier were used mostly in sequence. To make this possible and safe, work with procedures should also consider adaptation of parallel processes.

4. **Fragmented knowledge of system may lead to poor understanding of the total picture**. Fragmentation of tasks may lead to fragmented safety responsibility. It is difficult, whether it is an old or new organisation, to gain overall understanding and understanding in the systems when they are fragmented, virtual and geographically spread. Especially in the interface defining the line between operator's and vendors' tasks this may lead to unwanted actions, actions taken by actors who are note having responsibility for performing the task. In addition, operator may loose control of which vendor is involved, especially if many vendors are involved or they are changed often. If not sufficient focus is placed on responsibilities that may give a situation where responsibilities to operator and vendors are not clear.

5. **Misunderstood effects and practical solutions of change processes related to IO** (especially for old installations). Such change processes usually give changed roles and responsibilities which may result in misunderstood practice, especially in unusual situations, like crisis. This will also affect control room operators.

The interviews showed that focus in the technological development was good. Especially important for cooperation with vendors are computer and network technologies, which make the tools for cooperation across distance. Regarding these two aspects the interviews shoved that the development had come far. Requirements and barriers to the technological solutions were considered good. However it is also a fact that technology is becoming much more complex with IO and operation is highly dependent on it. This may give some challenges to computer and network security. Finding solutions to these challenges are therefore critical.

[4] www.samarbiedforsikkerhet.no

In the data acquisition most threats were found in organisational matters. Regarding challenges to organisational elements, there were made separate considerations for new and old installations. Factors to organisation and man will be solved more easily in new projects and installations. On old installations old habits and practices have to be broken up and changed before new ones can be established. On new installations it is possible to build organisations without bother with old routines.

There was broad agreement in the interviews that the main challenges are at organisational factors. Next to that are elements to man and last elements to technological factors. Informants in Statoil said that ‘from a technical point of view much challenges are solved’. It was also mentioned that the good results in technological solutions are not sufficient to make success in IO. Some actors in the industry are realizing that it is necessary to make major changes and improvements in people’s attitude, culture, building new organisations and making new work processes related to the IO principles.

It is still too early to say if problems related to unequal focus on MTO will occur. As mentioned the main focus have been on technological solutions which has helped defining and correcting important drawbacks to safety in technology. On the other hand the lack of focus in organization and man makes it highly possible that surprises and negative effects to safety will occur related to them. At the present state IO is therefore having negative effect on safety in aspects to man and organisation.

4.3.1 The change process and workers involvement

At Snøhvit a totally new organisation is built, meaning that the project do not have to bother about changing an existing organisation into working with IO. The aspect is however important for other projects in the industry dealing with existing offshore organisations. This is an organisational (O) issue, and was mentioned in the interviews as a potential problem to safety in IO. There was a concern that poor focus in change processes could lead to misunderstood effects and solutions for work tasks in IO. Also the political aspect of including workers and trade unions is important for success in change process. Many of the changes followed by IO will influence operators work greatly, and some informants mentioned low focus in worker participation and involvement of trade unions, as a potential problem. The following issues were said to be important to consider:

- How to relocate personnel offshore to onshore need to be addressed. Few people offshore will be able to find new jobs in the oil and gas industries near their homes at shore.
- Personnels' reluctance in changing work schedule and models for salary.

The report '*eDrift på norsk sokkel - det tredje effektivitetsspranget*' (OLF, 2002) also mention reluctance from trade unions as a potential problem. The report states that it is important to emphasise the challenges in IO and to assure participation of workers in the change process. The report addresses this as a potential organisational barrier.

If the change process and worker participation are not taken care of properly it will probably influence safety in IO negatively, i.e. in a reluctance to use the new technological solutions and change work procedures. Many of the problems related change processes are important for offshore personnel. It also becomes important to success in IO when the same personnel are part of the changes IO gives. If these processes are not taken care of adequately it may lead to problems in making the necessary changes in man and organisation to have safe operation.

4.3.2 Interaction between man, technology and organisation:

The challenges and problems to man, technology and organisation mentioned in the last section are illustrated in the following figure:

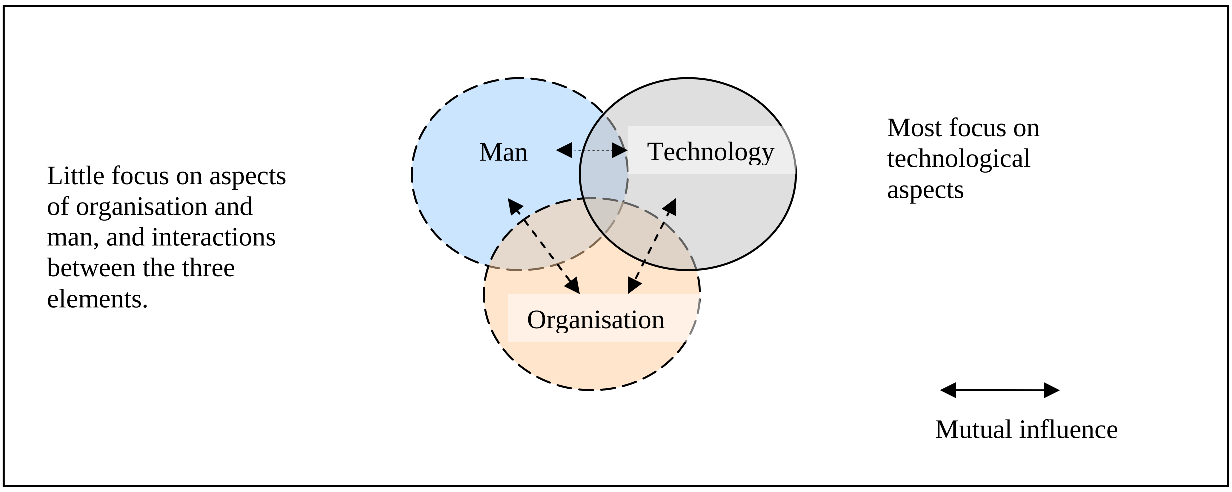

Figure 14: Unequal focus in MTO

In addition figure 14 shoves another highly important characteristic of MTO, the mutual influence each element have on the other. In the case of IO new technological solutions are realized. These new technological solutions will most likely affect organisational aspects and people involved. In the previous section (4.3) some problems to each element in MTO were given. These problems however do not arise in isolation to man, technology or organisation.

Regarding barriers the focus has mostly been on physical barriers in technology. But not only is there a lacking focus in barriers to man and technology, there is also a lacking focus in how the three perspectives mutually affect each other. Thinking about how the new technology will affect organisation and people was hardly mentioned in the interviews, and no reports were found about this. Taking a perspective like this would help the industry in mapping possible threats to IO.

The data acquisition showed some examples about how the three elements in MTO will mutually affect each other. Two such examples are:

1. A good example is how problems by not including workers and trade unions in change processes can emerge (as discussed in section 4.3.1). If the reluctance with personnel to change work schedule and models for salary are not solved, many possibilities in technological changes may not be realized. The necessary changes in man and organisation for having safe operation will also be difficult.

2. One other example is how the organisation is reorganized because of new technological possibilities, and how cultural aspects may be affected by the organisational changes. The new technology makes it possible to work on and support the installations remotely. Several control rooms may be involved in this. In this thesis two control rooms at Snøhvit and ABB are studied. As mentioned earlier, being located at different places can lower trust, because of rapid changes of personnel at vendors, reluctance to share information and misunderstanding because of different language and expressions used. These cultural aspects may again affect how the technological solutions are used e.g., solutions for communicating may not be utilized fully because of lack in trust. This is an example of how MTO not only affect each other but also mutually affect each other. See figure 15.

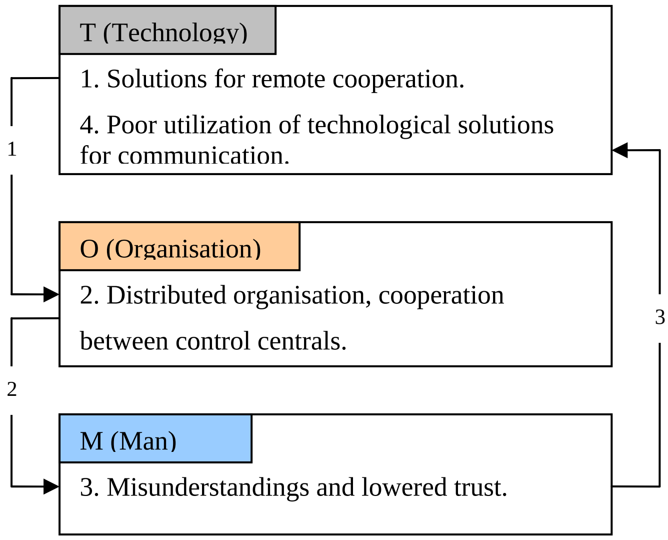

Figure 15: Example of mutual influence in MTO

Mapping the most important mutual influences at an early stage would help in understanding and take care of the most critical threats to safety. Above a couple of examples of influences on vendor cooperation in control rooms were given. It is recommended that more such analyses is done, both in cooperation across control rooms but also to help understand important safety aspects to IO generally.

Looking at technology separately from man and organisational will give a wrong impression since they are all affected by each other e.g., technological solutions may not be suitable for operators to use, or organisational changes affect human factors and people's willingness to participate. Both the neglect of man and organisation, mentioned in the previous section 4.3) and the neglect of how the three elements affect each other will probably lead to faults, ineffective work or the need for restructuring IO solutions afterwards. This is another shortcoming telling that IO will have negative effect on safety.

4.4 Conclusion

The three previous chapters (4.1, 4.2 and 4.3) indicate that there are three major strategic shortages in ensuring safety in IO.

1) First of all there are no plans in how to improve safety through IO. Although many sources say that improved safety is a benefit of IO, it has not been an initial specified goal in IO nor is it a driving force. Safety should however be one of the main goals of IO implementation.

2) Second threats and possibilities to safety in IO, i.e. vendor cooperation, are not mapped and addressed. The data acquisition found several such elements related to vendor cooperation. Similar lists of threats and possibilities should be made in all important parts of IO, and most important to plan how to take care of them.

3) Although IO is affecting all three elements in MTO, only safety perspectives in technology are well taken care of. This means that safety barriers are lacking in organisation and man, and that IO at the present state are affecting safety negatively in these two. Low focus in how the three elements in MTO will influence each other will probably also have negative effect on safety.

Considering the three points above, the effect on safety with IO have some major challenges. If the challenges are not met, the safety level may very well decrease. How IO will affect safety is dependent on how the three elements above is addresses. The present situation however shoves that safety in IO is not a planned goal and few threats are handled and no plans are made in how to take care of the possibilities. Also shortcomings in barriers to man and organisation imply that IO probably will have negative effect on safety in these. It is therefore more likely that surprises and negative effects to safety will occur, and that IO will affect safety negatively.

In order to correct this, important shortcomings should be addressed. There should be a more goal driven focus in how to take care of safety in IO, and safety critical factors to man, organisation and technology should be identified. If this is done it is possible that IO in the future will improve safety. Given the shortcoming above an interesting question is how safety can be improved through IO i.e. how possibilities can be assured and treats avoided. This is addressed in research question two, given in the next chapter. Among other things HRO and MTO is used. It is however crucial that actions are taken as soon as possible.

5 How can IO improve the level of safety in the oil and gas industry?

'*IO is a possibility for new ways of thinking, cooperation between actors, building of trust and sharing of tasks. Combining these elements with the new technological solutions and properties of virtual organisations, one gets unique opportunities to improve the HSE management*' (from interview with the Petroleum Safety Authority).

As indicated in chapter 4 there are some important challenges to overcome in IO to assure good results in safety. But if those are overcome there are unique opportunities to improve safety in IO. On of the most threatening findings to safety is the lack of focus in how to achieve better safety trough IO. Identifying threats and possibilities and plan how to take care if them as well as developing plans in how to enhance safety through IO would increase the possibility of actually getting good results. It would make it more certain that improved safety is actually achieved.

In the previous chapter effects on safety in IO were identified. In this chapter suggestions about how to improve safety are given. This analysis is done through the theory of HRO, the concepts of MTO, properties in VO and the achievement of double-loop learning. The suggestions in how to improve safety is given regarding the focus area in this thesis, vendor cooperation and cooperation across distance. Improvement suggestion about, among other tings, problems found in the previous chapter are given. One of the problems found was that threats and possibilities were not mapped. This chapter starts out with a more in-depth explanation of the possibilities to give a better understanding about what should be focused on in the industry. Second, the identified threats are also found as shortcomings to MTO in the previous chapter and HRO in this chapter. In this chapter improvement suggestions are given towards HRO and MTO, which means that threats are also given suggestions about. Most of the problems are found recommendations for. The success in correcting problems is mostly about willingness in the industry to put enough effort into work with safety in IO.

5.1 Possibilities to improve safety

Being aware of possibilities with IO to improve safety is highly important to utilize the safety potential fully. Taking care of these possibilities and make sure that those are realized is important in gaining a high level of safety in IO.

First of all there are some advantages in that less people are located near dangerous energy sources. According to Haddon (1980) this is safety efforts to barriers, see figure 9. The energy source and vulnerable target is separated in time and space. Transportation of personnel is reduced because of possibilities to use experts independent of geography, both at vendor and operator. Also less people may be located offshore and therefore less people are exposed to the hazards. It is clear that this depends on the remaining risks the personnel offshore are exposed to. If their risk level are equally raised the win to safety caused by less people offshore will be neutralized. Taking care of safety for the remaining personnel offshore is therefore crucial.

Based on the possibilities to improve safety listed in table 4.2, the following main categories of possibilities to improve safety are found. These are important to realise when implementing IO, and improving safety in IO, i.e. vendor cooperation:

1. **IO gives the possibility to have better awareness on how work is done and that right people are making decisions. It is possible to have more involved vendors who are experts in their fields. Focusing on realising this potential should therefore be done.** If this is accomplished it may give better decisions. Personnel both onshore and offshore have support through IO from necessary disciplines and experts. Faster response form vendors and experts will probably reduce the time to solve problems, and give possibilities of finding faults faster. This will make possible to avoid critical situation more effectively and by that avoid accidents. Letting vendors take care of tasks in which they are experts in give the possibility of having the best personnel do the work, and therefore take more safe and effective decisions. Closer contact between expertises offshore and onshore, both at vendor and operator, gives a broader focus on uptime and optimal solutions, also toward safety.

2. **The technological solutions in IO make it possible for operators to have one standardized and familiar interface in their control rooms, and to chare information**. They do not have do travel and work on several different installations, many of those they may not be familiar with. This reduces the risk of doing wrong actions because of unfamiliar surroundings. Technological solutions also make it possible for personnel in different locations to see the same information and documentation about a problem which will make it easier to gain a common understanding of and solve problems. Joint technological solutions and dedicated channels make it easier for vendor and operator to share information and communicate.

3. **With IO closer cooperation with vendors is possible. If this cooperation is well taken care of it may have positive impact on safety**. Closer cooperation with vendors may in it self give better cooperation, communication and follow-up. As mentioned technological solutions and dedicated channels make it easier for vendor and operator to share information, which can improve the cooperation and communication. It may also give faster response form vendors and experts and possible reduce the time to solve problems. Letting vendors take care of tasks in which they are experts in give the possibility of having the best personnel do the work, and by that be more effective, safe and getting more work done. Focusing on cooperation and making good processes for this will probably improve the climate and barriers for making contact. Training was highlighted to build confidence in cooperating. Generally it is important to build common and good culture both socially and technologically to have good cooperation.

4. **A possibility for vendors to have safety (HSE) management according to operator's requirements.** Closer integration of vendors in operation give an opportunity for vendors to have sufficient resources or initiative to manage safety as well as the operator, or be able to follow up and have an safety (HSE) management according to the operator's requirements.

5. **IO may be used to improve the total HSE management**. **The operative HSE management also have to be located onshore in the control rooms.** HSE management system has to be actively used also onshore. This is important for

successful implementation of IO when it comes to safety (HSE). Personnel onshore and offshore need to have a shared interest in having common models and common understanding of their own and others work, common understanding both in operationally matters and the risk that surround tasks. This can be done in having the same requirements for using and following HSE management systems both offshore and onshore.

6. **Implementing IO gives a possibility to evaluate and improve present routines**. The evaluation should continue good elements and improve shortages.

7. **A possibility to build common and good culture both socially and technologically**. One overall comment in the interviews was that to make IO successful the cooperation between vendor and operator has to be much better than it is today. At the same time a good implementation processes and use of IO was mentioned as a way of improving the cultural aspect. One should improve trust and work with reducing the scepticism and differences often seen between operator and vendor. Establishing procedures and practice in team work, and involving both parts in this need to be done.

Above there are listed seven main categories with possibility to improve safety in IO. However interviewing more people in the industry or making more in-depth analyses would probably show more important possibilities. Such an analysis is however not done in Statoil. The possibilities to improve safety mentioned above need some planning in how to actually make them happen. If this is not done it is less likely that they will improve safety, e.g. if focus in improving routines are lacking routines will probably not be changed properly. If focus in cooperation with vendors are lacking requirements for good cooperation may be left out. The possibilities mentioned above are actually important steps in improving safety in IO. The possibilities show that if cooperation with vendors is taken care of the right way, it may have positive impact on safety. Making sure that they are taken care of is therefore important.

5.2 High Reliability Organisations is not achieved in IO at present

The oil and gas industry fits well into Perrow's description of organisations having complex interactions and tight couplings, see chapter 2.2. These kinds of organisations have a significant potential for major accidents. As described in chapter 2.2 High Reliability Organisations (HRO) is a designation of organisations which manage to stay stabile and avoid major accidents even though they operate in a complex environment where deviations can give serious consequences. If use of IO in the oil and gas industry could help building HRO it would be a major advantage to safety. An interesting perspective in answering how to improve safety thorough IO is therefore to see how characteristics of IO fits into the description of HRO, and most important to identify improvements to become an HRO.

There are many perspectives of IO in the oil and gas industry, many of them have been realised but many are still to come. One usual way of looking at this is through processes called G1 and G2, as described in chapter 1.3. The perspective taken in this thesis when analysing the situation against HRO is based on the *present situation*, as situation mostly characterized by G1 processes. In addition to the present situation the *directions of the IO development at the present state* is considered.

As described in chapter 2.2 there are two important aspects to look for in HRO, organisational redundancy and spontaneous reconfiguration of the organisation. Based on the data acquisition these are the properties to organisational redundancy:

Table 2: Organisational redundancy[5]

Structural/instrumental preconditions:	***Cultural dimensions:***
+ **Technological solutions**: solutions that allow personnel in different locations monitor the same information and documentation about a problem which will make it easier to gain a common understanding of and solve the problem.	- **Distance to actors and installations may give misunderstandings**: the distance to experts and physical installations can result in communication problems and poor understanding of the problem.
+ **Support from disciplines and experts**: personnel have support through IO from necessary disciplines and experts. Fast and various supports from experts allow solving problems faster and before they evolve into a critical stadium.	- **Distance and separation of operator and vendor may give reduced trust**: better trust was mentioned as an important element in bettering cooperation, and working with reducing the scepticism and differences seen between operator and vendor. The distance and separation of operator and vendor may lead to problems with trust.
+ **Dedicated channels for cooperation**: such channels make it easier for vendor and operator to chare information which improves the cooperation and communication.	- **More focus in cooperation is needed**: today the focus in cooperation is low. More focus on cooperation is needed which possibly will better the cooperation climate and barriers for making contact.
- **Computer and network security**: these technologies are becoming much more complex with IO and the operation is more dependent on it. Finding solutions to these challenges are therefore critical.	- **Lack of trust in vendors**: lacks of trust in vendors because of rapid changes in personnel at vendors. Lack of trust may restrict cooperation and communication.
- **Low awareness of vendors involved**: operator may loose control of which vendor is involved, especially if many vendors are involved or they are changed often.	- **Problems in political issues**: political issues like how to relocate personnel offshore to work onshore, problems in changing work schedule and models for salary. This may give problems to trust and willingness to change.
- **Poor development of work processes**: according to the interviews some of the main lacking elements or challenge to organisational factors was to develop work processes and finding ways/practice to cooperate with each other.	- **Problems because of different culture, language and expressions**: IO implies more integrated organisations which may give new kind of problems in cooperation because of different cultures, daily language and expressions used. Such problems are observed in similar situations.
- **Shortcomings in ICT standardisation**: the present shortcomings in standardisation of data and common standards in ICT security may make it difficult to	- **Most focus in technology. Lack of focus in organisation and man**: focus until now has been on technology. The industry are realizing now that it is

[5] The table is based on statements from the interviews. '+' means positive effect on organisational redundancy while '-'means negative effect on organisational redundancy.

openly share information and observe each other.	necessary to make major changes and improvements in peoples' attitude, culture and building new organisations and work processes related to the IO principles
- Examples of poor understanding of alarms: the PSA mentioned that they during supervisions of alarm systems had observed that the control room operators understanding of alarms and functionality in the systems they operated were often pretty bad and varying.	**- Communication problems**: one example on problems towards vendors was communication. The two parts were from different industries and had different ways of accomplishing tasks. Because of this they did not understand each other.
- Examples of vulnerability to information security: in general there were given examples of situations in relation to information security, or the lack of it. There are examples of platforms with downtime because of wrong signals or viruses.	**- At Snøhvit work with culture and trust had not started yet**: regarding shared culture and trust at Snøhvit the interviews indicated that these processes are not started yet.
- Change processes that give misunderstood effect and practical solutions: such change processes usually give changed roles and responsibilities which may result in misunderstood practice, especially in unusual situations, like crisis.	**- Lack of focus in how to work together**: establishment of procedures and practice in team work have to be focused on. This part is lacking now.

During the data acquisition it became clear that most work had been done in making technological solutions feasible and safe, and that safety results in technology were good. Challenges were related to routines, work processes and cultural related factors.

As chapter 2.2 and figure 8 shows the attributes to structural/instrumental preconditions and cultural dimensions are:

- Structural/instrumental preconditions: **Possibility** of direct observation, overlapping competence, tasks or responsibility
- Cultural dimensions: **Capability and willingness** to exchange information, provide feedback, and reconsider decisions by one self and colleagues

Regarding the prerequisite for organisational redundancy one may say that the element of structural/instrumental preconditions is a bit better taken care of than cultural dimensions.

By focusing on technological solutions for exchanging, sharing and accessing data and information the possibilities for direct observation, overlapping competence, tasks and responsibility (structural preconditions) are to some degree taken care of. However, by poor development of work processes and shortcoming in ICT standardisation, the same structural preconditions are having major shortcomings. Shortcomings are also found in cultural aspects. The focus on integrating personnel and experts in different locations, and making them capable of cooperating and solving problem, are low. Distance between operators may give misunderstandings and different cultures were mentioned as a possible drawback. The interviews showed that work and focus in how to make people capable and willing to cooperate to a small degree were taken into consideration.

In addition the interviews showed examples of problems to culture. An exact example was about problems towards communicating with vendors. The operator and vendor were discussing possibilities for cooperating. The two parts were from different industries and had different ways of performing tasks, therefore they did not understand each other nor did they see how each of them could benefit from the cooperation. The discussion therefore only turned out to be about costs, and the process ended with no agreement. The example shows that different cultures and practices in companies may give reluctance to cooperate.

Another example is that work towards making political issues, like relocating personnel, changing work schedule and models for salary is not completed, which means that problems related to changes *inside* the operator organisation may occur. It is therefore much likely to experience problems related to cultural aspects in IO.

Based on the characteristics given in table two, IO gives organisations located near the lower left corner in figure 8. These organisations are called '*Low Reliability Organisations*'. See figure 16.

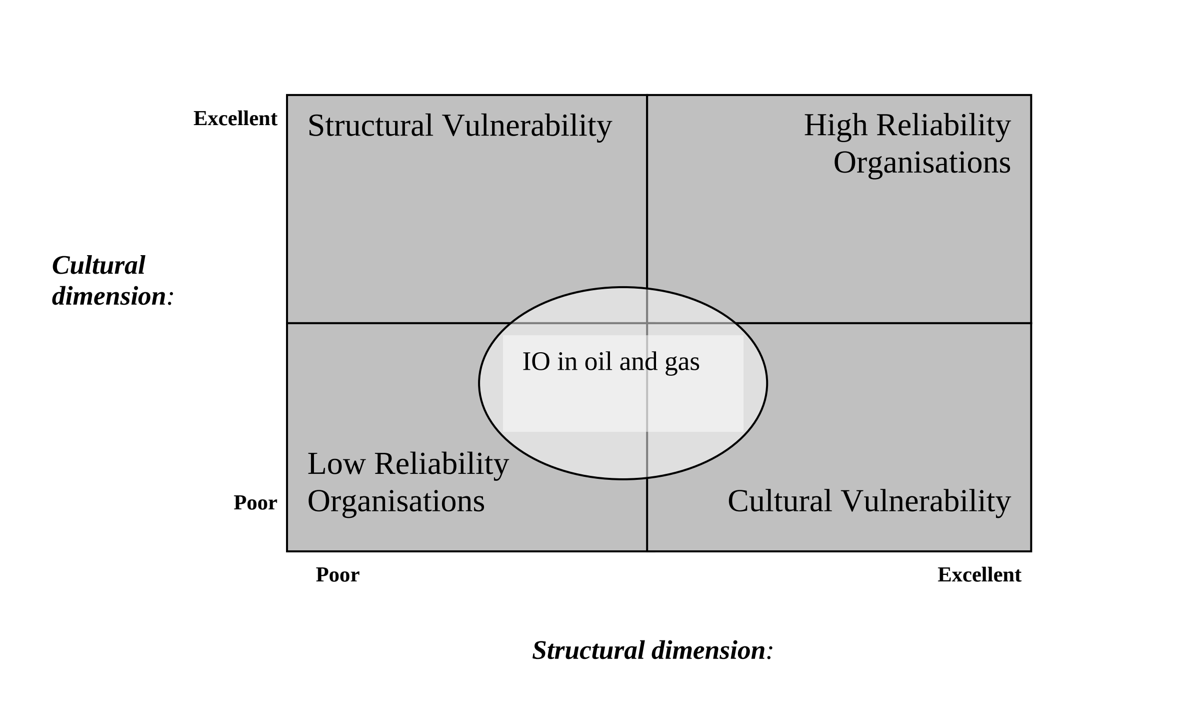

Figure 16: IO in relation to HRO at present

Figure 16 are however not absolute. The characteristics according to structural and cultural dimensions vary to some degree from project to project. The figure only illustrates the main trend in the industry.

In gaining a HRO focus now should be located to shortcomings in cultural aspects and organisational preconditions.

Another important part of being a HRO is the ability to spontaneously reconfigure the organisation. Elements in the data acquisition about this are:

Table 3: Spontaneous reconfiguration[6]

Affecting spontaneous reconfiguration *positively*	**Affecting spontaneous reconfiguration *negatively***
Reduced transportation of personnel: Reduced transportation of personnel because of possibilities to use experts and vendor personnel from onshore or located another geographically place.	**Low competence at people approving work**: The competence at persons giving 'work permission' may be a problem. The depth knowledge may be located at the vendors but still it may be the operator who gives permission.
Fast and various supports from experts: Personnel have support through IO from necessary disciplines and experts. Fast and various supports from experts make it possible to solve problems faster and before they evolve into a critical stadium. This will make it possible to avoid critical situation faster and by that avoid accidents.	**Misunderstood change processes**: Misunderstood effects and practical solutions of change processes related to IO (especially for old installations). Changed roles and responsibilities that result in misunderstood practice, especially in situations of crisis.
Awareness of how and who is doing work: Better awareness on how work is being done and that right people are taking decisions.	**Fragmented knowledge:** Fragmented knowledge of systems and tasks as a result of giving vendors more responsibility for tasks. This may lead to poor understanding of the total picture.
Work is preformed thorough a familiar interface: Operators are working thorough a familiar interface in their control rooms. They don't have do travel and work on several different installations, many of those they may not be familiar with. This may reduce the risk of doing wrong actions because of unfamiliar surroundings.	**Low focus on work processes:** low focus on work processes can make it difficult to cooperate in situation of critical incidents. It can be difficult to understand who is responsible for tasks.

Regarding spontaneous reconfiguration of organisation it is difficult to make one clear conclusion. At the present state there are no examples of vendors being directly part of the daily operation by using their own control rooms. But what is observed is that experts are easier to contact and gain help from when needed. Personnel offshore are also getting assistance from onshore when needed which have been helpful in solving problems and planning daily operation. By not having to transport personnel offshore when needed but to use the expertise immediately from onshore, gives possibilities for reconfiguration and solving problems faster. It is also possible to contact and let the best people work on the tasks in question and let them work thorough a familiar interface in their control rooms. All this

[6] The table is based on statements from the interviews

helps to ensure a better solution to problems and most important to make it possible to solve unexpected problems. The ability of solving unexpected problems is an important part of being able to reconfigure the organisation. But there are some problems regarding further development in IO and integration of vendors. The most important being that fragmented knowledge of system may lead to poor understanding of the total picture. Fragmented knowledge of systems may occur if several actors are only having depth knowledge in their own disciplines and the total picture and connections between the elements are lost. The interfaces between areas of responsibility are therefore important to look after in further work.

Based on the indications in the data acquisition it is most likely to say that the potential for spontaneous reconfiguration have increased. In IO to day support from onshore personnel, mostly inside the operator company, are helping the organisation solve problems faster and find more optimal solutions to them. The conclusion is therefore that the present development in IO has made the possibility for spontaneous reconfiguration better. The challenge to come is to continue this development when vendors are becoming more integrated in operation, especially regarding fragmented knowledge of systems.

Snøvhit:

In the case of Snøhvit the interviews brought up that little work was laid down in creating routines, procedures and taking care of cultural aspects, but that such work was supposed to start soon. Snøhvit is still in the project phase and until now it had not been suitable to do this kind of work. It was however made clear that defining routines and procedures were supposed to be done before operation start. At the present state Snøhvit fits into the analysis in figure 16. Part of the structural dimension are taken care of by making technological solutions which make it possible for direct observation of other operators and to carry out overlapping tasks and having overlapping responsibility. The cultural dimension is however lacking. ***There has been little work with operators' capability and willingness to cooperate. Work processes and aspects to man, regarding cooperation, have not been prioritized. It is therefore uncertain if necessary information will be shared, if operators will give feedback to each other and if they will reconsider each others decisions. These are all aspects to the cultural and structural dimension and lacking in work with IO at Snøhvit.***

Improvements in HRO:

The analysis above is based on a broad interpretation of the IO development in Statoil, and the picture given above will probably vary in different IO projects. This analysis is only indicating an IO trend in the industry. The shortcomings to organisational redundancy and spontaneous reconfiguration will probably not become a problem in normal operation, where people are performing known tasks and equipment are functioning as intended. Problems will however most likely occur in situations of deviations and crisis. It is in these situations the strengths of HRO are most visible, and important to have. In crisis management it is important that actors are able to solve problems with use of other abilities, practices, processes and human resources than in normal operation. It is in such situations improvements in organisational redundancy and spontaneous reconfiguration is crucial to achieve.

As the analyses and figure 16 indicates there are some elements lacking to make IO an HRO. Therefore there are also some important elements missing in IO to be able to take care of safety in an adequately way, especially in crisis management. As figure 16 indicates most elements needed to improve safety in IO are to cultural aspects and structural dimension, while spontaneous reconfiguration is better looked after.

5.3 Improving safety through HRO aspects

When improving safety in IO it is useful to focus in how IO can evolve from a Cultural Vulnerability Organisation to a High Reliability Organisation. According to figure 17 the organisation will than be in the upper right corner:

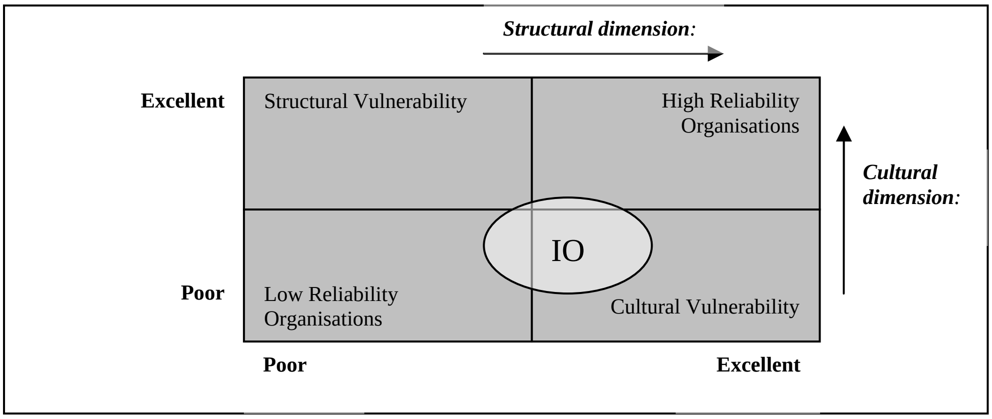

Figure 17: Needed improvements in organisational redundancy

The figure illustrates that improvements need to be done in both elements of organisational redundancy, i.e. structural and cultural aspects. To become an HRO both cultural and structural factors needs to be excellent.

Most effort is needed in the cultural dimension. Such effort should result in that the *capability and willingness to exchange information* is good, that operators provide *feedback* to each other and that they *reconsider decisions* by one self and colleagues. Some efforts are also needed in the structural dimension. Such effort should result in *possibility* of *direct observation*, *overlapping competence*, *tasks or responsibility*.

Finding solutions to all the challenges given in chapter 4 and in HRO is a complex job, but still highly important. Based on the data acquisition and theoretical aspects it is here given some suggestions on how to improve the shortcomings in organisational redundancy and spontaneous reconfiguration, but also improvements in MTO are considered. The first suggestion, ‘general improvement’, is a general suggestion for change processes in IO. It is a precondition to be able to make the necessary changes to organisational redundancy and spontaneous reconfiguration. The next improvement suggestions are to ‘aspects to cooperation and interfaces’ and ‘aspects to routines and procedures’. Again the suggestions for improvement are based on cooperation between actors and control rooms.

5.3.1 General improvement

In chapter 4.4 political issues in the organisation were mentioned as a problem to safety. Issues like the change process, trade unions and worker involvement. Examples of problems are how personnel onshore and offshore are relocated and how work schedules and models for salary is made. If these processes are not taken care of adequately it may lead to problems in making the necessary changes in man and organisation for having safe operation. This aspect is most important for ‘old’ installations having personnel located offshore.

Generally people are ready to change when they appreciate the change for themselves and the organisation. This includes an attitude of ‘some of this is good for me’, ‘it is fun to take part in this’ and ‘I see that these changes will give good results’. It is also important that people involved feel they have sufficient control of how the changes will affect them.

Personnel should also, to some degree, be able to understand what and when changes affecting them will take place. It is important to remember that *people do not oppose to changes, but to be changed* (Cummings, Worley, Huse (2004)). These elements should be considered when changing organisations and implementing IO.

In addition to the elements above important success factors to help the process are (Cummings et.al, 2004):

a) To assure commitment in all levels of the organisation.
b) Have an open and honest communication with involved parts form the start.
c) Develop a solid implementation plan with clear goals and consistent plans.
d) Highlight the advantages both for people and the organisation.

Focusing on aspects to change processes in IO would make it easier to achieve the necessary changes and improvements to organisational redundancy and spontaneous reconfiguration.

5.3.2 Aspects to cooperation and interfaces

Aspects to cooperation are affecting both organisational redundancy and spontaneous reconfiguration, and MTO barriers. However focusing on this is most important for improvements in cultural aspects. In general more focus on cooperation will possibly improve cooperation climate and lower barriers for making contact. By letting vendors take care of more tasks they are also getting more impact on business processes, processes that in traditional oil and gas organisations belonged only to the operator. Vendors are given the possibility to make more decisions that have direct consequences to the operator's result. Vendors will have more responsibility and therefore more effect on safety barriers. All this are important aspects of cooperation. The following suggestions to improvement in cooperation and interfaces are given:

1. **Focus on trust between operator and vendor**

Trust was mentioned to be an important element in keeping safety in the interface between operator and vendors. By being located physically together trust was believed to develop faster than by being located geographically dispersed. Different location of personnel was in fact thought to decrease the trust. In worst case this may give a situation where the operator does not trust vendors in performing tasks or vice versa. Especially in the interface defining the line between operator's and vendors' tasks this may lead to unwanted actions, actions taken by actors who are note having responsibility for performing the task. The following elements are important in building trust, and should be focused on:

a. ***Good (change) processes for implementation of IO***
b. ***Common understanding of what to achieve with IO***
c. ***Common language and information***
d. ***Early clarification of responsibilities***

Improving trust would strengthen the shortcomings to cultural aspects in organisational redundancy. It would also help in establishing important safety barriers in human (man) aspects. If actors trust each other the willingness to exchange information is improved and it is more likely that the person with best competence is taking care of tasks.

Results from work in Schlumberger showed that similar gave good results towards subcontractors. Schlumberger took an active role to establishing systematic subcontractor management to better manage service quality and HSE performance of subcontractors (Alary, 2006). Among other things efforts were made to develop the cultures at certain contractors by providing assistance, including training and coaching.

2. **Focus on aspects to communication, both equipment for communication and cultural aspects for information sharing.**

As mentioned above different location of personnel may in fact decrease trust. With low trust, communication between actors can be difficult. Communication problems can also emerge because of poor technological equipment and poor culture for information sharing. The ability to share information and understand each other are critical and something that has to be considered in work with IO. One has to compensate for the distance and develop tools to help communication and the fact that operators are not sitting in the same room, watching each others body language and the same information. Focusing on both communication equipment and cultural aspects for information sharing should therefore be done. Making good technological solutions for communication will improve the structural aspects in organisational redundancy, by improving the possibility for direct observation and give possibility for performing overlapping tasks and support each other in operation. This is also an important organisational barrier, in that it gives possibility to have organisational redundancy across distance. By working with cultural aspects for information sharing and making sure this will not become a problem, one is improving the cultural aspect of organisational redundancy. The capability and willingness to exchange information and to provide feedback is improved.

3. **Focus on procedures for permission**

To ensure that safety is look after in the interface procedures for permission are important to develop. While trust is a more cultural and human element procedures is a formal and organisational way of ensuring safety. To day procedures for approval of enquiries for changes are used, and also procedures for ‘work permission’ when the actual work or change is to be accomplished. These procedures are supposed to ensure that faults and erroneous action are spotted before they are carried out. To day it is the operator who gives these permissions, but in an IO situation where the vendor may has the best knowledge of the actual equipment and consequences of work the, vendor should be made part of the approval or permission procedures. Focusing on this will be an important improvement in spontaneous reconfiguration of organisation. In a demanding situation or crisis it is important to have the best person make decisions, and by that the situation can be solved much faster. It will also improve organisational barriers.

4. **Use common safety goals and plans in keeping safety in the interface between vendors and operator. Establishing a common scorecard is also recommended.**

Another element that may lead to problems with fragmented responsibility for safety is if the management in the companies are not discussing safety results goals together. The evaluation one company does may not be the same as the other, or something that should be a goal or safety issues is not being discussed by any of the companies because they believe the issue are taken care of by the other. In a situation like this there is obviously a fragmentation problem. Improving this will improve the structural dimension of organisational redundancy because of improved possibility for having overlapping tasks and responsibly.

In the interviews HSE management were also pointed out as a way of ensuring safety in interfaces. One important element is that safety (HSE) goals, plans and indicators should be developed in cooperation with vendors. To ensure a common understanding and integrate vendors in the organisation, operational goals and plans should also be discussed together. Both common safety goals and plans and common operational goals and plans are important in keeping safety in the interface between vendors and operators. Safety goals and plans should be discussed in cooperation with vendors. This will help to give operators and vendors the same understanding of task and problems, and to help them learn and understand each others knowledge and capabilities and give understanding of the interface. This will make it easier to know what resources to use, and therefore improvement in ability to spontaneous reconfigure the organisation is made. Doing this may also help establishing trust and better the cultural dimension of organisational redundancy, and improve barriers to man and organisation. To day operators and vendors are doing these things separately, so major changes regarding work processes and procedures needs to be done. Making goals and plans common would also improve structural aspects in organisational redundancy, i.e. it would be easier to have consistency in tasks.

Occidentals of Elk Hills, Inc (OEHI) developed a Scorecard for Safety that encourages contractors to perform activities that lead to better safety (Dudics, Riviera, 2006). By grading contractor's effort in key areas, focus and attention can be brought to bear on performing activities that will help avoid accidents and incidents. Measuring parameters were based on the following 'best practices'; 1) demonstrated management commitment, 2) staffing for safety, 3) safety planning-pre-project/pre task, 4) safety training and education, 5) worker involvement and participation, 6) recognition and rewards, 7) subcontractor management, 8) accident/incident reporting and investigation, 9) drug and alcohol testing. These parameters are focusing on inputs to safety work rather than lagging efforts (like the Recordable Incident Rate (RIR)). Measuring and following-up of contractors regarding these 'best practices' gave a decrease in incidents and accidents. Similar efforts are recommended for vendor cooperation in the oil and gas industry. Establishing a common score card would be a useful tool to improve safety.

5. **Use HSE management at vendors to prevent fragmented responsibility to become a threat to safety.**

Common HSE management were in the interviews mentioned as a way of ensuring safety in interfaces. HSE management is important to prevent fragmented responsibility to become a threat to safety. By giving vendors more responsibility for tasks it is short way to also give them more responsibility for barriers. This development should be followed by expanded requirements and responsibility for HSE management at vendors. If vendors are given more responsibility for task and barriers without the focus in HSE management being changed, problems in safety caused by fragmented responsibility may very well occur. Making these changes would improve organisational aspects since the management system is improved.

Alary (2006) showed that similar efforts in Schlumberger gave good results towards subcontractors. Schlumberger took an active role to establishing systematic subcontractor management to better manage service quality and HSE performance of subcontractors. Specific efforts were made to develop the maturity of QHSE systems at subcontractors. This effort gave improved safety results.

6. **Cooperate in change processes**

In an integrated organisation consisting of several companies, changes will happen, both in technology and in members of the organisation. To day operator and vendors are mostly doing change processes separately. Vendors are doing changes because of changed contracts from operator or internal wishes of better performance. To better manage the interface in IO change processes should be a common process. A decision to change, the coals and important elements in this process should be a joint decision. The importance of cooperation in change processes was also mentioned in the interviews. Doing changes processes separately in an integrated organisation will probably increase the change of getting mismatches when the changed parts are merged afterwards. As a result of separate change processes responsibilities (in the interface) may have changed but not understood. Cooperation in change processes would help to maintain the ability in spontaneous reconfiguration of organisation, in that people are fast updated in new situations. Also barriers in technology and man are better taken care of.

7. **Focus on making clear and understood responsibilities.**

When two or more companies work together regularly, defined responsibilities and clear understanding of responsibilities among actors have to be established. The situation a few years from now may wary well be that vendors are more directly responsible for operation and parts of the barrier system e.g. a vendor may have direct access to parts of the emergency system and another may have direct access to safety critical valves. An example of this was found in the interviews with ABB. They feared situations where personnel at Statoil interfered with their tasks in the SAS system. Such scenario was in the interviews thought to have potential for serious consequences to decision making in critical situations. First of all the actors at vendors and operator should be told and shown the area and tasks they are responsible for, especially in the interface. If work to define and take care of the interface is not done properly it may possibly result in vaguely understood responsibilities. To make a definition of who is responsible for what and to have one head responsible person is also important. Clear responsibilities and access control is especially important if actors have direct remote access to the systems. To establish one best practice for all actors entering the systems can improve this. If several actors have access to the same systems, e.g. the operator and one vendor or two vendors, then procedures need to be made to assure only one actor access at the same time, and that transfer of work from one actor to the next are safe and tidy. Also information to actors about who is having access at the present time is important. This would improve barriers to man and organisation.

Defining responsibilities was a highly important step in Schlumberger's QHSE work towards subcontractors (Alary, 2006). They developed a responsibility matrix to map subcontracting processes and corresponding responsibilities. They realize that coordination between departments was a key element to ensure that critical QHSE processes were incorporated in all contracting processes. Many contractors could be involved and it was important to keep an overview of everyone having tasks and responsibilities to perform.

8. **Use training and practice to become able to make better decisions in critical situations**.

To involve right personnel and warn all actors in critical situation is important for safety in operation. Training can be used to make sure this is understood. Training should especially consider possible incidents resulting in cooperation between several actors to solve a problem. Work processes involving new ways of working and involving several actors should be trained on in relation to deviations and decision making. It is also important to train in using routines and procedures involving cooperation, and the training should involve both vendor and operator. By sufficiently training, responsibilities and activities in the interface will be better understood and also well described formally. This will give the actors a clear understanding of their tasks. This would improve barriers to man in that good knowledge is looked after, and also cultural dimensions in that capability of information sharing are improved.

When designing training scenarios it is recommended to use experiences from Crew Resource Management (CRM) team training. CRM was in the beginning developed by the aviation industry, but has been adapted for use in other settings, such as offshore oil installations. *'CRM involves enhancing team members' understanding of human performance, in particular the social and cognitive aspects of effective teamwork and good decision making. The training is designed to reduce operational errors which could cause an accident, and to give crews additional skills to deal with problems it they are faced with an emergency.'* (Flin, 1997; pp 121). Flin (1997) also gives a number of elements which appear to be particular important for effective team performance in emergency command centres for oil and gas installations; understanding of team roles, communications, group decision making/problem solving, assertiveness, team attitudes, stress management and shared mental models. I recommend including these elements also for raining in collaboration with vendors.

9. **The operator should take responsibility for developing safety in cooperation.**

The operator is the one having the license and being responsible for operation of the oil fields. This will not change in IO, although vendors may be more involved in operation. Therefore the operator needs to be responsible for the overall safety when task are outsourced. This will help to make sure that safety is not neglected in planning and operation. Generally it is important that the actor responsible for safety is the one having authority to affect and make changes to safety. An actor like this is the operator, also in IO. Responsibility for tasks may be shared but the overall responsibility for ensuring that safety is taken care of in the IO, must still be on the operator. Important elements in making IO safe will therefore have to be initiated by the operators. This also means a responsibility for ensuring that vendors are taking necessary safety precautions in IO and in control room cooperation.

Earlier Schlumberger's work towards subcontractors is mentioned (Alary, 2006). Schlumberger took initiative to select subcontractors according to QHSE performance, and to help subcontractors improve QHSE results when necessary. Elements in the initiative were establishment of clear roles and responsibilities and systematic monitoring processes ti ensure compliance and evaluate performance. The initiative contributed significantly to improve QHSE performance. It gave reduction in frequency and severity of subcontractor-related incidents, and created a solid foundation for future improvements.

5.3.3 Aspects to routines and procedures:

Aspects to routines and procedures are affecting both organisational redundancy and spontaneous reconfiguration, and MTO barriers. However, they are most important for structural preconditions in organisational redundancy. Routines and procedures are important to make formal guidelines in organisations and in describing ‘best practices’ in performance. The following suggestions to improvement in routines and interfaces are given:

1. **Routines and procedures for common work should apply across company borders.**

Earlier routines and procedures were an internal matter for each company and often not available outside company borders. When vendors are more involved in operation and some work are common, this may not be adequate anymore. A way of preventing fragmented responsibility to become a safety problem is to have consistency in routines and procedures in operator and vendors companies. Some informants said that routines and procedure *have to apply across company boarders*. Changes to procedures may be in content but at least in how to accomplish them and who is involved. Such changes are most important in routines and procedures for task involving both operator and vendors. This would improve the structural dimension in that possibility for overlapping task and observation is improved, and barriers to organisation in that possibility for organisational redundancy are improved. More people are able to understand and foresee other operators work.

2. **Focus in updating routines fast across companies.**

Procedures have to be updated fast at both vendor and operator. A change in procedures at the operator need to be discussed with vendors and implemented at the vendor to as soon as possible. To day changes in procedures at operators take long time to be implemented in the vendor’s procedures. Having common procedures at vendor and operator may possibly improve this problem, but it is especially important to follow up that changes are implemented at vendors. Especially the ability for spontaneous reconfiguration of organisation is improved by this, but also the structural dimension in that possibility to observe and understand each other are updated fast.

3. **Focus on work procedures and dependencies among them.**

The data acquisition showed that until now development of work procedures in IO was one of the most lacking elements. Important work procedures in IO should therefore be focused on. This involves both procedures for personnel at the operator and procedures for personnel at both vendor and operator. Regarding work procedures for both vendor and operator, ways to cooperate with each other are especially important to consider. In addition to developing work procedures, work has to be done in making procedures and work processes able to function in the interface and connection with each other. Connections between work processes are important to address because when several geographically dispersed actors are involved in tasks it is more difficult to detect poor connections between work processes. Tracing such connections early will therefore improve safety. With IO and also more use of concurrent design it is possible that use of procedures will be used more in parallel, while they earlier were used mostly in sequence. To make this possible and safe work with procedures should also consider adaptation of parallel processes. Making these changes would improve structural dimensions in organisational redundancy in that the possibility to have overlapping task is improved. Also barriers in organisation are improved in that it is moor room for flexibility.

4. **Develop work processes and procedures for readiness.**

Lowered amount of staff offshore may give task conflicts in situations of readiness. But also cooperation of operator and vendor may give task conflicts in readiness. Work processes for readiness are highly important to think through when implementing IO. Especially the procedures and processes to transfer responsibility and change responsibilities are important. Another element that needs to be addressed is the location of responsibility for decision making in situations of readiness. It must be decided where the operative responsibility should be located in situation of readiness; offshore, onshore, vendor or operator. Is should also be decided if this responsibility can be located at several places or if it is necessary to transfer it to just one place. The solution to these challenges is not unique, but no matter what solution is chosen it is important to develop work processes and routines for readiness. And most important to make sure these are understood across actors, also at vendors. Especially the ability for spontaneous reconfiguration of organisation is improved by this. In situations of crisis it is possible to smoothly change organisational model and reallocate responsibility.

5. **Focus on routines for reporting incidents involving control rooms.**

To day there is poor practise for reporting incidents caused by properties in control rooms. The operators in the control rooms, both offshore and onshore, should write down safety critical results of an advice or action he/she did. Practice and routines for reporting incidents caused by IO, especially related to cooperation, should be focused on. Chapter 5.6 describes this more thoroughly. This would improve barriers to man in that improvement of knowledge is better looked after.

6. **The operator needs to check how procedures and work permission works in practice.**

An interesting element with procedures and permissions is to what degree the operator checks the functionality of them in practice. Such checks should be performed and they should especially consider elements missing whit procedures and work permission, things that can result in safety critical situations or things done outside the formal procedures. The operator has the overall safety responsibility and such checks can address important shortcomings to safety. A CRIOP analysis of cooperation may be useful in this. Such verifications will improve structural and cultural dimensions in that they ensure the possibility and capability of observing and understand each others work.

5.3.4 Snøhvit

The data acquisition showed that most of the technological challenges at Snøhvit were solved, while little work had been done in aspects to man and organisation. There was also some scepticism in the interviews about how *the cooperation with ABB* would be. Especially ABB working towards the installations from ARMOR and the communication between the control rooms were mentioned. Making cooperation smooth is much about making solutions for people and organisation. It is therefore important to start making work procedures and work with cultural aspects. This is necessary for Snøhvit to be able to move from being a Low Reliability Organisation to become a High Reliability Organisation. Regarding the general improvements given above, Snøhvit should especially focus on making procedures and work processes. These are some recommended improvements for Snøhvit:

1. **Focusing on technological equipment for communication and cultural aspects for information sharing should be done**. The cooperation with ABB implies people

working together across distance, which can lover trust and make communication difficult. Focusing on technological equipment for communication, that people is able to use the equipment and cultural aspects for information sharing should therefore be done. This would improve structural and cultural dimension in that the possibility and willingness to exchange information is improved.

2. **Definition of responsibilities, best practice and transfer of work should be made.** Personnel in the control rooms both at ARMOR and Snøhvit are not used to cooperate across distance. Responsibilities for actors should therefore be defined, but most important are efforts to make sure actors really understand their responsibility. To take care of possible conflicts in cooperation ‘best practices’ for actors entering and working on the systems should be made. Another important element is to implement procedures in transfer work from one actor to the next, and make sure they are safe and tidy. CRIOP can be used to verify and validate this.

3. **Making, training and testing routines and practice in cooperation should be accomplished.** Given the fact that personnel in the control rooms are unfamiliar with cooperation across distance, training should be used to make sure that right personnel are involved in critical situation and decision making. The training should especially consider possible incidents resulting in cooperation between several actors to solve a problem, and that involve both Statoil and ABB. Also daily operation and use of routines involving cooperation should be tested, for this the scenario analysis in CRIOP is useful. For cooperation and tasks involving both Statoil and ABB consistency in routines and procedures in the two companies should be established.

4. **Work processes for readiness are important in cooperation**. Work processes should consider the location of responsibility for decisions in readiness, what should be done by ABB and what should be done by Statoil. Transfer of responsibility and change of responsibilities in readiness are also important. And most important to make sure these practices are understood across actors.

5. **Implement a practice in reporting incidents caused by IO.** As mentioned earlier there is poor practise for reporting incidents caused by IO in the industry. This is discussed in chapter 5.6. Generally reporting should be done to be able to evaluate and

improve use of control rooms. The control centrals at Snøhvit and ABB should also use this practise. It will then be possible to continuously improve cooperation with ABB.

6. **Use CRIOP in ARMOR and cooperation with ARMOR as soon as possible.** Until now CRIOP has neither been used *in* ARMOR nor for the *cooperation with* ARMOR. Only for the control room at Snøhvit has CRIOP been used. Validating and verifying aspects of cooperation is important in making safe organisations. A new CRIOP is planned close to operation and it is therefore highly recommended that ARMOR is included in this CRIOP and that the e-operation checklist is used. Also Statoil should recommend ABB to use CRIOP in ARMOR.

Accomplishing the improvements given above would ensure better results from the test phase and improve the chance of continued cooperation with ARMOR. It should therefore be focused on accomplishing them as soon as possible.

5.4 Build MTO barriers – especially to man and organisation

Barriers and focus on MTO have already been discusses through the pervious section, 5.3 and in chapter 4.3. In this chapter some additional evaluations of barriers in MTO are given.

Barriers should be considered to all aspects of MTO, and be physical, non-physical, active and passive. The focus in technology has helped in building physical barriers, both active and passive. The low focus in man and organisation means that barriers to these two are lacking. Non-physical barriers like good routines, work processes, and culture are little considered. According to Reasons (1997) ‘defence in depth’ theory, high hazard systems as oil and gas installations should have several levels of barriers and defences to bring the total risk to an acceptable level. Thinking of barriers to all aspects of MTO in IO would help in gaining ‘defence in depth’, meaning that more focus has to be placed in man and organisation.

Equally important is it to include all control rooms in the barrier consideration. IO may imply that more tasks and equipment are taken care of by vendors. Then also barriers have to be taken care of by both the operator and contractor. This in turn means that contractors are

given more responsibility for the work done. Based on this it is crucial to remember that the total system has to represents all necessary barriers across actors.
Although the development has come furthest in technology and many informants said that challenges to technology are not an obstacle for IO anymore, most of the focus is still in technology and technological barriers. To make IO more safe, work should therefore now be done in areas of man and organisation, but also in mutually influence between the three elements. This would make safety obstacles in IO easier to overcome, and possibly reduce the amount of surprises in the future. From an MTO perspective barriers to safety in IO are not sufficiently taken care of. For more predictable results regarding safety, the industry should focus more on barriers in organisation and man.

Snøvhit:

During the interviews the following information were found regarding barriers in cooperation at Snøhvit:

- Mainly there is a focus in technological safety and making the computer systems secure.
- There has been little focus on making work procedures.
- Processes toward shared culture and trust at Snøhvit are not started yet.
- ARMOR and ABB did not participate in CRIOP.
- Another CRIOP is planned closer to operation. ABB and ARMOR are not planned to be included.
- HF analyses are used in the control room at Snøhvit.

As the interviews show all three elements in MTO are considered for the control room located at Snøhvit. This is done through HF analyses and use of the CRIOP methodology. The cooperation with ARMOR was however not considered in these studies, meaning that a highly important part of IO, cooperation, was left out. Regarding ARMOR and Snøhvit there have been a strong focus on making the technological solutions safe, but aspects to organisation and man in cooperation is left out, as the shortcomings in the HF analysis and CRIOP confirm. This means that Snøhvit fits well into the general figure 14 about MTO focus in IO in the oil and gas industry. To verify barriers in cooperation it is important that the next CRIOP looks into work practice for both rooms and that the e-operation check list is used.

The interviews also gave some indications of why work procedures were not focused on:

- A need of more time to let ‘things mature’ before making documents and work procedures.
- Avoid making things that may not be necessary.
- Use the time until operation to gain some experience, which will help in making documentation. It will help decide what documentation is necessary.
- Statoil is still lacking some governing documents about the kind of cooperation that is used with ARMOR. These documents will cover similar types of rooms, not just ARMOR/Snøhvit. It is therefore said to be difficult to make documents of work processes and organisational matters.

The main explanation is to have experience in operation and let ‘things mature’ before making procedures. It is however much likely that ‘things will mature’ in wrong direction if responsibility is not defined early. If bad habits is developed it is difficult to change them afterwards. The possibility of getting poor results from cooperation is also higher. It is therefore highly recommended that work procedures and practices are developed now.

5.5 Use CRIOP as a tool to improve safety in IO

The firs versions of CRIOP were made to cover aspects in one single control room. Both the check lists and scenario analyses were designed to validate and verify aspects inside the control room. An interesting question is therefore to what extent CRIOP is able to validate and verify the new aspects of cooperation between control rooms. During the interviews it was said about CRIOP in IO that:

- The most important elements in IO to be taken care of by CRIOP are; **cooperation, collaboration, responsibilities and interaction**. In IO it may often be the situation that there no longer are only one control room which is doing monitoring and corrections. Two or more rooms may be involved in the daily operation and cooperation. In such a situation it is therefore important to consider both rooms when using CRIOP, both for checking requirements but also that daily work and cooperation are understood.

This means that the collaborating element in control rooms is important for CRIOP to be able to validate and verify. The interviews showed both positive and negative opinions about CRIOP in use for more than one control room:

+ The e-operation check list, although not fully tested and made part of the official check lists, were mentioned to have good questions and were appropriate to use. But doing this one has to remember that the check list *may not* consider every relevant area.

+ It is possible to use good scenarios to verify and validate if responsibility for safety related tasks are taken care of. Perhaps it should be made some new elements in how to build such scenarios.

+ CRIOP is a useful tool. When planning and executing CRIOP all actors having relevant tasks should be participating. This also goes for relevant personnel from vendors and personnel located in other centrals who are involved in the operation. The people actually working in the centrals are essential to invite. Vendors need to be part of CRIOP when their control rooms are part of cooperation.

+ The scenario analysis were mentioned to have especially good potential to check if actors understand tasks they are supposed to do, and the responsibility placed on each location (onshore, offshore, vendor and operator). Regarding scenario analysis it was mentioned to be highly important to involve both (or all) centrals.

+/- It is difficult to verify if responsibility for safety is understood and taken care of by all actors at an early phase. It is possible to make a picture of this with scenario analyses, but to really verify this CRIOP have to be done also during/close to operation.

- Many informants were unsure if CRIOP (including the e-operation checklist) was abele to verify cooperation. **At same time these were informants without experience in using CRIOP in IO, and without knowledge about the new e-operation check list**. Although all the checklists in CRIOP were mentioned to be relevant in IO, they were said not to cover every aspects of IO.

- The check lists may have shortcomings in verifying how cooperation and responsibility actually works. The scenario analyses were mentioned to better for this. One interesting view mentioned in the interview was to what degree it is possible to consider responsibilities thorough standards and checklists. It is important to be aware of the difference in how well procedures are written and the actual practices among workers. According to the interviews the CRIOP checklists are able to verify that responsibilities are defined and taken care of adequately in internal documents, but they are not to the same extent able to check if this actually works for real. However the scenario analyses were mentioned to be useful for checking such practices.

One general observation during the interviews was that actors in the industry did not really consider the e-operation check list as part of the official CRIOP methodology, mainly because the check list is placed as an appendix in the methodology. People were thinking about it as not fully developed and therefore not appropriate. This may also be a reason why some people in the industry did not think CRIOP as a tool capable of validating and verifying IO elements like cooperation. Because of the good experiences and thoughts about CRIOP as a tool for cooperation in control room, and because cooperation geographically dispersed is a highly important part IO, it is important to do something about the industry's awareness of the e-operation check list and CRIOP as a tool in IO. Although some aspects in IO may not be covered in the methodology ye, it is no excuse for not using CRIOP in IO. It is only by using it and gaining experience it is possible to improve and correct present shortcomings. There are anyway already many good elements in CRIOP capable of validating and verifying cooperation, collaboration, responsibilities and interaction. Especially the scenario analyses were mentioned as a useful tool for checking up on elements in cooperation. CRIOP should therefore be used in the industry. This would increase the focus of cooperation as an important element to address in control rooms.

Some observations about the timing of CRIOP and HF analyses were made in the interviews. It was said that:

+ **The timing of doing CRIOP at Snøhvit was considered good**. CRIOP were used in the project phase 'detailed engineering'. This was a bit too early in that many questions could not be answered and the scenarios were difficult to make realistic. However this is supposed to be considered in the next CRIOP. The analysis resulted in some corrections. Some of them were taken care of and some of them accepted.

+ **Informants at Snøhvit said the CRIOP analysis was useful and that they were satisfied with it**. It helped them to verify that the control room design fulfilled requirements and wishes. Also the multi-disciplinary team work was useful. Issues were raised which would probably not be discussed otherwise.

-/+ HF analyses were done before the CRIOP analysis in the Snøhvit project. **This gave some major changes that were expensive and difficult to gain acceptance for.** The HF analyses were said to be carried out to late in the project. It was difficult make changes when the control room were already planned and made illustrations of. However the most important changes were taken care of. It was mentioned that the changes would have been less expensive if they were made earlier. The changes and costs of CRIOP were minimal. If however HF analyses were not done in front of CRIOP the cost of changes from CRIOP were considered to be much higher.

- Difficult to design good scenarios in the CRIOP at Snøhvit at such an early state. Operators had not used the systems and control room yet. All checklists were used but it was not possible to answer all the questions in them, especially in the checklists job organisation, procedures and work descriptions and training and competence. Most of these elements were not considered yet.

- There is a general tendency in Statoil that HF analysis is made a bit late in projects, making it difficult to get accept for changes in the control room design. But because of the HF analyses, the CRIOP analyses were said to usually result in few corrections.

These answers indicate that the results of CRIOP are often quite good and that there often are small changes to them. This is because HF analyses are performed earlier in the projects. The HF analyses however are often performed a bit too late in projects and it is therefore difficult to gain acceptance for changes in design. By doing such analyses late in the process it is costly to make changes and it may be difficult to get understanding for why the changes are necessary, although the changes may be important to safety and reliability. It is highly important that such analyses are performed at a time making it possible to implement necessary barriers and functionality to man, technology and organisation. The interviews also stress the importance of making more than one CRIOP. It is difficult to answer every aspect of CRIOP at an early state but at the same time it is necessary to perform CRIOP early to have the possibility of changing shortcomings. A later CRIOP is necessary to be able to validate and verify aspects not finished at an early state.

Based on the discussion above the following recommendations are given:

- Accelerate the work with making the e-operation check list part of the main checklists. This is important for the industry to start using CRIOP as a tool in cooperation.

- CRIOP with the e-operation check list and suitable scenarios should be used by the industry to verify and validate cooperation in control rooms. Cooperation is a highly important part of control rooms in IO and tools like CRIOP should be used to train and check elements related to this.

- Make HF analyses early in the process, to be able to get optimal design regarding all aspects of MTO. Making a CRIOP is also important to verify and validate that the planed design is good. CRIOP analyses should be made both early in the process to be able to correct faults and later in the process to verify that the end design actually are good.

One other possible recommendation is to look into the possibility of making an e-operation example for the scenario analysis. This could increase actors’ awareness of the scenario analyses as a useful tool to validate cooperation, and how to use CRIOP in IO.

5.6 Improve practice in registration of IO incidents

An interesting observation during the data acquisition, and especially the interviews, was that not much information was found about IO incidents related cooperation and use of control rooms. It is natural that incidents regarding cooperation with vendors were lacking since there are no vendors participating in remote support towards Stjørdal. The support rooms at Stjørdal do not have real time cooperation with control rooms at vendors, nor are there any vendors located in the control rooms at Stjørdal. What is more surprising is that operators in the centrals at Stjørdal had few examples of incidents caused by cooperation between Statoil's own centrals either. Examples of unwanted consequences of cooperation between onshore and offshore were not given. One of the explanations in the interviews to this finding was that incidents had not occurred because of good preparation of tasks. Such preparations were made by simulations of all critical tasks before actual accomplishing them. Still it is strange that no such incidents or at least near incidents were mentioned.

The data acquisition however shows another possible reason for the lack of incidents, a lack of practice to register incidents caused by cooperation in IO. This was said in the interviews:

- **The present way of documenting faults and unwanted incidents in IO are insufficient**. The existing systems for learning and reporting faults (Synergi and 'Rapport Uønsket Hendelse' (RUH) etc.) are shoving weaknesses in IO, especially for control rooms onshore. The systems are not being used by personnel in these centres.

- **Poor practise showed by control room operators offshore** to use the reporting systems. They are at the top of the decision chain and rather solve the occurred problem than writing down what happened.

Because of this it is also difficult to trace and remember incidents. The existing systems for learning and reporting faults are shoving weaknesses in IO, especially for control rooms onshore but also for such rooms offshore. The systems are not being used by personnel in these centres. The PSA confirmed this fact and said that it is low possibility of finding a reported incident describing, for example the consequences of an advice given in a control room. Today there are very few reports from control room operators describing incidents caused by their work.

If this observation represents the usual practice across control rooms in Statoil, it shows major weakness in the possibility to improve IO work in the centrals. As Statoil's steering principle, the PUFF (Planlegge, Utføre, Følge opp, Forbedre)[7] circle says, one shall work with continuous improvement in activities. This circle is built on the theory of Deming's circle (Wig, 1996), which illustrates the learning process as a cycle from planning to correction. In CP2 Ledelse og Styring (Statoil, 2002)[8] the circle is illustrated like this:

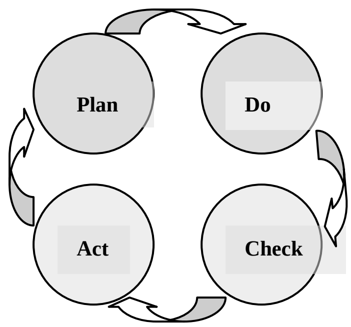

Figure 18: PUFF – Planlegge, Utføre, Følge opp, Forbedre

The principle says that all activities shall have defined goals and be systematically followed up through the phases: planning, execution, check and correction. The steps may be viewed as a learning process. To achieve improvement it is necessary to follow the sickle all the way around. By rotating the circle several times continuous improvement is achieved. If learning or improvement is not achieved the circle is terminated to early or some of the steps are repeated without being accomplished properly. In the planning phase (Plan) goals about what to achieve and plans about how to get there is made. In the step marked 'Do' the plan is executed. In the step 'Check', an assessment of the status is made, i.e. if the plan is followed and if the goals set will be met. In the last step, 'Act', corrective actions are made, i.e. actions to get on track in reaching the goals. It is also important to sum up experiences. After this the whole process is repeated.

[7] Described in the governing document CP2 Ledelse og styring (2002).
[8] Governing document in Statoil

The PUFF principle is important to follow if cooperation between control rooms is to be improved. If the practice of reporting and documenting incidents caused by the control room is lacking, as the data acquisition indicates, an important step in ensuring totally rotation of the PUFF circle is missing. Only if incidents are recorded is it possible to investigate, look for patterns and correct important shortcomings. It is also important for control room operators to get used to thinking about how their work in the centrals may trigger incidents. Deviations and errors produce opportunities for learning, and to register such errors in a reporting system improves this learning process. This gives an opportunity to correct shortcomings, as faults in design or insufficient routines, and by that fulfil all the steps in PUFF. Better practice in documenting incidents where control rooms are involved should therefore be developed.

As mentioned in chapter 2.5, Argysis (1992) makes the distinction between single-loop and double-loop learning. If practice in reporting and documenting accidents and incidents to IO are missing, the opportunity for the organisation to have double-loop learning is highly reduced, and it is most likely that only single-loop learning will occur, se figure 22:

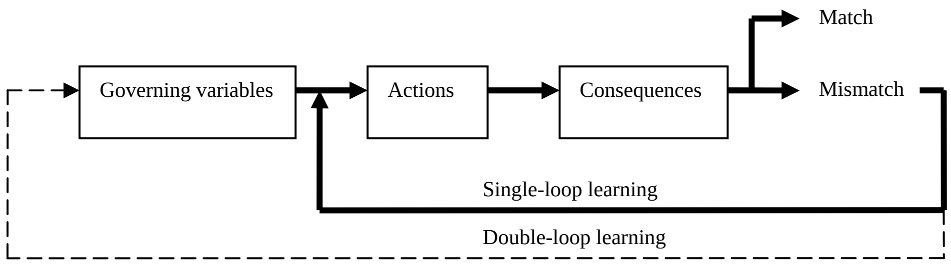

Figure 19: Only single-loop learning in control rooms

If operators do not have any culture for register and describing incidents caused by the control room and interaction between control rooms, it is most likely that opportunities for the organization to learn and make improvements are lost. The opportunity to spot repeating faults in practice, systems and routines are small and therefore is little chance of changing the governing variables. Variables like design, procedures or work organization.

According to Van Court Hare (Kjellén, 2000) the situation is characterized by feedback control on level zero and level one. Incidents are not documented, but there is a possibility to correct deviations identified by accident investigations or safety inspections. Corrections are made on an individual and incident level. Feedback control on level three and four are less likely. Because incidents are not registered there is little chance to change routines, design, policy and goals after the incident.

This shortage to fulfill the PUFF principle and double loop learning is also a shortage to safety in IO. It is a shortage because lacking elements in safety are less likely to be spotted and corrected, and therefore important barriers both in man, technology and organization is also lacking. The possibility for an organization to learn and improve is highly important to able to spot and take care of shortages to safety. If this possibility is lacking it will much likely affect safety negatively. Better practice in documenting incidents where control rooms are involved should therefore be developed.

5.7 Improve experience transfer from project to operation and between projects

The PROMIS (Project Model in Statoil) gives the steps and requirements to projects in Statoil. As figure 5 illustrates a project evolve in time through decisions gates. After decision gate 5 there is a phase called ‘conclusion phase’. ‘*The conclusion phase is the phase in the project model where the experiences made in the project are documented and lessons learned transferred to the organisation*’ (Statoil, Project Model in Statoil; PROMIS – a common framework for projects in Statoil; pp11). The conclusion phase is described to contain, among other things, hand-over of experiences and preparation of final experience report. The purpose of this is to ensure that the organisation has access to, and is able to learn from the experiences made, and the competence achieved in the project.

PROMIS clearly states that experience transfer is an important part of projects in Statoil. However the interviews indicated that experience transfer is often lacking between projects. Relevant finding in the interviews are:

- An experience report was not developed after an IO project at HNO.
- Generally experience reports are seldom made.

- A pre-study looked into IO solutions at other fields and a report was made of possible solutions at Snøhvit. Some persons visited Stjørdal and looked at the centres in HNO. There is little written documentation about experiences used.

It seems like little information about lessons learned in other projects are use when IO projects are started. One similar shortcoming found in the interviews is lack of experience transfer and learning between project and operation. Projects in Statoil are organized such that different persons are working in the projects and in operation. Possibilities to observe the chosen solutions in daily use are therefore often lacking. The people responsible for design and technological solutions are not able to observe how their solutions actually work. Important possibilities for continuous improvement are therefore lost.

According to the case study description made in chapter 1.2 figure 20 illustrates the situation in many projects.

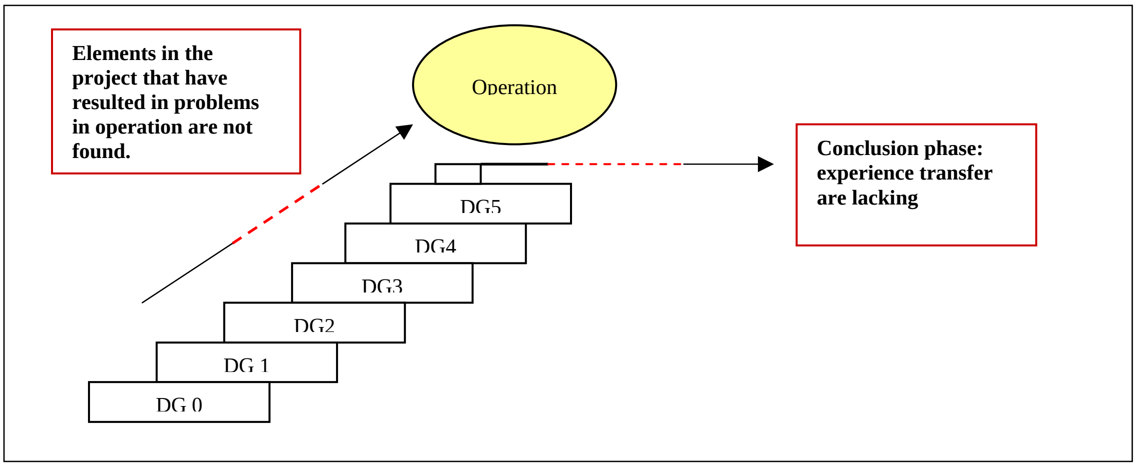

Figure 20: Lack of experience transfer

Both Snøhvit and HNO fit well into the situation described in figure 20. Experience transfer from other projects is lacking.

As figure 20 illustrates there are shortcomings both in awareness of experiences transfer between project and operation and between projects. Experience transfer as described in PROMIS is usually not accomplished. This is an important finding. If shortcomings in experience transfer are lacking, the process of improving design and solutions between

projects are difficult. Important possibilities for continuous improvement are lost. Regarding safety it is more likely that the same problem will occur several times in different locations. Improving experience transfer and use of PROMIS is therefore highly important. By doing this it is more likely that shortcomings in all aspects of MTO will be improved.

5.8 Use important experiences from other fields and industries

Some work in documenting experiences with control rooms has already been accomplished in Statoil, and a report is made bout experiences from a selection of fields. The report is however internal and confidential, but I was allowed to use some of the findings given that the fields and report were kept anonymous. The following finding are retrieved form this report. Confirmation about these findings can be retrieved from Dr. Vidar Hepsø in Statoil[9]. Most of the experiences were about how cooperation between control rooms *in* Statoil have been useful and given better and more effective decisions. But also examples of effective video conference with vendors were given. It is therefore likely to believe that collaboration (use of control rooms) towards vendors may also be effective. Important experiences are:

1. **The possibility to become more effective in daily work through support/control rooms are dependent on; choice and use of ICT-solutions, shape and use of room, change of work processes (ways of working) and how the change of work processes are managed. The interviews showed that implementing work processes at an early stage gave best utilization and results of collaboration in control rooms.** These are all important experiences. In particular, such experiences are also found in HNO. It was mentioned in the interviews that people form Snøhvit had been visiting HNO to learn from their experiences. It seems like it is mainly technological solutions and building facilities that are focused on in this visit, while work processes are left out. Change of work processes is important in gaining effective collaboration in the centrals. Snøhvit have not focused on this, leaving out an important lesson learned in HNO. It is therefore highly important for Snøhvit to start making work procedures and processes for people in the control rooms at Snøhvit and ABB.

[9] Dr. Vidar Hepsø, VIHE@statoil.com

2. **Old habits and practice may be used even though new ICT solutions are implemented. In such a situation the possibilities in new technological solutions are not utilized fully.** At one field the control room had given small changes in work processes. It was observed how the room were only used to share screen picture during discussions. The actors were thinking about not destroying good work practice established through many years of operation. They tried to perform work the same way as before with the use of new technology. These were also the workers not satisfied with the effects of using support rooms. This is another example of how important it is for Snøhvit to start thinking about work procedures and practice.

3. **To avoid interfere with important work in the control rooms, rules about what to be done inside the room and what to be done outside the room should be established (especially if the room is used as daily work place).** The support rooms which have made such kind of rules had positive experiences with it. Rules like how to use mobile phones, what kind of conversation to take outside the room, private work and so on. Awareness of how to use the control rooms are important to establish also at Snøhvit and ARMOR.

4. **Operators in control rooms may get a 'stage-feeling' when entering the room, especially for people not having daily work place in the room. Some people may not feel the visibility of entering 'the stage' comfortable.** In some fields it was observed that people were standing at the walls and sneak forward to talk in the microphone, while others thrived and enjoyed being visible. The open, unlimited and transparency in such rooms may felt like a barrier for some people, especially outsiders. This aspect to man (M) is a challenge for use of control rooms. It is probable that such situations are more likely to arise in control rooms where different companies are cooperating, like at Snøhvit. If people do not know each other and each others cultures, entering the 'stage' may be more difficult. Given the fact that such problems have been observed in Statoil, these aspects should be considered at Snøhvit too. Efforts should be made to overcome this barrier as soon as possible. Efforts should be made in making people in the centrals, both people having their daily work space there and people working there occasionally, get to know each other.

5. **Insufficient teaching in equipment may give poor utilization of equipment in cooperation.** There were examples of poor utilization of panels because operators did not know how to use them. Especially the smart boards were not used. This is an important experience that should be considered at Snøhvit. Knowing how to use equipment for cooperation is important for personnel at Snøhvit and ARMOR. CRIOP should be used to verify and validate this.

6. **Important factors for effective utilization of support/control rooms are; continuous online connection and for the operators to have their regular work place in the control rooms. It gives pro-active rather than re-active work.** This means that the online connection between centrals is not turned of when not in use, and that operators should have their daily work place inside the room. Support rooms practicing this were more pro-active than re-active in work, and could fast and easy mobilize knowledge and experts when needed. Problem solving and decision making were made faster. This effect were not to the same degree found in control rooms not using continuous online connections and the rooms as daily work place. This is an important experience for Snøhvit to consider in cooperation with ABB.

7. **Closeness, communication, trusts and to avoid rivalry were important to make good relations between offshore and onshore.** Also a hint that work practice and aspects to man should be addressed at Snøhvit.

8. **The most important elements for technological solutions and building facilities are:**
    - High quality video and rear-projection screen should be used. It is also important to avoid laud fans.
    - Transparency in rooms which means using sound absorbent glass walls and doors in stead of sound absorbent opaque materials.
    - Possibility of having day light and using light colours at walls.
    - Tables placed in V shape adjusted to video facility and to support cooperation.
    - Support tables for looking at papers and folders and folding seats at walls.

In addition to the above experiences found in Statoil, some findings in my autumn project, '*Erfaringer med fjernstyring*' (Andersen, 2005) about experiences with remote operations is important to consider:

9. **It is important to have sufficient personnel in the control rooms**. Low manning in control rooms were not mentioned as a problem in the interviews, nor was it an impression in the industry that minimum manning in the control rooms were a goal. This might be because of high profit and good economical results in the industry at present. Experiences from other industries however show that too few people in the control rooms often lead to problems. High work load and fatigue were found to give safety critical incidents. It is therefore recommended to focus on appropriate amount of staffing, even though decrease in profit or operators availability becomes a problem. It is important that the control room operators are able to handle their tasks without to much stress. Too many tasks often gives situations were messages and important information are lost.

10. **It is important for control room operators to be able to improvise and show flexibility in tasks**. This was found to be important for the ability to spontaneously reconfigure the organisation. Multi disciplinary competence and ability to know which resources (both human and technically) are needed is important qualities. It must be focused on the control room operators' ability to improvise in unexpected incidents. To accomplish this it is important to focus on understanding of other operators' tasks, creativity and technical skills.

The ten lessons above are all important experiences in future design of control rooms. Using experiences from other projects and industries will probably help improving safety in IO.

5.9 Use properties in Virtual Organisations to improve safety

Virtual Organisations (VO) has some of the same characters as IO. Theories in how safety in VO is taken care of are therefore interesting to explore to improve safety in IO. In chapter 2.4 a description of VO were given. Virtual organisations are organisations comprised of multiple, distributed members, temporarily linked together for competitive advantage. Implementation of G2 processes implies integration of operator and vendor centres, and probably participation in daily operation by both of them. VO is supported by distributed information technology and it is possible to work together independent of geography, which is true for IO as well. The last important property in VO is shared value chains and business processes. If this is true for IO as well is more uncertain.

Advantages to VO include adaptability and flexibility - the ability to respond quickly to market changes and ability to form and dissolve relationships with other members of the virtual. Adaptability and flexibility may be compared with the property to spontaneously reconfigure the organisation in HRO. The ability to form and dissolve relationships with other members is important in IO to be able to make use of the best vendor or expert, and to change them if needed. A goal in IO is to make it possible to change and connect to different vendors dependent on who is able to best fulfil the tasks. This makes temporary linkages between the distinct organisations important to have.

Below some important risks propensities in VO are given. These propensities are also important to be aware if when taking care of safety in IO:

Tasks and technology:

VO considers tasks and technology to possibly be inherently risky. This is also true for IO. Task, e.g. oil exploration, executed by distributed member of the virtual organisation is risky. The technology used to execute task, e.g. drilling equipment, is also complex and may be inherently risky. Safety efforts to tasks and equipment should therefore be taken care of. As the discussion in previous chapter shows, safety efforts to technology are well taken care of.

Human and organisation:

VO considers human and organizational error as part of VO. Human and organisational errors can continue to propagate in organizations as long as humans and organizations are a part of them. Therefore such errors must be considered when making barriers and taking care of safety. As the data acquisition showed, problems caused by humans and organisation are highly relevant in IO, and less effort have been done in these areas than in technology. Suggestions of how to take care of this are given in previous sections.

Organisational structures:

Organizational structures in organizations may make risk mitigation difficult. This is also an element found in the data acquisition as a threat to safety. Examples of how organisational structures may be a threat to safety are:

- Virtual management structures can reduce physical oversight and contact.
- Organizational relationships presumably based on shared commitments to safety may not be equally shared among members of a virtual organization.

These two points are considered earlier in discussions about fragmented responsibilities and that safety (HSE) coals and systems need to be more common.

Organizational culture:

Different organisational cultures in the companies may send confusing or contradictory messages to members about risk tolerance. No information was found about this in the data acquisition and this aspect is not considered earlier in the thesis. It is however an important element and should be part of part of the improvement suggestions:

- ***Make sure that culture and messages about risk tolerance in the organisations are consistent.***

If this is not taken care of actors in the organisations may have different agendas when accomplishing tasks, e.g. safety bulletins that celebrate the number of accident free days while the organization simultaneously rewards workers for flaunting safety practices and ‘living on the edge’. This of coarse may give that some actors are doing tasks not consistent with the organisational wishes.

Migration of risk between organisational members:

Because virtual organizations are distributed, networked organizations with fluid and shared business processes, risk in the virtual organization can migrate between organizational members, making risk identification and mitigation difficult. These aspects are to some degree considered in that responsibility for barriers and tasks may be difficult to gain oversight to when several companies cooperate. ***The fact that VO defines migration as a potential problem strengthens the suggestion that efforts should be made in defining responsibility.***

Individual goals, policies and cultures:

It may be the case that members have their own individual goals, policies, and cultures. Members are bound in temporary alliances and developing a shared culture of reliability and shared commitments to reliability goals is difficult. ***Even though it is difficult to achieve shared goals and culture, it is an important aspect. All actors cooperating in IO should have shared coals and cultures to safety. Being aware of the difficulties is important and tells us that goals and cultures needs to be constantly followed-up.***

The risks propensities to VO above have identified some important areas for safety in IO. Many of these areas were already considered in the data acquisition and some of them made improvement suggestions about. But there are also some aspects in VO that are not considered for IO yet, but that give some clues to what may become threats to safety in the future. New elements are;

1. ***To make sure that culture and messages about risk tolerance in the organisations are consistent.***
2. ***Risk migration is likely to become a potential safety problem which strengthens the suggestion that efforts should be made in defining responsibility.***
3. ***Achieving shared goals and culture it is an important but difficult aspect. Being aware of the difficulties are however important and tells us that goals and cultures needs to be constantly followed-up.***

5.10 Conclusion

First of all there are many possibilities in IO to improve safety. Some of the most important elements are to make it possible to use vendors' expertise and to have the best people make decisions. The technological solutions make it possible to cooperate independent of distance, and to make use of a wide range of experts. If cooperation with vendors is taken care of the right way it may have positive impact on safety.

HRO is not achieved in IO at present. The data acquisition indicated that both elements in structural and cultural aspects of organisational redundancy were lacking, and also some shortcomings to spontaneous reconfigurations of organisation. Much of this is because of a thorough focus in technological solutions while solutions for man and organisations are not developed to the same degree. This situation is also valid for Snøhvit. It was found that IO at present are characterised as 'Low Reliability Organisations' rather than HRO. To correct this, as well as shortcomings in MTO, some recommendations should be considered.

First of all a general recommendation to political issues are given, which means working with making the organisation ready to accept necessary changes in IO. Second recommendations to cooperation and interfaces are given. Effort in building trust between operator and vendor should be made. Also efforts to aspects of communication are necessary, which means both equipment for communication, capability of using the equipment, and cultural aspects for information sharing. When several different companies and operators are working remotely towards the same installations, focus on procedures for permission is important and also focus on making clear and understood responsibilities. It is also recommended to use training and practice to become able to make better decisions in critical situations. To look into the possibility of using common safety goals and plans, and establishing common scorecard with vendors are suggested. Actively using vendors HSE management to prevent fragmented responsibility to become a threat to safety is another possibility. Last but not least, it is highly recommended that the operator takes responsibility for developing safety in IO, which means they are also have responsible for considering safety aspects towards vendors.

Recommendations in aspects to routines and procedures are also given. It is recommended that routines and procedures for common work apply across company borders, and that it is focused on updating routines fast across companies. Another recommendation is to focus on developing work procedures and processes for readiness when vendors geographically dispersed are involved. Last, it is suggested that the operator needs to check and evaluate how procedures and ‘work permission’ function in practice.

Similar recommendations are made for Snøhvit to correct shortcomings to HRO and MTO. Firs of all they are recommended to focus on technological equipment for communication and cultural aspects for information sharing. Defining responsibilities, best practice and transfer of work with ARMOR should be accomplished. Making, training and testing of routines and practice in cooperation should be done. Also for Snøhvit work processes for readiness in cooperation are important, and to implement a practice in reporting incidents caused by IO. Last it is highly recommended to use CRIOP in ARMOR and cooperation with ARMOR as soon as possible.

Regardin MTO, more focus on barriers to organisation and man is needed to get more predictable results in safety. At Snøhvit all three elements in MTO are considered for the control rooms located *at* Snøhvit. This was through HF analyses and use of the CRIOP methodology. The cooperation with ARMOR was however not considered in these studies, meaning that a highly important part of IO, cooperation, was left out. Regarding ARMOR and Snøhvit there have been strong focus in making the technological solutions safe, but aspects to organisation and man in cooperation is left out. To verify barriers in cooperation it is important that the next CRIOP looks into work practice for both centrals and that the e-operation check list is used.

Because of the good experiences with CRIOP as a tool for cooperation in control room, and because cooperation geographically dispersed is an important part of IO, CRIOP should be used in the industry. It is also recommended that work with making the e-operation check list part of the main checklists is accelerated. HF analyses are recommended to be executed early in the design process, and CRIOP should be made both early in the process to be able to correct faults and later in the process to verify that the end design actually is good.

To improve shortcomings in double-loop learning and have better opportunity to improve safety, improved practice in registration of IO incidents related to control rooms is recommended. A similar finding in how to improve safety is to improve experience transfer from project to operation and between projects. Experience transfer as described in PROMIS is usually not accomplished, and practice for this should be improved. With these shortages important possibilities for continuous improvement are lost. Regarding safety it is more likely that the same problem will occur several times in different locations.

An important element in improving safety in IO is to use important experiences from other fields. During the study some experiences were found. The most important is that the possibility to become more effective in use of control rooms are dependent on; choice and use of ICT-solutions, shape and use of room, change of work processes (ways of working) and how the change of work processes are managed. The interviews showed that implementing work processes at an early stage gave best utilization and results of collaboration in control rooms. This is another reason why Snøhvit, and other IO fields, should start developing work procedures. Important experience from other fields in Statoil is not taken into consideration.

Last properties in VO should be used to improve safety. Taking a perspective of VO some elements not yet considered were found. It is important to make sure that culture and messages about risk tolerance in the organisations are consistent. Also risk migration is likely to become a potential safety problem which strengthens the suggestion that efforts should be made in defining responsibility. Last achieving shared goals and culture it is an important but difficult aspect. Being aware of the difficulties are however important and tells us that goals and cultures needs to be constantly followed-up.

Part four: Summarization

6 Summarization

This chapter summarises important findings and conclusions, evaluates work during the study and gives suggestions about further work.

6.1 Main findings and Recommendations

This thesis is based on the present development in the oil and gas industries, use of integrated operations (IO). New technological solutions, especially in information and communication technology and real time data, make it possible to restructure oil and gas fields. The traditional split of tasks between people onshore and offshore, vendor and operator is not as obvious anymore. Transitions to use of IO imply new ways of organizing work, both offshore and onshore. Based on this, the purpose of this study was to investigate how use of IO affects safety related conditions in the oil and gas industry. Since IO covers many aspects delimitations had to be made. In this thesis IO is related to cooperation between control rooms and cooperation across distance involving vendors. A case study was made about Snøvhit and cooperation with ABBs control room ARMOR. Therefore, the main focus is on safety related collaboration between STATOIL and ABB, but general findings for the industry regarding cooperation and safety in IO are also given.

To answer the problem two research questions were stated:
R1: How does use of IO affect the level of safety?
R2: How can IO improve the level of safety in the oil and gas industry?

R1 was answered before R2. R1 explored the actual impact on safety in IO, and showed some areas with shortcomings. These finding, among others, were used in answering R2, how to improve the level of safety in IO. In the following the main results and recommendations are given.

6.1.1 The impact on safety in IO

First driving forces in IO and safety as an element of this were explored. It was found that even though safety (in HMS) is proclaimed as important in governing documents in Statoil, it is not a driving force in IO. Nor is it an initial stated goal in IO. Improved safety was often mentioned as a benefit of IO, but little information about why and how IO would improve safety were found. Based on low awareness in the industry about how IO can enhance safety, it is uncertain if IO will have this particular effect at all. The lack of focus in how to achieve better safety trough IO will probably affects safety negatively.

Next threats and possibilities to safety in IO, i.e. cooperation with vendors, were identified in the report. How IO will affect safety is depending on how threats and possibilities are taken care of. It is important to make plans to avoid threats and make sure possibilities are realized. For vendor cooperation and cooperation in control rooms this is usually not done, not at Snøhvit either. Because of this it is more likely that the threats will occur and the possibilities fail to appear.

In the study an analysis of MTO aspects on safety was made. It showed highly unequal focus in the three aspects. The main focus was in technological solutions which helped defining and correcting drawbacks to safety in technology. On the other hand a lack of focus in organization and man was found. Although IO is affecting all three elements in MTO only safety perspectives in technology are well taken care of. This means that safety barriers are lacking in organisation and man, which makes it highly possible that surprises and negative effects to safety will occur related to them. Also low focus in how the three elements in MTO influence each other will probably have negative effect on safety. At the present state IO is therefore having negative effect on safety in aspects of man and organisation.

Given the above findings it is more likely that surprises and negative effects in safety will occur, and that IO will affect safety negatively.

Recommendations:

- Increased safety must be one of the main goals in IO implementation. This would increase the possibility of actually getting good results in safety. It would make it more certain that improved safety is actually achieved.
- Identify threats and possibilities and make plans in how to take care if them, as well as making plans in how to improve safety through IO. This would increase the possibility of actually getting good results. In this study this is done for control room cooperation, but it also should be done for other areas in IO.

- More focus on safety and barriers to man and organisation is needed, and on mutual influences among them. This would improve the present negative impact IO has in these areas.

Generally these recommendations imply an increased focus on safety, and that the level of safety is dependent of how much the industry is focusing on safety.

6.1.2 Use of IO to improve safety in the oil and gas industry

First of all it is important to be aware of the possibilities in IO to improve safety. Seven main categories of possibilities to improve safety were found; IO gives a possibility to have better awareness on how work is done and that best people are making decisions**.** The technological solutions in IO make it possible for operators to have one standardized and familiar interface in their control or control rooms, and to share information. Closer cooperation with vendors is possible. If this cooperation is well taken care of it may have positive impact on safety. It is also a possibility for vendors to have safety (HSE) management according to operator's requirement, and IO may be used to improve the total safety (HSE) management. Implementing IO gives a possibility to evaluate and improve present routines, and it is a possibility to build common and good culture both socially and technologically. Being aware of possibilities in IO to improve safety is highly important to utilize the safety potential fully. Taking care of these possibilities and make sure them are realized is therefore important in gaining to improve safety in IO. This should be done in IO projects. By realizing these possibilities vendor cooperation will have positive impact on safety.

Aspects of HRO were used to make recommendations of how to improve safety in IO. If use of IO in the oil and gas industry could help building HRO it would be a major advantage to safety. An assessment of the present characteristics of IO, also at Snøhvit, showed that there are some elements lacking according to HRO. Therefore there are also some important elements missing in IO to be able to take care of safety in an adequately way. The present situation showed that IO can be defined as a Low Reliable Organisation, and that most elements needed to improve shortcomings in HRO are in cultural aspects and structural dimension, while spontaneous reconfiguration is better taken care of. Some recommendations in how to improve shortcomings in HRO and MTO (found in the previous chapter) were given:

Recommendations:

- General improvements in ‘political aspects’ should be made. This implies focusing on the change process and worker involvement. See 5.3.1, a-d.
- Improvements in aspects to cooperation and interfaces must be made. It is recommended to focus on trust between operator and vendor, and to focus on aspects to communication (both equipment for communication and cultural aspects). Next procedures for permission should be addresses, and use of common safety goals and plans at operator and vendor. It is also recommended to cooperate in change processes and to focus on making clear and understood responsibilities. Use of training and practice to become able to make better decisions in critical situations is also important. And at last the operator must take responsibility for developing safety in collaboration. See 5.3.2, 1-9.
- Improvements in aspects to routines and procedures should be made. It is recommended that routines and procedures for common work should apply across company borders, and to update routines fast across companies. Next it is recommended to look into routines and dependencies among them. It is also recommended to develop procedures and processes for readiness, and to focus on routines for reporting incidents involving the control rooms. Last it is recommended that the operator checks how procedures and work permission actually works in practice. See 5.3.3, 1-6.
- Some special recommendations for Snøhvit were made. Most importantly to have better focus in cooperation aspects to safety. Snøhvit should especially focus on making procedures and work processes for cooperation, and to make ARMOR part of a CRIOP analysis. See 5.3.4, 1-6.

Regarding MTO barriers more focus should be placed on barriers in man and organisation. Thinking of barriers in all aspects of MTO in IO would help gaining ‘defence in depth’. Equally important is it to include all control rooms in the barrier consideration.

Verifying and validating cooperation in control rooms are important and CRIOP were found to be a useful tool in assuring safety in IO. CRIOP may have some shortcoming in ability to handle every aspect of cooperation, but it has a lot of positive and good elements, making it important that the industry start using it. Also the timing of CRIOP an HF analyses were found important.

Recommendation:

- Accelerate work with making the e-operation check list part of the main checklists. CRIOP, with the e-operation check list and suitable scenarios, should be used by the industry to verify and validate cooperation in control rooms. Make early use of CRIOP to be able to implement necessary barriers and functionality to MTO, but also use it close to/in operation to be able to check every aspect of work and design in the control room. In general HF analyses need to be performed earlier in the projects.

A general shortage was found in lack of practice to report incidents caused by work and cooperation in the control rooms. Because of this shortcoming in reporting culture, the control room operators are missing an important possibility to evaluate consequences, learn from experiences and make improvements of their actions. Therefore experience transfer and organisational learning in IO is insufficient. Organisational learning is more characterized as single loop learning while it should be characterized as double loop learning.

Recommendation:

- Make routines and practice for reporting incidents caused by the control room or involving the control room operators.

Shortcomings in experience transfer between projects, especially related to PROMIS (Project Model in Statoil) were found, but also shortcomings in experience transfer form project to operation. This is an important finding. If experience transfer between projects is lacking important possibilities for continuous improvement and organisational learning are lost. Regarding safety it is more likely that the same problem will occur several times in different locations.

Recommendation:

- Improving experience transfer between projects and use of PROMIS.

Experiences from other fields showed that it is essential that work procedures and practice is developed early, and in parallel with technology, to gain good results in cooperation and use of control rooms. Still there is low focus on developing work processes across control rooms, also at Snøhvit.

Recommendation:

- Work procedures and work practice for ARMOR and Snøhvit should be developed now. Early development (and change) of work processes should be part of all control room projects in Statoil. To make sure these procedures and processes are understood, and that responsibilities are taken care of, testing and training in should be done. It is recommended to use CRIOP and especially the scenario analyses for this.

By using properties of virtual organisations (VO) some important safety aspects in IO were identified. Many of these areas were already considered in the data acquisition and some of them made improvement suggestions about. But there were also some safety aspects in VO not considered yet, and that gave clues to what may become threats to safety. These are aspect like risk tolerance, risk mitigation and shared goals and culture.

Recommendation:

- Take care of safety aspects related to VO. It is recommended to make sure messages about risk tolerance in the organisation are consistent, and to be aware of risk migration as a potential safety problem. Efforts should therefore be made in defining responsibilities. Last it is recommended to focus on achieving shared goals and culture in the cooperating companies. See 5.9, 1-3.

6.2 Conclusion

The thesis describes how use of IO affects the level of safety and how IO can improve safety in the oil and gas industry. In the study IO is limited to cooperation geographically dispersed across several companies (operator and vendors).

In the first research question 'How does use of IO affect the level of safety?' three main elements are important. First of all safety has not been an initial stated goal in IO nor is it a driving force. Second threats and possibilities to safety in IO; i.e. vendor cooperation, are not mapped and addressed. Third IO affects all three elements in MTO, but only safety perspectives in technology are well taken care of. Which means that safety barriers are lacking in organisation and man, and that IO at present are affecting safety negatively in these two. Based on these three elements the effect on safety, by use of IO, has some major challenges. The impact on safety in IO is dependent on how much the industry focuses on safety, and how the three elements above are addresses. However, given the present situation, it is more likely that surprises and negative effects on safety will occur.

Given the shortcoming above an interesting question is how safety can be improved through IO. This is addressed in research question two; 'how can IO improve the level of safety in the oil and gas industry?' First of all there are many possibilities in IO to improve safety. Some of the most important elements are to make it possible to use vendors' expertise and to have the best qualified people making decisions. The technological solutions make it possible to cooperate independent of distance, and to make use of a wide range of experts. If cooperation with vendors is appropriately taken care of it will most likely have positive impact on safety.

HRO is not achieved in IO at present. The data acquisition indicated that both elements in structural and cultural aspects of organisational redundancy are lacking, and also some shortcomings to spontaneous reconfigurations of the organisation. To correct this situation some remedial actions should be considered. I recommend focusing on worker involvement, cooperation and interfaces and aspects to routines and procedures. For Snøhvit it is highly recommended to use CRIOP for cooperation with ARMOR as soon as possible.

To get more predictable results regarding safety in MTO, more focus on barriers to organisation and man is needed. To verify and validate cooperation and barriers in MTO it is important that CRIOP and that the e-operation check list is used for all control rooms involved.

CRIOP were found to be an important tool in assuring safety in IO. CRIOP, with the e-operation check list and suitable scenarios, should be used by the industry to verify and validate cooperation in control rooms. Also the e-operation check list should be made part of the main checklists. CRIOP analyses should be made both early in the process to be able to correct faults, and later in the process to verify that the end-design is good. In general HF analyses need to be performed earlier in the projects.

Practice and routines in registration of IO incidents related to control rooms should be made. This would give better opportunities for improving safety and improving shortcomings in double-loop learning. Improving experience transfer from project to operation and between projects is also important for safety. With this shortage, important possibilities for continuous improvements are lost. An important element in improving safety in IO is to use experiences from other fields. The data acquisition showed that implementing work procedures and processes at an early stage gave best utilization and results of collaboration in control rooms. This is another reason why Snøhvit, and other IO projects in Statoil, should developing work processes in parallel with technological solutions.

Last properties in VO should be used to improve safety. Taking a perspective of VO some elements not yet considered were found. Like the importance of making sure culture and messages about risk tolerance in the organisations is consistent, and that risk migration is likely to become a potential threat to safety and therefore needs to be followed up.

6.3 Evaluation of the study process

This discussion is based on the concepts in chapter 3.4.1, credibility, verification and transferability in results.

Credibility is about mapping and evaluating possible sources of errors in the research material. During the work I had the possibility to work in Statoils research environment in integrated operations at Rotvoll, and had possibility to discuss findings and problems with my supervisor and other persons in Statoil. I had two teaching supervisors during the work, one of them working with IO in Statoil and the other working as a researcher at SINTEF. My work is naturally influenced by their opinions and views. This has strengthened the possibility to avoid errors in the research material. It also made it easier to get important and essential information through documents and discussions with people, who were updated on the present development in IO.

To be able to get external opinions about the objective I have tried to involve persons in other parts of the oil and gas industry as well as people in other departments of Statoil. The questionnaires were evaluated by en independent researcher at SINTEF, Camilla Tveiten, who has experience from work in the oil and gas industry and CRIOP. By doing this, I got a third-party evaluation of a highly important prerequisition for the work; the questionnaire has been the base for most of the collected data.

At the end of writing the thesis one person in Statoil and two persons at SINTEF read the thesis and gave an evaluation of the content. It was important to involve people at Statoil to get the findings verified, and most of all to get a validation and verification of the recommendations made. Involving researchers at SINTEF was important to receive an independent evaluation related to the adequacy of the thesis' scientific work and approach, but also the findings and recommendations. By doing this I have tried to discover and avoid possible errors in the research material.

Verification is about whether the thesis actually answers the questions given, or whether the research gives correct answers. It is also about the quality in data and the interpretations made. During the study I have tried the best to assure good quality and accuracy in the work.

This was especially important during the interviews. In order to obtain the best possible basis of information, the interviews were carried out with as different persons from the oil and gas industry as possible. In the report I have also mainly tried to use findings from interviews confirmed or mentioned by more then one informant.

A count for criticism is that more informants from each sector and company could have been contacted. There are many important stakeholders in the oil and gas industry and some of them are only represented in the interviews with one informant. This was a deliberate choice based on available time and resources. I decided to talk to as many actors or stakeholders as possible, in stead of concentrating on only people in Snøhvit and Statoil. However many of the same aspects to safety were mentioned among the informants, and it brought a balanced view of IO into the work. It is therefore not seen as a major weakness that the informants in the interviews were picked out broadly. The verification however would have been better if more people from each company/stakeholder were interviewed. Another cont for criticism is that recommendations are limited to problems identified in interviews and documents. This is no guarantee for all relevant areas being covered. There may very well be other important safety elements in IO not considered in this report.

Because IO may imply several aspects, from technological solutions offshore to change in work practice onshore, it is difficult to answer questions about safety in IO fully. To make it possible to answers the research questions given and to give good answers to the questions, delimitations in focus were made. By focusing mainly on cooperation across distance and companies in control rooms I hope to have gained verification in results. But by doing this many aspects in safety in IO were left out, meaning that only a small part of safety in IO is answered. This part is however answered thoroughly.

An explicit discussion of the thesis coverage of research questions and objectives are given in section 6.4.

Transferability is important for the possibility of transferring results to similar cases. The thesis has had a split focus, both IO in general and Snøhvit in particular. During the work it was observed that findings in particular and findings in general were much the same. It is therefore likely to believe that the results at least are transferable to other fields and IO projects in Statoil. Depending on the state of IO development in other companies, many of the recommendations may be transferable to other oil and gas companies.

6.4 Verification of Research Questions and Main Elements

In chapter 1.1 two research questions and some main elements to cover in the report were given. It was also described how the main elements are answered by the research questions. In this section a discussion about whether the thesis answers the main elements set up to be covered by the work is accomplished.

The first element, ‘map the status/experiences with use of IO this far in the oil and gas industry’ is answered in chapter 1.3, thorough the present status according to G1 and G2 processes. It is also answered in chapter 1.2 in the case study description of Snøhvit. Element two ‘investigate if there are areas that are negatively exposed from a safety related perspective when IO is introduced’, is answered in research question one (chapter 4). In general it was found that several areas may be exposed because safety has not been an initial stated goal in IO. In particular areas to man and organisations are negatively affected because they at present are not considered as well as technological solutions. The element is also partly answered in research question two where it was found that HRO is not achieved in IO at present i.e. IO have negative effect on organisational redundancy and ability to spontaneously reconfiguration of organisation. Element three ‘investigate if outsourcing to vendors may have positive effect on safety when IO is used’, is answered in research question two (chapter 5.1). Several possibilities to improve safety by using vendors were found. Making sure these possibilities are accomplished would give positive effect on safety when outsourcing tasks to vendors. Element four ‘identify areas that have shortcomings or needs extra attention’ is answered both in research question one (chapter 4) and research question two (chapter 5). In chapter four it was found that barriers to man and organisation were lacking and needs more attention. Also increasing the focus on safety and making plans in how to improve safety in IO needs attention. In chapter five it was found that lacking elements in HRO needs more attention, and that attention should be given to experience transfer in IO. Element five ‘give suggestions and recommendations for improvement when IO is used, among other things towards CRIOP’ is given in research question two (chapter 5). Recommendations are given in improving aspects of MTO and HRO, both in general and at Snøhvit. Also recommendations related to experience transfer, use of experiences from other IO projects and use of characteristics in VO are given. Recommendations in use of CRIOP are given both during the discussion of the other mentioned recommendations (especially for Snøhvit), and separately in chapter 5.5.

6.5 Further work

During the study some area of interest outside the delimitations of the thesis were seen. Areas important to consider in work with safety in IO.

IO includes a lot of elements. This thesis has only looked into a small part, cooperation across distance involving vendors. A similar study of safety should be done in other areas too, especially a mapping of possibilities and threats to safety, as well as how to handle them, is important.

A future aspect of cooperation found, was the possibility of vendors having their own subcontractors working through their control rooms towards the operator. This makes the situation more complex and responsibilities more difficult to handle. Safety aspects according to this situation should therefore be looked into.

Not much information about how cooperation and work in control rooms actually works was found during the study. This is however important information to be able to improve cooperation and design of control rooms and work processes. A more thorough study of this should therefore be accomplished. Both positive and negative experiences as well as and causes of incidents and accidents should be looked into.

CRIOP was found to be a useful tool in verifying and validating cooperation between control rooms. The aspect of making good scenario analyses can however be difficult. I therefore recommend to loo into this more thoroughly. The scenario analysis needs to be able to really check that responsibilities are understood and that there are no problems in communication.

In this thesis I have recommended to train in collaborating with vendors in control centrals. I have also said that it should be used experiences from CRM training. This kind of training has already been used for control rooms in oil and gas installations, but not as much for collaborating between control rooms. I therefore recommend explore this more thoroughly, i.e. how to use CRM to train in collaboration across distance involving vendors and control rooms.

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APPENDIX A: Interview guide

Introduksjon

1. Litt om oss/meg og oppgaven samt målsetting med intervjuet.
2. Informasjon om intervjuet: båndopptaker, ca 45 min

Bakgrunn

3. Stilling, ansvarsområde, gjort tidligere?
4. Erfaringer med, og tilknytning til, arbeid med IO?

Dagens bruk av IO

5. Hva legger du i begrepet IO?
6. Hva er dagens bruk/status av IO?
7. Hvilke aktører er involvert?
8. Hvilken rolle har underleverandører her?
9. Hva er drivkreftene bak/hva ønsker man å oppnå med IO? *
10. Har IO økt eller senket sikkerhetsnivået, hvordan?
11. Stilles det krav med tanke på sikkerhet når underleverandører skal ta seg av oppgaver?
    - Er disse kravene forstått?
    - Har det vært problemer med dette?
12. Eksempler på episoder/historier i forhold til uønskede hendelser?
    - Hva var årsakene til dette (rotårsak og årsakskjeder)?
    - Hvilke konsekvenser hadde hendelsen?
    - Hvilke forbyggende og skadebegrensende barrierer eksisterte?
13. Prosjekterfaringer som har gitt ulemper/problemer i driftsfasen med IO?
14. Måtte planene/løsningene endres underveis i etableringsfasen, hvordan?
15. Har løsningene blitt endret etter oppstart, hvordan?

Fremtidig bruk av IO

16. Hvilke suksesskriterier må oppfylles/hva er grunnpilarene?
17. Hvilken utvikling ser du for bruk IO?
18. Hvilke ulemper og muligheter har IO for sikkerhetsnivået?
19. Hvilken organisering av oljefelt vil IO gi?

  - Hav og land
  - Operatør og leverandør

20. Hva vil IO si for samarbeid med underleverandører (pos og neg)?
21. Vil utfordringene ligge på tekniske, menneskelige eller organisatoriske forhold?
22. Kan du peke på konkret forslag til forbedringer (MTO)?

Økt tjenesteutsetting

23. Hva er de størst mulighetene og truslene tjenesteutsetting gir?
24. Har man pr i dag sett noen sikkerhetsmessige ulemper med tjenesteutsetting?
25. Hvordan bør sikkerheten ivaretas i grensesnittet operatør/leverandør?
26. Vil økt bruk av tjenesteutsetting ha implikasjoner for sikkerheten mtp:
    - Samsvar rutiner og prosedyrer?
    - Kommunikasjon mellom aktører? *
    - Fragmentert ansvarsforhold mtp sikkerhet?
    - Adgangskontroll på systemene?
    - Felles kunnskap og oppdatering om aktørers arbeid på systemene?
    - Beslutningstaking ved kritisk hendelse?
    - Ansvar for tilsyn og kontroller?
27. Hvor/hos hvem bør sikkerhetsansvaret ligge?
28. Hvem tar ansvar for sikkerheten og sørger for at det blir implementert?
29. Er samarbeidet pr i dag mellom leverandør og operatør tilfredsstillende?

Erfaringsoverføring

30. Brukte dere erfaringer fra andre IO miljø i prosjektfasen?
31. Deler dere driftserfaringer med andre IO miljø?
32. Har erfaringer fra prosjekterings- og driftsfase blitt benyttet ved etablering av andre lignende anlegg?
33. Har dere benyttet erfaringer fra andre bransjer eller selskaper ved utforming av sentral og arbeidsprosesser?

34. Med tanke på informasjonsdeling og -systemer:
    - Hvilket system for rapportering av hendelser brukes, og fungerer det som et bra læringsverktøy og til erfaringsutveksling?

  - o Trengs det felles standarder og informasjonsrutiner når det gjelder rapportering av uønskede hendelse og lignende?

Annet

- Er det noe innen temaet du ikke føler er dekket av spørsmålene?
- Ser du andre relevante vinklinger som det ikke er spurt om?

Spørsmål om CRIOP

a) Hva vil IO si for bruk av CRIOP-analyser?
   - o Er det områder av CRIOP som ikke lenger egner seg like godt?
   - o Hvor er det nødvendig med oppdateringer, konkrete forslag?

b) Hvilke elementer ved IO (også fremtidig) er vanskeligst og håndtere med CRIOP?

c) Hvem har ansvaret for å gjennomføre CRIOP-analyser og hvem bør være er med på planleggingen av dem?

d) Når underleverandører blir mer involvert i driften, må disse inkluderes i CRIOP på en annen måte?

e) Er CRIOP i stand til å omhandle samhandling skikkelig?

f) Kan CRIOP sjekke:
   - o Om ansvar for alle sikkerhetsrelaterte elementer/oppgaver er ivaretatt?
   - o Om ansvaret for sikkerheten er ivaretatt og forstått hos alle aktører?
   - o Om rutiner og praksis for kommunikasjon mellom aktører er gode?
   - o Om fordeling av funksjoner mellom kontrollsentraler og mellom aktører er godt ivaretatt?
   - o Om systemet for læring og erfaringsoverføring mellom aktører er godt?
   - o Om det eruklarheter i ansvarsfordeling mellom aktører?

35. Når i prosjektet ble CRIOP gjennomført?
    - o Ble e-drift sjekklista brukt?
36. Burde CRIOPen vært gjennomført på et annet tidspunkt (tidligere/senere)?
37. Hva var resultatene av CRIOPen?
    - o Store endringer på designet?
    - o Viktigste resultater?
38. Hvordan har CRIOP blitt benyttet?

- Som verifisering i etterkant av kontrollromsutforming?
- Hjelpemiddel under utforming?

39. Hvilke positive og negative erfaringer har man med CRIOP i IO sammenheng?
40. Ble det foretatt HF-analyser i designfasen?
    - I så fall hvilke?
    - Når i designfasen?
41. Hvilken kjennskap har du til e-drift sjekklista?
42. Kan e-driftsjekklista ivareta samhandling mellom flere kontrollrom?

APPENDIX B: Results form interviews

This appendix summarises important information found during the interviews. To structure the information some main categories important to the research questions are used, and information found placed in these categories. Information found is not split on the two research questions. See chapter 3.3 for information about the informants.

The driving forces towards IO implementation:

4. **Financial aspects**
   - Smarter ways to run processes and installations during operation will give more oil and gas from the reservoirs and therefore get better financial results.
   - It will give reduced cost of operation.
   - Higher profitability.
   - Lover the costs by better utilization of available technology.
   - Increased income.

5. **Competitive advantages**
   - A wish to be the leading country in IO, and develop solutions that can be leading in IO implementation in other countries. A way of getting market shares in the future.
   - The need and wish to be a part of the development in IO. Some informants pointed out that the rationalie behind this decision was not sufficiently assessed in all operator companies. Not all of them have made goals and plans for what to achieve with the new tools, technology and ways of working. It is more like buying equipment and building control rooms just to be part of the IO trend.

6. **Efficiency in operation**
   - A reduced need to make timely and costly transportations of people.
   - Enhanced availability on scarce human recourses which give reduces time to solve problems.
   - Better and more effective use of available technological solutions.
   - Better utilization of data and information.

7. **Decision making**
   - Possibilities to find the best people/knowledge to solve problems and thererfore make better decisions.
   - Integrated operations will give faster response because it is possible to use vendors and experts located other geographical places.
   - Effective decisions because it is possible to solve problems remotely and to do that in multidisciplinary teams.
   - Utilization of technological solutions to make decisions faster.

<u>IO effect on the safety level (enhanced or lowered):</u>

Answers to effects on safety were given in factors that have enhanced and factors that have reduced safety:

Elements that may enhance the safety level:

1. **Reduced transportation** of personnel because of possibilities to use experts independent of geography, and located at both vendor and operator.

2. **Less people may be located offshore** and by that less people are in immediately connection with the hazards.

3. Better awareness on how work is done and **that right people are making decisions**.
   - Technological solutions make it possible for personnel at different locations to see the same information and documentation about a problem which will make it easier to gain a common understanding of and solve the problem.

   - Personnel both onshore and offshore have support through IO from necessary disciplines and experts. Fast and various supports from experts make it possible to solve problems faster and before they evolve into critical incidents. This will make it possible to avoid critical situation more effectively and by that avoid accidents.

   - Closer contact between expertise offshore and onshore gives a broader focus on uptime and optimal solutions.

4. Operators are working through one **standardized and familiar interface** in their control or support rooms. They don't have to travel and work on several different installations, many of those they may not be familiar with. This may reduce the risk of doing wrong actions because of unfamiliar surroundings.

Elements that may give reduced safety:

1. Distance to experts and physical installations can result in communication problems and **poor understanding** of the problem.

2. The distance and separation of operator and vendor may lead to problems with **trust**.

3. **Computer and network security**. These technologies are becoming much more complex with IO and the operation is more dependent on it.

4. Virtual intruders are more difficult to spot and **access control** on computer and technical systems may be a problem.

5. Misunderstood effects and solutions of **change processes** in IO (especially for old installations). This may give changed roles and responsibilities that result in misunderstood practice, especially in situations of crisis.

6. Operators with **poor knowledge** who are giving "work permission" may be a problem if the operator gives permission and the depth knowledge is located at the vendors.

7. **Fragmented knowledge** to systems because of spread tasks and responsibilities may give poor understanding of the total picture.

8. New ways of managing operative work may give substantially new risks, in **complexity** and in the way distinct elements of work processes are connected. Connection that is difficult to follow and understand.

9. **High focus in operational perspectives** and solving operational challenges (as the situation in many projects today is) will not guarantee that the risk level in operations is improving.

Safety requirements and safety aspects towards vendors when they are responsible for tasks:

Requirements towards vendors in general:

- **Work procedures and practice** are not considered as well as requirements towards safety in technological aspects.
- Safety requirements in **computer and network** technology were considered good towards vendors.
- **Technological barriers** are well planned or taken care of.
- **Work permit**. Permission is given by the operator before anyone outside the site can work on the systems. No one is allowed access to work on the systems without this permission.
- Procedures to **approve changes** on the systems or installations before they are carried out.
- Vendors are bound to follow **Statoil's governing documents.**

IO implications on cooperation with vendors:

- One overall comment is that to make IO successful the cooperation has to be ***highly improved in comparison with current situation***. There were given some prerequisitions for good cooperation:

  - Better trust was mentioned as an important element, and working with reducing the scepticism and differences often is seen between operator and vendor.
  - Establishing procedures and practice on team work.

- Regarding processes toward shared ***culture*** and trust at Snøhvit the interviews indicated that these processes are not started yet. Some informants pointed out that to be able to sit in the same or different rooms and cooperate, require personnel who feel safe and confident in themselves, colleagues and their surroundings.

- Elements in cooperation that may have positive effects on safety:
  - Better **cooperation, communication and follow-up** because of closer cooperation with vendors.
  - It will give **faster response** form vendors and possibly reduce the time to solve a problem.
  - More **involved vendors** who are experts in their fields.
  - More focus on cooperation which possibly **improves the climate and barriers** for makeing contact.
  - Joint technological solutions and dedicated channels facilitate vendor and operator to share information which **improves the cooperation and communication**.
  - **Training** was highlighted to build confidence in cooperating.
  - To build common and good **culture** both socially and technologically.

- Elements in cooperation that may have negative effects to safety:
  - An over focused desire from vendors to make profit from IO may lead to **lost focus in keeping an effective virtual organisation**.
  - Operator **lose control of which vendor is involved**, especially if many vendors are involved or they are often changed.
  - Lacks of **trust** in vendors because of rapid changes in personnel at vendors.
  - IO implies more integrated organisations which may give new kind of problems in cooperation because of **different cultures, language and expressions** used.

<u>Examples of incidents related to vendors and challenges in tracing incidents:</u>

In the case of Snøhvit and the cooperation with ABB there are accounted any experiences about this yet, but some experiences were collected form HNO.

- Results so far (from the interviews in HNO) indicate that there are ***no incidents related to IO***. The interviews revealed that the main reason was that they made simulations of critical tasks before actual accomplishing them.

- In general there were given examples of ***situations in relation to information security***, or the lack of it. There are examples of platforms with downtime because of wrong signals or viruses.

- The PSA mentioned that they during supervisions of alarm systems had observed control room operators with **poor and varying understanding** of alarms and functionality in systems.

- One example of ***problems towards vendors was communication***. The operator and vendor were discussing a possible cooperation. The two parts were from different industries and had different ways performing tasks, therefore they did not understand each other, nor did they see how each of them could benefit from the cooperation. The discussion therefore only turned out to be about costs. The process ended with no agreement.

- During the interviews it was mentioned some major ***challenges in the area of tracing incidents related to vendors***:
  - **Investigation** of incidents in an IO setting will represent a challenge with the present investigation methodology and understanding of work processes.

  - The relations between **formal and real decision making** will differ more than to day. The capability and possibility to make decisions further down in the organisation will increase because of better knowledge and the possibilities IO gives for actors to understand a wider par of the business process. Many companies in the industry observe that actors are now seeing connections and relations that only onshore engineers were aware of earlier. More actors can then make decisions not formally located at their organisational place.

  - Some interviews shoved a concern that it will be **more difficult to understand incidents**. There is a need of R&D projects in this matter and the development of some models for how to understand incidents in IO.

  - The present way of **documenting faults and unwanted incidents in IO are insufficient**. The existing systems for learning and reporting faults (Synergi and ‘Rapport Uønsket Hendelse’ (RUH) etc.) are shoving weaknesses in IO, especially for support or control centres onshore. These systems are not being used by personnel in these centres.

- **Poor practise showed by control room operators offshore** to use the reporting systems. They are at the top of the decision chain and rather solve the occurred problem than writing down what happened.

<u>Organisation of oil fields with extended use of IO:</u>

Many informants believe that offshore organisations will become smaller and personnel relocated at shore. Other expected that there are few consequences to offshore staffing. Despite this there was agreement in some elements:

1. There will be **separate developments in old and new fields and installations**. New projects, like Snøhvit, will be based on unmanned installations and remotely controlled from control rooms onshore. Old platforms and installations will mostly remain manned. Some reductions are expected in the manning level, but the extent of this is not clear. It was in the interviews argued that in some old installations will be to difficult and expensive to implement new technical solutions for and to make them remotely controlled. It was argued that as long as some personnel have to be onboard it is only reasonable to also have the leadership and responsibility offshore. For many old installations the onshore centre will function as support while at new installations the onshore centres will function as controlling and decision element.

2. **Vendors are taking care of more tasks**. Tasks earlier performed by the operator will be shared between operator and vendor. At least when it comes to equipment and monitoring. The overall responsibility for daily operation and safety will still be placed on the operator. The vendors will take responsibility for their own equipment and the equipment they are experts in. In this situation the informants pointed out that it is important to make sure that responsibilities for tasks are understood by all actors.

3. There is now a squeeze in the labour market for competent people, and it is a challenge for companies to employ enough people with the right knowledge and education onshore and offshore. One prediction in the interviews were that the **companies with success in the future will be those who succeed in using their one and vendors competence in a smart way**. To have strong vendors and work with them in an integrated

organisation is a key factor here, and important in successful future fields. Cooperation between operator and vendor may by also contribute in solving the problem of labour market squeeze.

Challenges with IO related to man, technology or organisation and suggestions to improve this:

According to the informants the main lacking element or challenging elements to organisational factors was:

- Lack of focus in **work processes and ways/practice** to cooperate with each other.
- Poor focus on **change processes**.
- More focus in **common understanding** of the systems. Whether it is an old or new organisation it will be difficult to gain an overall and good understanding of the systems when they are fragmented, virtual and geographically spread.
- **Interactions between work processes**. In addition to making these formal and structural, work has to be done in making work processes able to function towards other work processes.
- Work processes may be constrained by **operational limitations** and this have to be considered.
- **Political processes** not considered good enough.
  - How to relocate personnel offshore to work onshore, few people offshore will be able to find new jobs in oil and gas where their home is.
  - Problems in changing work schedule and models for salary. All these are important factors to offshore personnel in the industry. It also becomes important to success in IO when the same personnel are being part of the changes that IO gives.

According to the informants the main lacking element or challenging elements to technological factors was:

- **Standardisation** of data
- Common **standards** in ICT security
- **Sensors**. In the case of sensors this has sown to be more difficult than first thought because of conditions in pressure, temperatures and chemicals used.

- It may be difficult to implement IO in old installations because they are **not built for these changes**. IO will extend the lifetime of installations, an extension they were not built for. It may not be enough space on the installation to implement the new equipment or it may not be arranged for the necessary changes.

Suggestions on how to improve insufficiency in MTO:

- **Redundancy** in networks, **good routines** and **barriers**
- Create **good procedures** and work with **cultural aspects**.
- Organisational improvement by becoming more **tasks oriented** and tear down organisational walls. It is important to make **dialogue**, **communication** and sharing of **responsibility**.
- Organisational: make suitable **solutions for tasks**, scenario based solutions. It is important to **train** in ways of collaboration, both normal and deviational situations. To fully take into consideration IO vendors should be involved in these processes.
- Make the **whole organisation part of the changes**, not just the easy accessible people onshore. Problems with involving the organisation offshore to the same level as the organisation onshore are mentioned as a problem in the oil and gas industry.
- **Map risks and consider consequences.**
- Make good **change processes** and take care of the **humans** involved.
- **Communication from top management** on the importance and implications of IO processes.
- **Involve experts in MTO**, people who know how to work with organisational, man or technological challenges. Let them meet and work in cooperation to make solutions that involve all relevant MTO elements.
- Collect and use experience from **other industries**.
- Change projects trigger adaptation processes of personnel. In change processes also **take care of/manage the adaptation process of people**. The adaptation process should be managed by working with trust and participation of partners and stakeholders.
- Work with **HSE management** to make a common understanding of HSE consequences in the organisation, and how to manage and work with potential risks and threats.
- Make **plans in how to better HSE** through IO. Elements in these plans should be:

- How to make work processes.
- How to take care of the cooperation with stakeholders and vendors.
- How to change and develop the HSE management system to IO.
- Better follow-up of barriers, development of plans and goals in HSE.
- Ways to manage data and information.
- Ways of doing critical operations.

<u>Learning and experience transfer between actors:</u>

The ***present systems, routines and models for learning and experience transfer were identified not to be adequate*** for IO.

Some suggestions in how to take care of learning and experience transfer:

- The **vendors are integrated** in the organisation, treated **openly** and accepted as part of the organisation.
- **Regular and daily contact** ensures that experiences are shared and information is given.
- Organisations like NPD, PSA and OLF are arranging **forums and project** in IO topics across stakeholders in the industry.
- The need of a **common system and common practice for sharing of experienced** was pointed out. Such a system makes it possible to locate all information the same place. The informants said that such a system should be used across locations and actors. The system for reporting of incidents may also be considered as the system for experience transfer.
- When making common systems for sharing of experiences the importance of **involving control room operators and operators working with such systems** today were mentioned. These actors know how such a system should look like and what kind of information is needed.
- Establish **regular meetings** for discussing experiences relevant to all companies involved in operation. Preferably based on incidents and information in a common reporting system. The importance of having all actors preparing relevant experiences to the meeting was pointed out. This will help giving a common understanding of happenings and that all companies capture important experiences.

- It will be necessary to improve **competence** in managing and using systems for experience transfer.
- At Snøhvit there will most likely be made a new systems for collecting experiences, systems similar to FEM.
- An experience report was not developed after an IO project at HNO.
- Generally experience reports are seldom made

Major possibilities and threats to safety observed in IO and when vendors take care of tasks:

The following possibilities and threats were mentioned in the interviews:

Possibilities:

- Using experts for increase efficiency. Letting vendors take care of tasks in which they are experts in give the possibility of having **the best personnel do the work**, and therefore be more effective and getting more work done.
- Give better **regularity** and use of recourses.
- Possibilities for finding **faults faster**.
- An opportunity for vendors to have sufficient resources or initiative to manage HSE as well as the operator, or be able to follow up and have an **HSE management according to the operator's requirements**.
- IO may be used to make the **HSE management better**. The operative HSE management also have to be located onshore in the operation centres. Use of operative HSE management systems and HSE information has to be actively used also onshore. This is important for successful implementation of IO when it comes to HSE. Personnel onshore and offshore need to have a shared interest in having common models and common understanding of their own and others work, common understanding both in operationally matters and the risk that surround it. This can be done in having the same requirements for using and follow the HSE management systems both offshore and onshore.
- Possibility to **evaluate and improve present routines**. Continue with good elements and improve shortages.

Threats:

- If not sufficient focus is placed on responsibilities that may give a situation where **responsibilities** to operator and vendors are not clear.
- A **complex or fragmented** system or organisation. It is therefore important to have focus on simplifying and keeping a broad view in the IO change project.
- It may be **too much information** and data available to personnel.
- A too complex organisation to have a **complete understanding** of during operation. This also may lead to fragmented and incomprehensible responsibilities.
- Complexity in safety systems and **integrity problems** in the constructions.
- Vendors separated from the installations or operator's organisation may lose feeling of **ownership** for the systems and tasks they are doing. Involving them in organisational decisions is mentioned as a way of making ownership.
- **Poor information sharing** because of reluctance to give other companies information. Many companies will only give information if they receive similar kind of information in return, information considered to be sensitive or competitive. It may be difficult to see how information actually gains both companies if actors are used to be reluctant towards information sharing.
- Different location of personnel may decrease the **trust**.

<u>Safety in the interface between operator and vendor:</u>

The following were mentioned to build safety:

- **Building trust** will build safety. Elements mentioned build trust:
    - Good (change) processes for implementation of IO.
    - Common understanding of what to achieve with IO.
    - Common language and information.
    - Early clarification of responsibilities.

- **Procedures for permission** have to be made.
- Vendors should be shown the **area and tasks** they are responsible for, especially in the interface.
- **HSE management and HSE systems as a way of ensuring safety in interfaces**. Some important elements in this:

- HSE goals, plans and indicators should be developed in cooperation with vendors. Goals and plans should be a joint document.
- Common goals and plans in operational matters. To ensure a common understanding and integrate vendors in the organisation, operational goals and plans should also be made in a common discussion and written in a common document.

- **Cooperation in change processes**. Information in the interviews showed that to day operators and vendors mostly are doing change processes separately. Vendors are doing changes because of changed contracts from operator or internal wishes to perform better. To manage the interface given in IO the following suggestion were given:
  - Change processes should be a more common process.
  - The decision to change, coals and important elements in the process should be a join decision.

<u>Allocate the safety responsibility:</u>

At the present stadium the overall safety responsibility are placed on the operator or the license. In the interviews there was broad agreement in that this **responsibility also in the future had to be placed on the operator**, and that it had to be located **on site** close to the actual installations. Still it was pointed out that ***dividing*** **and delegate tasks are not the same as dividing the safety responsibility**. Dividing and delegating tasks and make use of vendors are considered an important element in IO.

<u>Snøhvit and ARMOR:</u>

General:

- **Little use of experiences from other IO projects**. A pre-study looked into IO solutions at other fields and a report was made of possible solutions at Snøhvit. Some persons visited Stjørdal and looked at the centres in HNO. There is little written documentation about experiences used.
- Cooperation with ABB and ARMOR is **a pilot project**. The test phase is supposed to start in May (2006) and proceed a year.

- **An evaluation is performed after the test phase**. The evaluation will tell if the cooperation with ARMOR was successful and worth carry on.
- The interviews showed **some scepticism** in how the cooperation with ARMOR would be. Especially ABB working towards the installations from ARMOR and the communication between the control rooms were mentioned. These elements will also be part of the final evaluation.
- ABB is supposed to work together with Statoil in developing and writing down **procedures**, although this activity has not started yet.
- There has been **little focus on making work procedures**.

The reason why work procedures had not been focused on yet:

- A need of more time. Time to let "**things mature**" before making documents and work procedures.
- Avoid making things that **may not be necessary**.
- Use the time until operation to **gain some experience**, which will help in making documentation. It will help to see what documentation in necessary.
- Statoil is still lacking some **governing documents** about the kind of cooperation that is with ARMOR. These documents will cover similar types of rooms, not just ARMOR/Snøhvit. It is therefore said to be difficult to make documents of work processes and organisational matters.
- Some documentation has to be Statoil's, some both Statoil's and ABB's and some just ABB's. This is difficult without having the necessary governing documents. It was also mentioned to be **difficult to see what should be made by whom**.

Requirements in operation:

- Informants in Statoil mentioned that the focus towards ABB on safety requirements and **safety elements was well taken care of**.
- Mainly there is a **focus in technological safety** and making the computer systems secure.
- A concern that **other vendors** were not as well taken care of and followed up. This may be vendors not having a control room like ARMOR.
- **Access control**. There is access control to the vendor's (ABB) control room and on the systems inside ARMOR. (It is however not clear if this safety barriers are charged

by the operator or vendor self. In the interviews it seemed like this was procedures made by the vendor without any guidance from the operator).

CRIOP and IO:

The questions about CRIOP can be summarizes in the following categories: shortcomings in the present methodology, ability to verify cooperation and the potential for use in IO.

Potential for use in IO:

- The **e-operation check list**, although not fully tested and made part of the official check lists, were mentioned to have good questions and appropriate to use. But doing this one have to remember that the check list may not consider every relevant area (because of the unfinished test phase).
- The most important element in IO to be taken care of by CRIOP were said to be **cooperation, collaboration, responsibilities and interaction**. In IO there may often be the situation that there no longer are only one control room which is doing monitoring and corrections. Two or more centrals may be involved in the daily operation and cooperation. In such a situation it is therefore **important to consider both central when using CRIOP**, both for checking requirements but also that daily work and cooperation are done well.
- Many informants were **unsure** if CRIOP (including the e-operation checklist) was **able to verify cooperation**. At same time these were informants without experience in using CRIOP in IO.
- Regarding scenario analysis it was mentioned to be highly important to involve **both (or all) centrals**. The scenario analysis were mentioned to have especially good potential in checking if actors understand what tasks they are supposed to do, and the responsibility placed on each location (onshore, offshore, control rooms onshore, vendor and operator).
- When planning CRIOP **all actors having relevant tasks should be participating**. This also goes for relevant personnel from vendors and personnel located in other centrals who are involved in the operation. The people actually working in the centrals are essential to invite.
- **Vendors need to be part of CRIOP** when their centrals are part of cooperation.

- It is possible to use good **scenarios to verify if responsibility** for safety related tasks are taken care of. Perhaps it should be made some new elements in how to build such scenarios.

Shortcomings:

- It is difficult to verify if **responsibility** for safety is **understood** and taken care of by all actors at **an early phase**. It is possible to make a picture of this with scenario analyses, but to really verify this CRIOP have to be done during operation.
- One interesting view mentioned in the interview was to what degree it is possible to consider responsibilities thorough standards and checklists. It is important to be aware of the **difference in how well procedures are written and the actual practices among workers**. According to the interviews the CRIOP checklists are able to verify that responsibilities are defined and taken care of adequately in internal documents, but they are not able to check if this actually works for real.

<u>CRIOP at Snøhvit:</u>

- ARMOR and **ABB did not participate** in CRIOP.
- **Another CRIOP** is planned later closer to operation. ABB and ARMOR are not planned to be included.
- CRIOP were used in the project phase **"detailed engineering"**.
- CRIOP was used to **verify the control room design** at the particular stadium. The analysis resulted in **some corrections**. Some of them were taken care of and some of them accepted.
- Informants at Snøhvit said the CRIOP analysis was **useful and that they were satisfied** with it. It helped them to verify that control room design fulfilled requirements and wishes. Also the multi-disciplinary team work was useful. Issues were raised which would probably not be discussed otherwise.
- **Difficult to design good scenarios** at such an early state. Operators had not used the systems yet.
- **Timing of doing CRIOP considered as good**. A bit too early in that many questions could not be answered and the scenarios were difficult to make realistic. However this is supposed to be considered in the next CRIOP.

- **HF analyses were done earlier in the project**. This gave some major changes that were expensive and difficult to gain acceptance for. Also the HF analyses were said to be carried out to late in the project. It was difficult make changes when the control room were already planned and made illustrations of. However the most important changes were taken care of. It was mentioned that the changes would have been less expensive if they were made earlier. The changes and costs of CRIOP were minimal. If however HF analyses were not done in front of CRIOP the cost of changes from CRIOP were considered to be much higher.
- **All checklists were used** but it was not possible to answer all the questions in them. Especially in the checklists job organisation, procedures and work descriptions and training and competence. Most of these elements were not considered yet.
- Probably **not used the checklist for e-operations**.
- There is a general tendency in Statoil that HF analysis is made a bit to late making it difficult to get accept for changes in the control room design.