NTNU

Faculty of Social Sciences and Technology Management

Department of Industrial Economics and Technology Management

NEW WORK PROCESSES THROUGH INTEGRATED OPERATIONS IN STATOIL

- FUNCTION ALLOCATION BY TRIAL AND ERROR?

INTEGRATED OPERATIONS ON THE NORWEGIAN CONTINENTAL SHELF; A CASE STUDY OF RESOURCE USE AND SAFETY IN THE LIGHT OF INCREASED SUBCONTRACTOR INVOLVEMENT

MASTER THESIS IN HEALTH, SAFETY AND ENVIRONMENT

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WRITTEN IN COOPERATION WITH STATOIL ASA

BY

KNUT IVAR HJELLESTAD

STATOIL

Norges teknisk-
naturvitenskapelige universitet
NTNU

Fakultet for samfunnsvitenskap
og teknologiledelse

Institutt for industriell økonomi og teknologiledelse

MASTEROPPGAVE

for

STUD.TECHN. KNUT IVAR HJELLESTAD

Fagområde	Helse, Miljø og Sikkerhet (Health, Safety and Environment)
Utleveringsdato	15.januar 2006
Tittel	**Integrete Operasjoner i norsk petroleumsnæring; et case-studie av ressursbruk og sikkerhet i lys av økt grad av underleverandørinvolvering** (Integrated Operations on the Norwegian conitental shelf; a case study of resource use and safety in the light of increased degree of subcontractor involvement)
Formål	Oppgaven har som formål å komme fram til anbefalinger for hvordan Integrete Operasjoner kan forbedre ressursbruken og sikkerheten på norsk sokkel.

Oppgaven vil presentere relevant teori knyttet til begrepet Integrete Operasjoner (IO). Ut fra denne teorien vil oppgaven så vurdere dagens bruk gjennom et praktisk case hos Statoil. Tidligere forskningssamarbeid som CORD vil være et sentralt element i denne vurderingen.

Følgende hovedpunkter skal behandles:

1. En innføring i begrepet Integrete Operasjoner (IO), og hva dette innebærer.
2. Definere og operasjonalisere andre nødvendige begrep.
3. Litteraturstudium for å avdekke og presentere relevant teori.
4. Hvordan har Statoil benyttet seg av IO hittil; innsamling og sammenstilling av data fra et praktisk case.
5. Vurdere empirien fra case-studiet i lys av CORD-metodikken. Konsekvens av økt leverandørinvolvering og -samarbeid vil vektlegges spesielt.
6. Forslag til videre forskning.

Veileder: Stig Ole Johnsen, SINTEF
Oppgaven utføres i samarbeid med Statoil.
Kontaktperson Statoil: Dag Sjong

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faglærer ved NTNU JAN HOVDEN,

bedrift/institusjon DAG SJONG, STATOIL **og**

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DECLARATION

Stud.techn. ______Knut Ivar Hjellestad______
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________ ___12/6-06____
Place Date

____
Signature

If people begin with certainties they will end with doubts. But if they are content to begin with doubts they shall end in certainty.

Sir Francis Bacon (1561-1626)

Preface

This master thesis is written at Department of Industrial Economics and Technology Management at NTNU and concludes my master degree in the field of health, safety and environment. This thesis has been written in cooperation with Statoil's research centre at Rotvoll in Trondheim.

The main objective with this thesis has been to identify how the introduction of the new Integrated Operations paradigm can improve the resource use and safety on the Norwegian Continental Shelf and how the change processes connected to the new paradigm should be carried out.

In my work with this master thesis I have been so fortunate that I have gotten much enthusiastic help from my teaching supervisors at both Statoil and SINTEF. I am very grateful for all help and support given to me by these two persons; Chief Engineer Dag Sjong at the IO Division at Statoil's research centre, and Senior Scientist Stig Ole Johnsen at SINTEF Technology and Society, Department of Safety and Reliability. The importance of having such persons that can open doors and give information about who I should talk to and where I should go, should be strongly addressed. The work would have been close to impossible, or at least very difficult, if it had not been for these two, so they have been an invaluable resource to me in my work on this thesis. Thank you very much for your professional guidance and contribution to my work.

I will also like to take the opportunity to thank all my informants and supporters for their time and commitment on answering my questions and inquiries. Without your contribution it would not have been possible to carry out this thesis.

Finally, to my friends and family; thank you very much for all your support, help, motivation and guidance through my period of study.

Trondheim, Monday 12th of June, 2006

Knut Ivar Hjellestad

Abstract

One of the main challenges of the petroleum industry in Norway nowadays is that the Norwegian Continental Shelf gets constantly more mature. This mature phase involves a reservoir development that is characterised by diminishing return of profit as a result of a decline in production whilst the production costs increases.

As a substantial part of the revenues of the oil and gas industry in Norway devolves on the authorities and thus contributes to Norway's solid financial situation, new thinking and new means are necessary to secure continued activities and added value on the Norwegian Continental Shelf. The Government Proposition no. 38 (2001 – 2002): About the Oil- and Gas Operations stated *Integrated Operations* as one of the central premises for accomplishing this.

There exists no definite definition of Integrated Operations. It is more an expression for a development than a defined set of solutions and techniques. The phrase is used to denote operation concepts where new information and communication technology solutions are used to optimise the operations on the Norwegian Continental Shelf, affecting both the technology and the work processes.

The objective of this master thesis has been to through literature, interviews and a case study identify how the introduction of the new Integrated Operations paradigm can improve the resource use and safety on the Norwegian Continental Shelf by influencing the operations of the oil and gas companies, how Statoil should work to analyse and ensure that the new work processes is designed with regard to safe operating, and how the change processes connected to the new paradigm should be carried out.

The interviews were carried out among scientists and employees either located in, or related to, the oil and gas industry through their professional position. The results are evaluated in elucidation of relevant research literature and discussed within an organisational frame.

Statoil have, in collaboration with other operators on the Norwegian Continental Shelf, developed a structured methodology for the function analysis and allocation of functions between sea – shore and man – machine. The methodology, named CORD, seeks to capture the phase of analysing and allocating functions as something more than just separate processes by coupling existing standards and guidelines to make a whole.

The research has identified both a need and a demand from the people in the industry for tools and methods, such as the CORD-methodology, that can improve the planning and carrying out of projects in Statoil. Statoil have at more than one occasion been ranked by Ministry of Petroleum and Energy as the worst company on the Norwegian Continental Shelf with regard to cost overruns. However, the research on the case revealed that the methodology and its improvement potential have not fully being exploited by Statoil on the Snøhvit field. It has also been found that the CORD-methodology is not a well known method in the industry. As the methodology is not very easy accessible, CORD should be made public in order to get the methodology and its benefits better known.

The research has further found that HF analyses were not carried out at start-up of the Snøhvit project, but rather was included after a certain time. By that time, many of the design solutions had already been chosen. This led to a more difficult work situation for the HF team as they had to defend each change they recommended since all these changes had issues regarding cost and time related to them. History has shown examples of accidents where poor HF design has been a contributing factor in an accident's outcome, and the importance of good HF design to avoid that mishandling makes a divagation escalate into an accident must be highlighted.

Through the research it has been revealed that the vendors in the oil and gas industry will steadily work closer together with the operators in the future through increased use of control rooms, operation centres and new collaborations; bringing the vendors closer to the decision-making. The challenges will be to optimise the interaction and cooperation between the operators and the vendors with respect to safety and performance, and the organisations should include the thoughts and ideas of the High Reliability Organisations theory to create collaborations that address these challenges.

In order to embrace the potential of Integrated Operations Statoil has commenced a corporation initiative. It states that Statoil shall be the leading firm on the Norwegian Continental Shelf by the end of 2006 when it comes to implementing Integrated Operations solutions. In general, changes are as good as worthless in a future perspective if they are not rooted into the corporate culture, and Statoil must highlight the pitfalls and recommendations of Kotter's theories in order to ensure that the changes in the work processes as a consequence of the corporation initiative accomplish this anchoring.

Sammendrag

En av hovedutfordringene til petroleumsindustrien i Norge nå for tiden er at den norske sokkelen blir stadig mer moden. Denne modenhetsfasen involverer en reservoarutvikling karakterisert av sviktende profitt som et resultat av synkende produksjon mens produksjonskostnadene stiger.

Ettersom en vesentlig del av inntektene til olje- og gassindustrien i Norge tilfaller staten og på den måte bidrar til Norges sterke finansielle situasjon er nytenking og tiltak nødvendige for å sikre fortsatt aktiviteter og verdiskapning på den norske sokkelen. Stortingsmelding nr. 38 (2001 – 2002): Om olje- og gassvirksomheten beskriver *Integrerte Operasjoner* som en av de sentrale forutsetningene for å oppnå dette.

Det eksisterer ingen bestemt definisjon av begrepet Integrerte Operasjoner. Det er mer ett uttrykk for en utvikling enn et definert sett med løsninger og teknikker. Uttrykket blir brukt for å angi driftskonsepter hvor nye informasjons- og kommunikasjonsteknologiløsninger utnyttes for å optimalisere operasjonene på sokkelen gjennom å endre både teknologi og arbeidsprosesser.

Målet med denne diplomoppgaven har vært å gjennom litteratur, intervjuer og en casestudie identifisere hvordan det nye Integrerte Operasjonsparadigme vil forbedre ressursbruken og sikkerheten på den norske sokkelen, hvordan Statoil bør jobbe for å analysere og sikre at de nye arbeidsprosessene er designet med hensyn til sikkerhet, og hvordan endringsprosessene tilknyttet paradigmeskifte bør utføres.

Intervjuobjektene har vært forskere og personell som enten var ansatt direkte i olje- og gassindustrien eller hadde tilknytning til næringen gjennom arbeidsstillingen. Forskningsresultatene har blitt evaluert og tydeliggjort gjennom relevant forskningslitteratur og diskutert innenfor en organisatorisk ramme.

Statoil har, i samarbeid med øvrige operatører på den norske sokkelen, utviklet en strukturert metodikk for funksjonsanalyse og allokering av funksjoner mellom hav – land og menneske – maskin. Metodikken, navngitt CORD, søker å fange funksjonsanalyse og funksjonsallokeringsfasen som noe mer enn bare en rekke separate prosesser ved å koble eksisterende standarder og retningslinjer og danne en helhet.

Undersøkelsene tilhørende denne oppgaven har identifisert et behov for metoder og verktøy, som CORD-metodikken, som kan forbedre planleggings- og gjennomføringsfasen. Statoil har ved med enn én anledning blitt rangert av Olje- og Energidepartementet som det dårligste selskapet på den norske sokkelen når det gjelder kostnadsoverskridelser på prosjekter. Til tross for dette har denne oppgaven funnet at metodikken og dens forbedringspotensial ikke har blitt utnyttet til fulle av Statoil ved etableringen på Snøhvit. Det har også blitt funnet at CORD-metodikken ikke er særlig kjent i industrien. Da metodikken ikke er lett tilgjenglig pr dags dato bør CORD bli gjort offentlig for å gjøre CORD og dens fordeler bedre kjent.

Undersøkelsene har videre funnet at human factors-analyser ikke ble utført ved oppstart av Snøhvitprosjektet, men i stedet ble inkludert etter en viss tid. Da de ble inkludert hadde mange av designvalgene allerede blitt foretatt, noe som medførte en vanskeligere arbeidssituasjon for human factors-teamet ettersom de måtte forsvare alle forslagene til endringer i forhold til kostnads- og tidsmessige aspekter. Historisk finnes det eksempler på ulykker hvor dårlig human factors-design har vært en medvirkende faktor til ulykkens omfang, og viktigheten av god human factor-design for å unngå at feilhåndtering får et avvik til å eskalere til en ulykke må understrekes.

Arbeidet på oppgaven har også funnet at leverandørselskapene i olje- og gassindustrien vil jobbe stadig tettere med operatørene gjennom økt bruk av kontrollrom, operasjonssentre og nye samarbeidsløsninger, noe som vil knytte leverandørselskapene nærmere til avgjørelsene. Utfordringene vil være å optimalisere samhandlingen og samarbeidet mellom operatør og leverandør med hensyn på sikkerhet, og organisasjonene bør involvere teoriene tilknyttet h*igh reliability organisations* for å sikre at det lages samarbeidsløsninger som har fokusert på de nevnte utfordringene.

For å sikre at Statoil griper potensialet tilknyttet Integrerte Operasjoner har Statoil initiert et konserninitiativ som erklærer at Statoil skal være det ledende selskapet innen utgangen av 2006 på den norske sokkelen når det gjelder å implementere Integrerte Operasjonsløsninger. Endringer er generelt så godt som verdiløse i et fremtidsperspektiv dersom de ikke blir forankret i konsernkulturen, og Statoil må fokusere fallgruvene og anbefalingene til Kotter for å sikre at endringene i arbeidsprosessene som kommer som en følge av konserninitiativet får denne nødvendige forankringen.

List of abbreviations

AR12	"Operation, maintenance and modifications", governing document in Statoil
ARMOR	ABB Remote Monitoring Operation Room
CE	Concurrent Engineering The main principle of CE is to integrate product and process development. By adopting a multidisciplinary, integrated workflow CE ensures that engineering and operations decisions are based on sound business lifecycle knowledge, reducing the design lead-time and improving both the quality and cost
CORD	Coordinated Operation and maintenance offshore – Research and Development The CORD-methodology is a structured method for the function analysis and allocation of functions between sea – shore and man – machine. CORD seeks to capture the phase of analysing and allocating functions as something more than just separate processes by coupling international standards and other guidelines to make a best practice; a methodology that includes all relevant aspects of the function analysis and allocation phase. CORD has more focus on the organisational aspects in a project than the older standards, in an attempt to cover the whole MTO-area.
CRIOP	Crisis Intervention and Operability Analysis CRIOP is a methodology to verify and validate the ability of a control centre to safely and effectively handle all modes of operations including start up, normal operations, maintenance and revision maintenance, process disturbances, safety critical situations and shut down.
FAD	The Norwegian Ministry of Government Administration and Reform
HF	Human Factors HF is the discipline that tries to optimize the relationship between technology and the human by application of relevant information about human characteristics and behaviour to the design of objects, facilities, and environments that people use.
HRO	High Reliability Organisation HROs are organisations that consistently operate under trying and hazardous conditions, and yet manage to have relatively few accidents.
HSE	Heath, Safety and Environment
ICT	Information and Communication Technology
IO	Integrated Operations The Government Proposition no. 38's definition of IO: *"use of information technology to change work processes to gain better conclusions, to remote control equipment and processes, and to move functions and personnel onshore"*.
MTO	Man-Technology-Organisation Knowledge and analytical techniques that focus on human and organisational factors. By explicit mentioning the three interrelated elements in the concept; Man, Technology and Organisation, the intention is to stimulate a comprehensive system-view.
NCS	Norwegian Continental Shelf
O&G	Oil & Gas
OD	Norwegian petroleum directorate
OED	The Norwegian Ministry of Petroleum and Energy
OLF	Norwegian Oil Industry Association
PTIL	Petroleum Safety Authority Norway
VO	Virtual Organisation A VO is an organisation where the members interact virtually with each other in a dispersed setting. VOs are distinguished from traditional hierarchical and network organisations by the temporary linkages that tie together the distinct organisations.
WD0603	"Human Factors Analysis Methods", governing document in Statoil
WR1279	"Human factors analysis", governing document in Statoil

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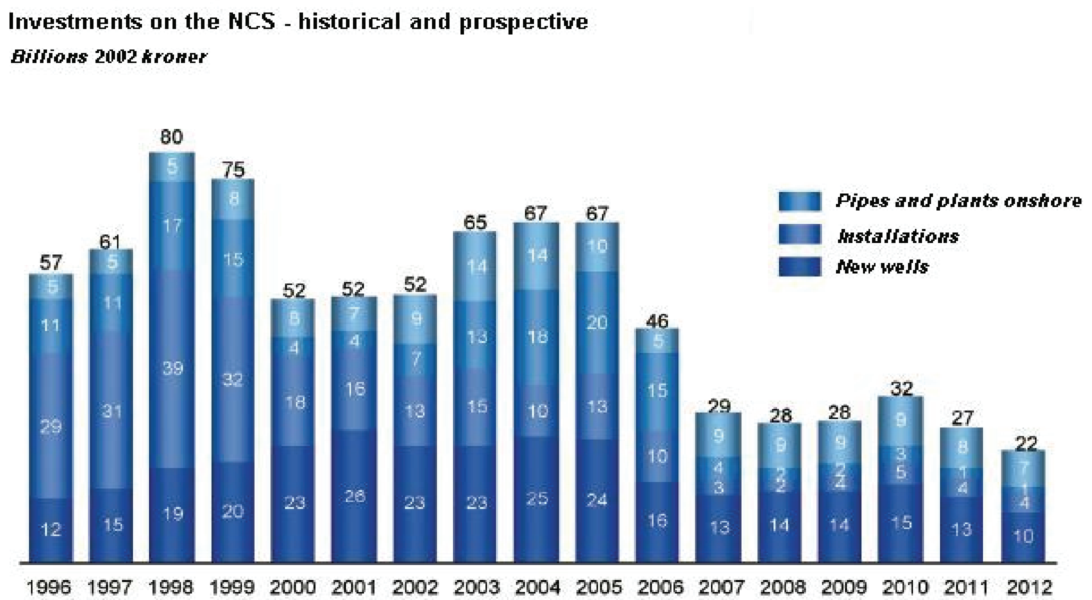
PART ONE: BACKGROUND AND OBJECTIVE

1. INTRODUCTION

One of the main challenges of the petroleum industry in Norway nowadays is that the Norwegian Continental Shelf (NCS) gets constantly more and more mature. This mature phase involves a reservoir development that is characterised by diminishing return of profit on investments as the produced amount of oil and gas (O&G) are decreasing whilst the cost of producing is increasing; resulting in that many of the fields on the NCS are getting close to unprofitable. This has led to a fall in investments on the NCS since its peak in 1998 (FAD, 2001), a trend that is thought to continue over the next years according to the Norwegian Petroleum Directorate (OD) (OD, 2005).



1-1 Total investments on the Norwegian Continental Shelf

The maturity on the NCS forces the industry to think alternatively and be innovative to improve the lifting cost connected to O&G production on the NCS. The solution so far has in many of the mature cases been tail production where smaller companies with leaner organisations have taken over the unprofitable fields and been able to produce at a lower cost rate resulting in expanded lifetime for the fields. But with the growing number of mature fields combined with the fact that the number of new discoveries are diminishing, the big companies no longer can do a runner when faced with a tail production scenario. The demands on profitability from the owners and the capital market combined with a cost- and tax rate level that is higher for the NCS that other O&G provinces implies that also the big actors have to do innovative thinking and develop themselves (OLF, 2003a).

1.1. The third efficiency leap

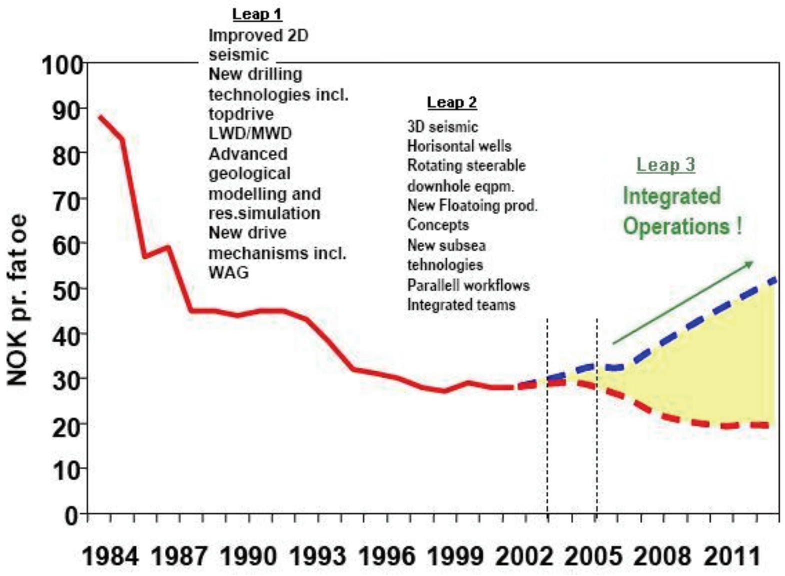
The operations on the NCS have historically seen two major efficiency leaps since Phillips Petroleum first discovered oil in the North Sea in the late sixties. The first of these two leaps happened during the middle of the eighties and was characterised by 2D-seismic, new drilling equipment such as "top drive"[1], new logging techniques during drilling, more advanced tool for geological modelling, and reservoir simulation. In addition to this, the leap also included new expulsion methods as alternating water and gas injection (OLF, 2003a).

The second leap happened ten years later, during the mid nineties. This time the central aspects was 3D-sesimic, horizontal wells, rotating steerable down hole equipment, new floating production concepts, new sub sea technologies and parallel workflows.

These two leaps not only each enhanced the extraction level considerably, but they also reduced the amount of hazardous spill pr produced unit and improved the safety levels, resulting in major reductions in the lifting costs over these periods (Tecpress, 2003).

The development of Integrated Operations (IO) solutions has a potential of becoming a third efficiency leap. It is the combination of new oil- and gas technologies combined with relevant information and communication technologies (ICT) solutions that lays the foundation for the possibilities connected to IO. A leap such as this could prevent the lifting costs to increase as predicted along the blue line in figure 1-2, and instead continue to decrease and make a longer production time possible even though entering tale production.

[1] Top drive is a hydraulic or electric motor suspended in the derrick (mast) of a drilling rig, which rotates the drill string and bit and is used in the actual process of drilling the well. Top drive reduces the amount of manual labour and associated hazards.

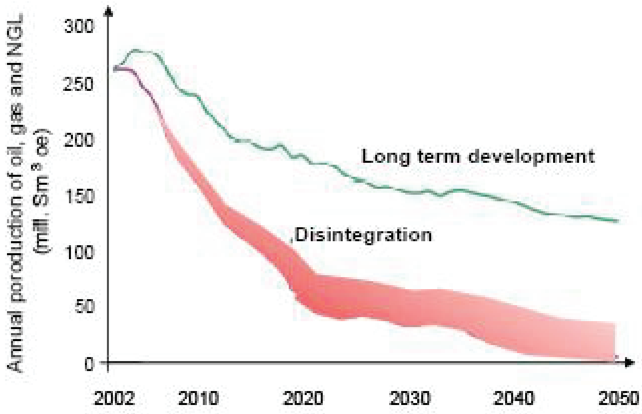


1-2 Lifting costs on the Norwegian Continental Shelf - historical

A substantial part of the revenues connected to the O&G industry devolves on the authorities and thereby contributes to Norway's solid financial situation. The industry also generates a considerable activity itself employing thousands of workers. While the different companies operating on the NCS embraces the possibilities IO gives, it is of political interest to ensure that the changes that IO brings to the O&G industry is not implemented on the expense of health, safety and environment (HSE) aspects, but instead are exploited in a way that utilizes the safety barriers and safety strategies and thereby improves the HSE levels; strengthening the industry and it's competition power towards foreign actors.

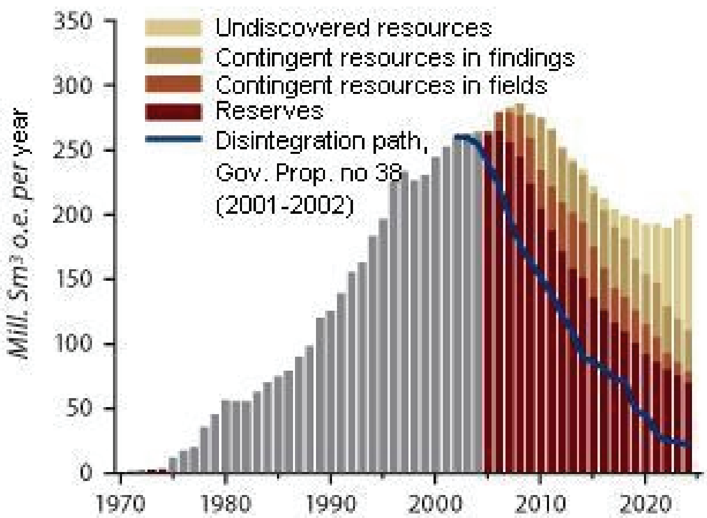
1.2. Government proposition no. 38 (2001 – 2002)

In June 2002 the Ministry of Petroleum and Energy (OED) in Norway published the Government Proposition No. 38 (2001-2002): About the Oil- and Gas Operations. With this proposition the government wanted to make clear that the goal was *"an offensive initiative that made a long term and ambitious exploitation of Norwegian oil and gas deposits possible"* (OLF, 2002). It was important to ensure that the remaining resources were fully exploited to further create revenues for the society. The fact that the Norwegian Government Petroleum Fund (later renamed to the Norwegian Government Pension Fund) amounted to about 610 billion Norwegian crones in the start of January 2002, and that at the time when the proposition was published, less than one forth of Norway's total petroleum resources had been produced underlined the importance of continued production on the NCS (OED, 2002). An important condition in securing this is innovation and technological development. The proposition described two possible development paths for the O&G industry on the NCS; the disintegration development, and the long term development. These paths are shown in figure 1-3.



1-3 Two development paths for the NCS

The long term development path has later seen adjustments. A report named "Petroleum resources on the Norwegian Continental Shelf 2005"[2], published by the OD (2005), increased the prognosis by 30 percent for the period up to year 2024 compared to Government Proposition No. 7's predictions. This increase constitutes to one fifth of the total remaining resources on the NCS. The adjusted prognosis is presented in figure 1-4.



1-4 Adjusted development paths in 2005

[2] Title translated to English by the author. Norwegian title: Petroleumsressursene på norsk kontinentalsokkel 2005.

This adjustment makes it even more important to work on ensuring as much as possible of the remaining resources are fully exploited. The proposition stated IO as one of the central premises for realisation of the long term development path (OLF, 2003a).

1.3. Government proposition no. 7 (2001 – 2002)

In December 2001 the Ministry of Government Administration and Reform (FAD) published the Government Proposition No. 7 (2001-2002): About Health, Safety and Environment in the Petroleum industry. This proposition focused on unacceptable or negative features within the industry, it focused on which measures or actions that was necessary to implement, and finally, it focused on which parties that had the responsibility to carry out these changes. The proposition described a situation where the consideration in regard to safety and working environment was in retreat. According to the proposition, the industry had moved from being a pioneer in the eighties in Norwegian industry in general, to a progress through the nineties characterised by *"being marked by changes in the oil companies' planning and accomplishment of operations as a consequence of stronger demands to profitability"* (FAD, 2001). A considerable drop in the oil prices during 1997 – 1998 enhanced this development. The consequences of these changes were that they had come on the expense of HSE. The ministry wanted to underline the importance of HSE and the expectation of the Norwegian Government and the Norwegian society in general that the industry would emphasise the HSE aspects to prevent that operations were done on the expense of safety levels in their future planning and decision-making processes.

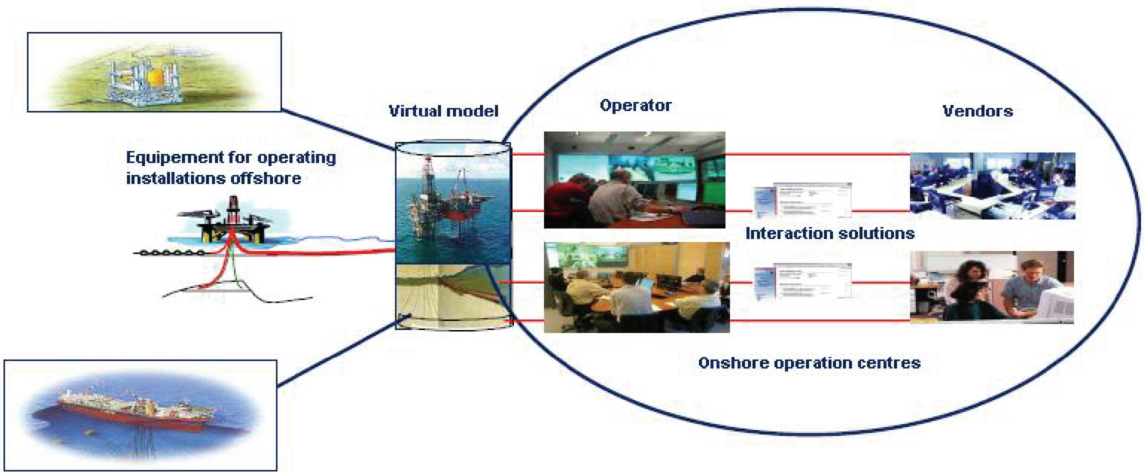
The proposition also identified a need for research & development (R&D), and several research programs were established in the wake of the proposition as a result of initiatives from nationalised research communities and institutions. One example of such a R&D program is the "HSE Petroleum" that was initiated by the Research Council of Norway in 2002. The program has a time-frame spanning from 2002 to 2006, and it consists of four different competence projects; HSE culture (K1), change – organisation – technology (K2), decision support tools (K3), and physical working environment and health (K4). It is K2 that focuses the most on IO as the goal of the project is to develop new knowledge that will improve the actors on the NCS performance when faced with organisational and/or technological changes (SINTEF, 2003).

1.4. Introduction to Integrated Operations (IO)

There exists no definite definition of IO. IO is more an expression for a development than a defined set of solutions and techniques. The phrase is used to denote operation concepts where new ICT- and real time solutions are used to optimise the operations in the O&G industry, affecting both the technology and the work processes. Several different concepts have been developed throughout the recent years. “Smart fields”, “eFields” or “Digital Fields” are just a few examples of the concepts that the industry has launched.

The Government Proposition No. 38 does provide a definition, though; *“use of information technology to change work processes to gain better conclusions, to remote control equipment and processes, and to move functions and personnel onshore”.* The aspects concerning Man-Technology-Organisation (MTO) is included in this definition, and IO is meant to embrace more than just technological steps forward.

A report written by a work group in the Norwegian Oil Industry Association (OLF) recommended that the expression *IO* should be used (OLF, 2003a). The expression was selected to underline that IO is about bringing different segments closer together; such as offshore versus onshore, operators versus vendors, or paring different disciplines with different functions; integrating them and making joint teams instead of having a world consisting of separate pieces. But integration and joint working does not necessarily mean face-to-face collaboration. The new ICT-solutions enhance the possibility of establishing virtual teams and organisations working together from different locations. Figure 1-5 illustrates the possible work processes related to IO solutions (Statoil, 2005a).



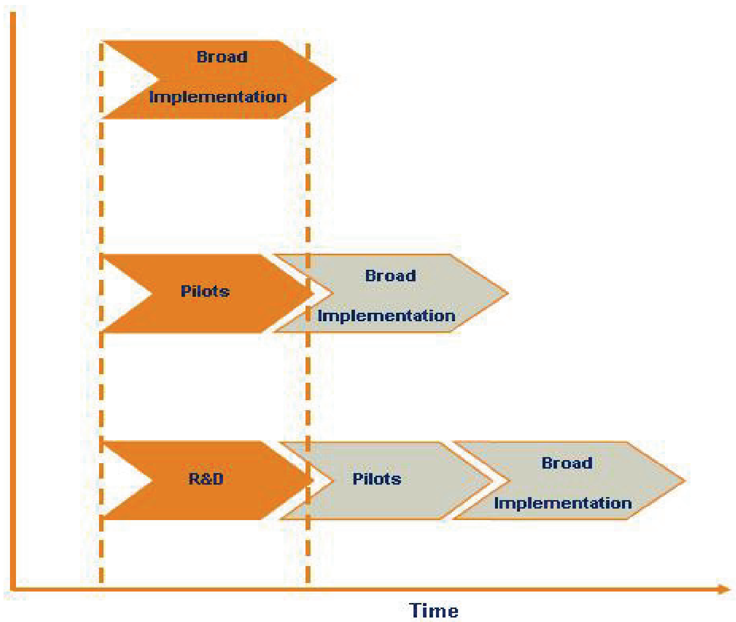
1-5 Illustration of new possible work solutions related to IO

IO is the expression that will be used in the rest of this thesis.

1.5. Statoil's IO corporation initiative

Helge Lund was appointed President and Chief Executive Officer in 2004. He was quick to state that Statoil should be the leading firm on the NCS by the end of 2006 when it comes to implementing IO solutions (Tecpress, 2005). To ensure this, Statoil commenced a corporate initiative in the autumn of 2004 with regard to IO. The initiative states that IO will increase the efficiency of exploration, operations and new developments through the use of new work practices as better and faster decisions will utilize technology that brings competence, data and tools together in real-time, independent of location (Nielsen, 2005). The initiative highlights three principal subjects:

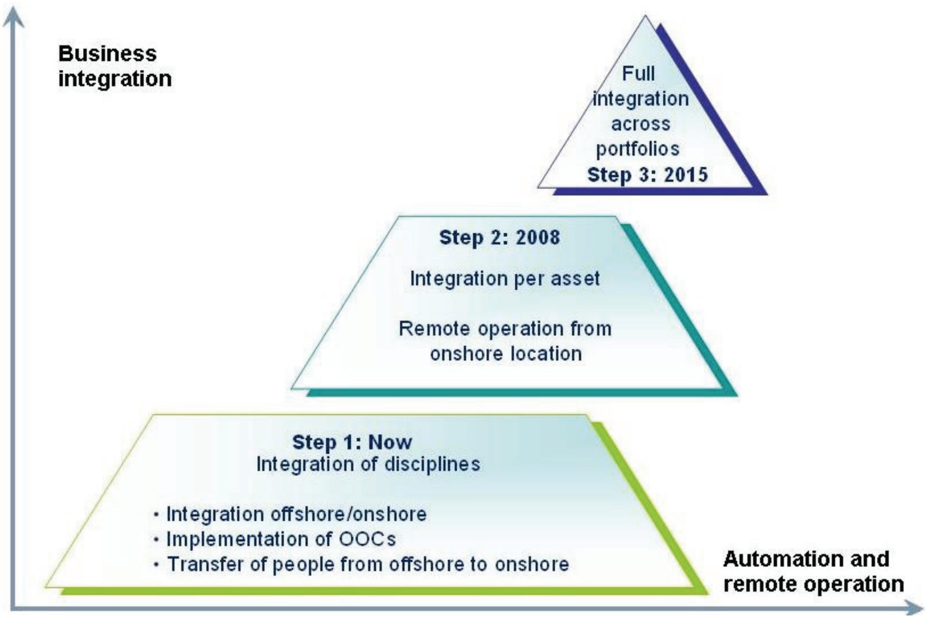
1. Research & Development
   - Statoil has seen a need for developing technology and processes in order to achieve the goal of the initiative
2. Pilots
   - A few of the projects have been given the status as *pilots*. These are projects that are being carried out to gain experiences that will be used in the broad implementation.
3. Broad implementation
   - Statoil will here select the improvements that are mature enough based on the criteria of feasibility and profit potential



1-6 The principal subjects of the IO corporation initiative of Statoil

The work connected with the initiative is being sought for by research communities in all of Statoil's segments (Statoil, 2005a). A core group on top of this coordinates, supervises and acts as an initiator on the communities, and the group has the responsibility of creating a big picture of the different campaigns in Statoil's organisation; ensuring precise and coordinated efforts towards the initiative.

In addition to their initiative, Statoil has also made a superior plan regarding IO and its implementation in a long-term perspective. This is presented in figure 1-7.



1-7 The vision of the concern initiative in Statoil regarding IO

The core group shall also ensure that IO-related activities not directly linked with the initiative can gain experiences from the initiative to maximise synergy effects and work towards standardisation of technology and system architecture across the Statoil.

1.6. Objective of the master thesis

As presented in the previous sections, IO is one of the key concepts related to dealing with the issues of the future on the NCS. The objective of this thesis is to present recommendations for how Integrated Operations can improve the resource use and safety on the Norwegian Continental Shelf. This is sought accomplished by presenting relevant theory related to the IO concept and its future, evaluate Statoil's practice of analysing their present IO solutions to ensure good design through the use of a case given by Statoil, and look into the future of IO. With this in mind, the following objectives are formulated for this thesis:

1. An introduction to the IO concept, and what IO implies

2. Define and operationalise other necessary terms and concepts
3. Unveil and present relevant theory through a literature search
4. Present Statoil's utilization of IO of today through collecting and collocation of data connected to a specific case given by Statoil
5. Evaluate the empiricism from the case study in the light of the CORD-methodology with a focus on an increase in vendor involvement and cooperation
6. Give suggestions for further research

A literature search, combined with a case study and interviews will be used in order to answer the objectives. The literature search and the interviews will aim to cover all of the objectives, whilst the case study will focus primarily on objective 4 and 5.

1.7. Case description

Snøhvit is a gas field operated by Statoil located in the north of Norway, about 150 km northwest of Hammerfest. The field was first discovered in 1984, and construction started in 2002. Operations are planned to start in 2007. The construction solution is sub-sea production units on depth between 250 to 350 metres. No surface installations exist on the field. The gas is being transported onshore through pipes on the bottom of the sea to a processing plant placed at Melkøya right outside Hammerfest (Statoil, 2005b). The offshore production will be 100 % remote controlled by personnel located in control rooms on Melkøya. Snøhvit will be the first field on the NCS that is operated this way (OLF, 2003b). Considering Snøhvit's location far up north it has been a stated goal from Statoil that the plant would consist of a lean organisation with minimum manning. With this in mind, Statoil and one of their vendors; ABB, has decided that ABB will establish an ARMOR (ABB Remote Monitoring Operation Room) in Bergen. The ARMOR infrastructure has been developed by ABB to enable the remote monitoring and engineering of plant control systems, and their associated applications (OilCamp, 2006).

1-8 ABB working towards Snøhvit

The compilation of the exact work procedures specifying in detail the role of the different parts was still an ongoing process at the time this master thesis was written (spring of 2006), but the core elements are worked out. ABB's task at Snøhvit will be with the technical aspects of the control systems. ABB will conduct updates and programming modifications on the system remotely from Bergen. With the establishment of the ARMOR in Bergen, ABB has moved the interface of the control system (i.e. keyboard, mouse and screen) from Hammerfest to Bergen, while the actual mainframe still is located on site at Melkøya. ABB's role does not include the operating of the Snøhvit plant, as the supervising of the plant is done by operators from Statoil. The ARMOR will be manned on a 24/7 routine[3], but ABB will also have staff placed locally on site as support to Statoil's operators and the ARMOR centre. Figure 1-8 illustrates how ABB will operate towards Statoil at Snøhvit.

1.8. Statoil's Onshore Support Centre at Stjørdal

The solution with one of Statoil's vendors operating from a different location than Statoil is a new fit in the history of Statoil. However, it is not the first example of control- and operations rooms as Statoil previously have established control rooms and onshore centres of their own. An example of this can be found at Stjørdal just north of Trondheim where Statoil's operation-organisations for Heidrun, Kristin, Norne and Åsgard are located. There, Statoil established a

[3] 24/7: 24 hours a day, 7 days a week

purpose-built land support facility during 2003 to integrate Statoil's installations in the Norwegian Sea more closely with operation-teams on land. This is illustrated in figure 1-9.

1-9 OSC and the Halten Nordland area

The centre was a pioneer project in Statoil, and specially tailored for the IO concept. It links personnel on rigs and platforms with in-house support functions on land, contractors, service companies and other external specialists. In that way, the centre can help to maximise added value.

1.9. Research questions

As a result of the objectives of the study, the following two research issues have been formulated:

R1 Investigate the activities and plans at Statoil with regard to the case:

a) Is the function analysis and function allocation at Snøhvit attended to in such a manner as recommended in the CORD methodology?
b) What are the potential pitfalls of the selected design concept in the Snøhvit case?

R2 Evaluate the future of IO:

a) How will an increase in vendor involvement and cooperation affect Statoil's operations?
b) How should Statoil work to ensure that new IO solutions and concepts are analysed and designed in a best possible way?

Research question 1 (R1) will highlight objective 4 and 5 related to the case study, whilst research question 2 (R2) has an aim of identifying the aspects of objective 1 and 6, in addition to substantiate objective 5 regarding a potential increase in the involvement of the vendors. Objective 2 and 3 are sought answered through part two of this thesis; the theoretical framework, on a basis of the literature search.

1.10. Limitations of the study

When designing new radical solutions as with the Snøhvit plant which is first of its kind on the NCS, attention needs to be given to feasibility studies, consequence analysis, planning, estimating of costs and many other similar aspects. In this thesis I will first build a theoretical platform in part two of this these; the *theoretical framework*, and afterwards relate the theory with the current standards and methodologies of function analysis and function allocation and its use in Statoil. I will thereafter evaluate the future of IO, and its influences on the operations of the actors on the NCS in light of the theoretical framework.

Science could be understood as a constant development of new knowledge. But without a presentation of existing knowledge it will be hard for both the researcher and the reader to decide whether the knowledge gather from this thesis is new or its significance. It is thus crucial to get a conceptual and theoretical understanding of the phenomenon and its aspects that is to be researched, to create a foundation in which supplying and integration of new knowledge can be added. Knowledge about the phenomenon is also necessary to be able to address the important problems.

The operation of the Snøhvit installation, and the cooperation solution with ABB, are both new solutions to Statoil. The theory is thus limited to earlier research literature on the topics of *change processes* and *change management*.

I will then focus on the design phase of the Snøhvit plant and its analyses regarding the control rooms and the collaboration Statoil – ABB. In chapter 1.6 "objective of the master thesis", it is stated that the recommendations of the "Coordinated Operation and maintenance offshore – Research and Development" (CORD) methodology will constitute the basis for evaluating the analysis of the design phase.

CORD consists of three projects;

1. Optimal operation and control of offshore installations
2. Technical condition
3. Safety-critical equipment

In this thesis I will concentrate on the recommendations of the first of these projects as this project focuses on optimal operation in combination of use of control rooms and remote operating. This is chosen because the Statoil case has control rooms and function allocation as primary issue.

In parallel with this master thesis another similar thesis was written by Siri Andersen; “Leveraging Safety through Integrated Operations”. Both theses explore safety perspectives in IO and are both written in cooperation with the same supervisor in Statoil. Other similarities are a common case study description of Snøhvit and cooperation in accomplishing some of the 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?” has a broader perspective and explores strategies for accomplishing IO changes in O&G organisations, whilst “Leveraging Safety through Integrated Operations” has a more detailed focus and explores geographically dispersed collaborations across companies. Another difference is that this thesis focuses on the CORD-methodology, whilst CRIOP is used in “Leveraging Safety through Integrated Operations”.

PART TWO: THEORETICAL FRAMEWORK

2. CHANGE MANAGEMENT AND ORGANISATIONAL LEARNING

Organisational experts have noted that the real value of the learning organisation is in the becoming. The learning organisation is not a destination to be reached; it is an ongoing process of change and renewal. As the organisations move towards their visions of a more integrated and accountable service, learning is a constant (Senge, 1990).

The latter years have seen some major changes in technologies of hazardous systems, in the organisations that operate the systems, and in the political and economic environments of these organisations. The present dynamic society brings with it some dramatic changes of industrial risk management (Rasmussen & Svedung, 2000):

- A very fast pace of change of technology
- The scale of industrial installations is steadily increasing
- High degree of integration and coupling of systems
- A very aggressive and competitive environment.

2.1. Perrow's Normal Accident theory

Charles Perrow started his work in the wake of the Three Mile Island disaster in 1979. *"Our first example of the accident potential of complex systems is the accident at the Three Mile Island Unit 2 nuclear plant"* (Perrow, 1984). While the Chernobyl nuclear accident in 1986 was partially caused by the failure of a safety system that was being brought on line; a failure that touched off an unforeseeable and irreversible chain of disruptions, the accident at Three Mile Island came about as the result of small errors that individually were insignificant, but that snowballed to a close to catastrophic result. Hang a curtain too close to a fireplace and you run the risk of setting your house on fire. Drive a car on a pitch black night without headlights, and you dramatically increase the possibility of crashing. These are matters of common sense, applied to simple questions of cause and effect. But what happens when common sense runs up against the complex systems with which we have surrounded ourselves?

2.1.1. Perrow's interactions

It has been argued that a complex system exhibits complex interactions when it has unfamiliar, unplanned, or unexpected sequences which are not visible or not immediately comprehensible. According to Perrow systems are either 'complex' or 'linear' (Perrow, 1984). Table 1 below shows the characteristics of both typologies.

Table 1 Perrow: Complex vs. Linear systems

Complex	Linear
Component proximity	Spatial segregation (of components and subsystems)
Common-mode Connections	Dedicated connections
Interconnected Subsystems	Segregated subsystems
Limited substitutions	Easy substitutions
Unfamiliar or unintended feedback loops	Few feedback loops
Multiple and interacting controls	Single purpose regulating controls
Indirect or inferential sources of information	Direct information
Limited understanding of the processes involved	Extensive understanding of process technology

2.1.2. Perrow's couplings

Coupling, or interdependence, is the degree to which organisation components depend on each other. Loose coupling means that the components can operate independently from one another. Tight coupling means a continuous interchange of information, goods or services. Perrow claimed that highly interactive and tightly coupled technologies pose an intractable control problem. Designing an organisation that is sufficiently decentralised to handle the interactive complexity and at the same time sufficiently centralised to handle the tight coupling is impossible according to Perrow (1984). The essential aspect regarding coupling is the question about availability of buffers, resources, time, and information that can enable recovery from failures. The looser components are coupled, the more possible it is that recovery paths exist. The tighter they are coupled, the fewer ways an organisation has to recover (Berniker & Wolf, 2001). Table 2 shows the differences between tight and loose coupled processes from a technical perspective.

Table 2 Perrow: Tight vs. Loose coupling

Tight coupling	Loose coupling
Time-dependent processes which cannot wait	Processing delays are possible
Rigidly ordered processes (as in sequence A must follow B)	Order of sequence can be changed
Only one path to a successful outcome	Substitution is available
Little slack (requiring precise quantities of specific	Slack in resources is possible, buffers and redundancies

resources for successful operation)	available

2.1.3. Perrow's argument

Perrow merged his two two-dimensional typologies and built an argument that state that some systems are intractable because they pose an organisational dilemma.

1. *A system with high interactive complexity can only be effectively controlled by a decentralised organisation*. Highly interactive technologies generate many non-routine tasks. Such tasks are difficult to program or standardise. Thus, the organisation has to give lower level personnel considerable discretion and encourage direct interaction among lower level personnel.
2. *A system with tight couplings can only be effectively controlled by a highly centralised organisation*. A quick and coordinated response is required if a disturbance propagates rapidly throughout the system. This requires centralisation. The means to centralise may, e.g., include programming and drilling of emergency responses. Moreover, a conflict between two activities can quickly develop into a disaster, so activities have to be strictly coordinated to avoid conflicts.
3. It follows from this that an organisational dilemma arises if a system is characterised by high interactive complexity and tight couplings. Systems with high interactive complexity can only be effectively controlled by a decentralised organisation, whereas tightly coupled systems can only be effectively controlled by a centralised organisation. Since an organisation cannot be both centralised and decentralised at the same time, systems with high interactive complexity and tight couplings cannot be effectively controlled, no matter how it is organised. The system will be prone to 'Normal accidents'.

The argument can be summarised as in table 3.

Table 3 Perrow: Organising for coupling and complexity

\ Interactions Coupling \	Linear	Complex
Tight	Centralise to handle tight coupling	Centralise to handle tight couplings AND decentralise to handle unexpected interactions
Loose	Centralise or decentralise (both will work)	Decentralise to handle unexpected interactions

Perrow started his research after the Three Mile Island accident, and after applying his argument to that accident he concluded that *"the technology of the plant was so interactive and tightly coupled that it created the organisational dilemma"* (Rosness et al., 2004). Perrow also recommended several strategies to control the risk identified in his argument.

1. With a complex system, you should try to reduce the degree of interactive complexity
2. With a tightly coupled system, you should seek ways to loosen the couplings
3. If you have to live with a high degree of interactive complexity, you should build a decentralised organisation
4. If you have to live with tight couplings, you should centralise your organisation

5. If your system has catastrophic potential, and you are not able to apply any of the above strategies, then you should discard your system

With reference to the last strategy, Perrow argued that some technologies should be discarded. Especially the nuclear business (i.e. nuclear power stations and nuclear weapon systems) created such a degree of interactive complexity that could confuse operators and make intractable system disturbances that Perrow was of the opinion that these operations should be discarded.

2.2. Virtual organisation (VO)

According to Grabowski (2006) *"the major distinction between virtual and other organisations is that the former are networked organisations that transcend conventional organisational boundaries"*. VOs are distinguished from traditional hierarchical and network organisations by the temporary linkages that tie together the distinct organisations, by the members' shared business processes and common value chains supported by distributed ICT, and by the VOs' rejection of status boundaries and lack of importance they ascribes to proximity (Preston, 1991). Hierarchical and network organisations, in contrast, generally establish more permanent linkages between members, and do not generally create shared value chains and interdependent business processes between members, as VOs do (Grabowski, 2006).

The benefits traditionally assigned to VO include adaptability, flexibility and the ability to respond quickly to market changes since the bonds among members of VOs are temporary considering VOs are noted for forming and dissolving relationships with its other members of the VO (Grabowski, 2006). However, this also includes that the success of VO are depending on the VOs' ability to create shared, interdependent business processes that are designed to achieve shared business objectives. VOs can only occur if the participants accept a mindset different from the traditional perspective on the formality, proximity, and functions of relationships (Preston, 1991).

Further, time becomes the critical variable in a virtual world, and responsiveness is rated just as important as cost and quality. This expectation of responsiveness is essential to the success of the participants and highlights the need for trust between them. Without trust, corporations will be unable to quickly pull together the necessary resources to take advantage of the structural benefits of VOs (Preston, 1991).

2.3. High reliability organisation (HRO)

Some organisations seem to cope really well with errors, and they do so over a very long time period. Researchers from the University of California, Berkeley, started calling this kind of organisations *high reliability organisations* (HRO) (Eede et al., 2006). HROs are organisations that consistently operate under trying and hazardous conditions, and yet manage to have relatively few accidents. These organisations operate in settings where the potential for error and disaster is very high. They have no choice but to function reliably because failure results in severe consequences. The question one should ask is *"how often could this organisation have failed with dramatic consequences?" If the answer to the question is many thousands of times the organisation is highly reliable"* (Roberts, 1990).

HRO theory emerged partly as a response to Perrow's pessimistic view on the feasibility of reliably operating highly interactive and tightly coupled technologies. HRO theory holds that significant accidents can be prevented through proper management of prevention and mitigation activities, something which is in contrast with Perrow's 'Normal Accident' theory presented in the previous section. Small errors can propagate into grave consequences and risk mitigation processes are thus critical to the survival of the organisations. The nuclear industry, aircrafts and air traffic control are some of the best examples of HROs. These organisations continuously face risk because the context in which they operate is high hazard. Elements of such systems can combine in unforeseen ways, and when errors occur they quickly amplify. Hence; the organisations face complexity and tight coupling in the majority of processes they run, and according to Perrow's theory, these operations should therefore be discarded. HROs are not error free, but given the inherent hazards, the complexity and tight couplings of the systems, the safety records are remarkable according to HRO theorists (LaPorte & Consolini, 1991). *"For a deployment period of six months there will typically be over 10000 arrested landings with no accidents. Over 600 daily aircraft movements across potions of the deck are likely with a "Crunch rate"- i.e. the number of times two aircraft touch each other- of about 1 in 7000* moves" (op.cit.).

It is often said that a chain is no stronger than its weakest link, but Laporte and Consolini (1991) found that the HROs use the principle of redundancy to derive highly reliable performance from less than perfect humans. HROs are characterised by prioritisation of safety and reliability as goals. HROs clearly define what they mean by safety goals and sets up safety standards against which they assess themselves. The systems and processes are designed to provide layers of defences, recognising that components or people are fallible. This is achieved by building in redundancy, i.e. including extra components that can take over in case a critical component fails. But they can also use the staff to create redundancy. Rosness et al. (2004) termed the error recovery capability in HROs *organisational redundancy*[4]. The organisational redundancy depends on two preconditions; structural/instrumental and cultural.

The *structural/instrumental dimension* of organisational redundancy concerns the personnel's possibility of direct observation of each other's work, overlapping competence and overlapping tasks or responsibilities. For instance, both the pilot and the co-pilot on an airplane can fly the aircraft. The *cultural dimension* concerns the capability and willingness to exchange information, provide feedback, reconsider decisions made, and intervene to recover incorrect actions. HROs devote a lot of attention on the development and maintenance of individual and collective competence (Bierly & Spender, 1995). LaPorte & Consolini (1991) observed apparently contradictory production enhancing and error reducing activities in the HROs as the staff reported errors without encouraging a lax attitude toward the commission of errors. Instead, they took initiatives to identify and improve flaws in their standard operating procedures.

Such varied communication provides a means of understanding roles, responsibilities and relationships, and through this develops shared mental models among the members of the HROs. As a result, autonomy and interdependence between system members is made explicit and more understandable, providing opportunities for sense making and discussion of improvements in the system (Grabowski & Roberts, 1997).

Another characteristic of HROs is their decentralised decision-making. This is needed to permit prompt and flexible responses by the field-level operators. An organisation faces two principal problems; the division of labour into tasks, and the coordination of these tasks. *Structuring* is the organisational process for solving these two problems (Lucas & Barudi,

[4] Rosness et al. (2000) suggested the following definition of organisational redundancy: "By 'organisational redundancy' we refer to *cooperation that allows the organisation as a whole to perform more reliably than each individual operator."*

1994), and according to Laporte & Consolini (1991) it is the redundant organisational structures that provide operational slack and assurance of task performance in dynamic environments linked with risk mitigation. The HRO members are socialised and trained to provide uniform and appropriate responses to crisis situations (Weick, 1987). This field-level response to crises is the "decentralised response" that forms a large part of HRO philosophy. The other side, "simultaneous centralisation," refers to the maintenance of the paradoxical *clear chains with slack of command* in crisis situations. This flexible delegation of authority and structure within given frames under stress is necessary. In crisis situations the system moves away from its normal rigid structure and informal authority is granted on the basis of competence rather than rank. For example, LaPorte & Consolini (1991) argue that while the operation of aircraft carriers traditionally have military systems with the commando lines clearly defined, even the seaman at the lowest level can abort landings. This local authority is necessary in the case of aborted landings because decisions must be made too quickly to go up a chain of command.

A third characteristic of HROs is the focus on constantly improving their operations. HROs are noted for developing a decentralised high reliability culture that is constantly reinforced through continuing practice and training. They have strong and deep human technical capability with constant human resource development through continuous training.
The important issues in this work are:

1. How can the organisation manage its complexity?
2. How can the organisation loosen its tight coupling?

To remedy these issues there are generally two principles. One is the principle of *mindfulness*, and the other is the Perrow inspired principle of *decoupling process design*.

The term *mindfulness* was introduced by Weick & Sutcliffe (2001). They stated that HROs accept the fact of failures, that there is no perfection of zero errors, and that when errors are inevitable, the organisations need to develop skills to detect and contain these errors at early stages. Organisations that know that they don't know everything have a far better chance of mitigating risks (Zack, 1999). The HROs aggressively seek to know what they don't know by training people to look for anomalies, to recognise and respond to a variety of problems identifying where system redundancies are needed. Acting from an assumption that the organisation knows enough may result in arrogance at best and bad management at worst.

"Arrogance and hubris breed vulnerability" (Weick & Sutcliffe, 2001). Constant awareness of the possibility of failure is a precondition for avoiding such arrogance, and avoidance of hubris is essential in achieving long term reliability.

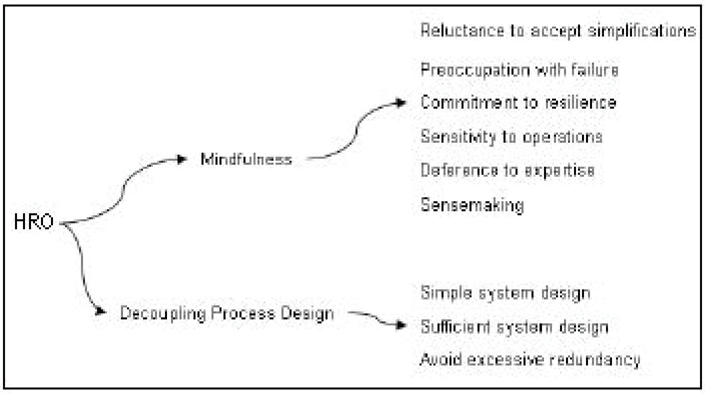
The organisations also practice on simulated accidents empowering people to act in order to respond promptly to problems, designing in redundancy in oversight of operations by using multiple communications channels making sure messages get through. Accidents are analysed to build organisational memory, to develop understanding and communicate concern for safety. All these cognitive processes of creating the knowledge needed for achieving this are summarised in table 4.

Table 4 Cognitive processes connected to the *mindfulness* principle

Preoccupation with failure	People are aware of vulnerabilities and mindful for signs of the unexpected Questioning and reporting is encouraged and rewarded Incidents are critiqued for lessons learned Open Communications Teamwork Obsession with liabilities of success
Reluctance to simplify interpretations	Counteract human tendencies to simply assumptions and expectations; select employees with non-typical prior experience Frequent job rotation Alternative frames of reference are encouraged and valued Establish practices that allow diverse perspectives to be heard and to surface information not held in common Complex models are adopted and help direct attention to small details.
Sensitivity to operations	Maintaining situational awareness (or the "big picture") is priority Leaders are in close contact with the front-line Decision-makers pay attention to real-time operational information through frequent operations meetings, operational performance indicators, and face-to-face interactions Detailed information is rapidly made available.
Commitment to resilience	Recognise that errors and imperfections are likely to happen Once errors are recognised, take prompt action to correct them Develop resources to rapidly cope and respond to unexpected changes Develop depth of knowledge and capability for swift feedback and learning Build people's skill in mentally simulating plant operations, make knowledge about the system transparent and widely-known Rapid pooling of expertise and use of information networks Build excess capacity; establish pockets of resilience through uncommitted resources.
Deference to expertise	Alter typical organisational patterns and role structures in deference to tempo of operational changes and unexpected problems, subtly loosen hierarchical constraints in favour of expertise Know expertise of personnel; migrate leadership and decision-making to those with the most expertise for the given situation People closest to the problem are empowered to make important decisions and solve problems and held accountable Leaders balance centralisation and decentralisation; people have tight social coupling around a handful of cultural values.

The problem with *mindfulness*, however, is that it does not deal with the way processes are designed. Processes are to a certain degree time independent, they are less rigidly ordered which offers multiple paths to a successful outcome, and they have built-in slack. All these qualities depend basically on the design characteristics of the processes (Eede et al., 2006). One way of doing this is by creating slack; more time and more freedom through physically separating the processes. The organisations will in this way have more buffers to cope with unexpected situations, but the drawback is that they at the same time become less fine tuned which will bring along a considerable increase in costs (op.cit.).

The latter of the two principles, the *decoupling process design* (DPD), has to do with solving the problem of loosening the tight coupling of HROs with regard to the design of the processes. The DPD is the lowest common denominator for providing a way of loose coupling the HROs. The DPD principle regroups organisational aspects that are directly related to the genuine quality of the design of the processes and systems. The main aspects of DPD are simplifying the system design. The system should be made simple, but obviously sufficient enough to perform its task and reach its goals. Avoiding excessive redundancy is a key word in the work of designing simple systems. The two principles are summarised in figure 2-1.

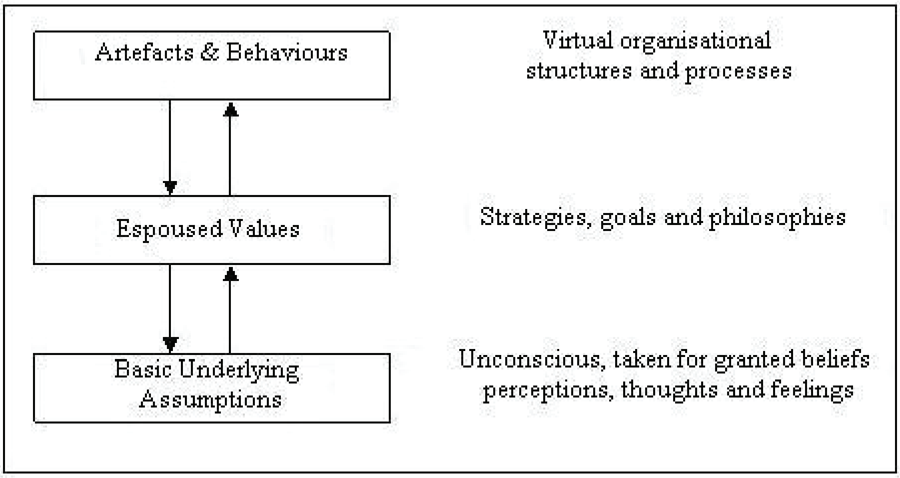


2-1 The HRO principles of Mindfulness and Decoupling Process Design

2.4. Schein – three levels model

There exists no single definition of what an organisational culture is. Schein (1992) acknowledges that even with rigorous study we can only make statements on elements of culture. We cannot explain culture in its entirety. Four years later, Schein (1996) defined culture as *"a set of basic tacit assumptions about how the world is and how it ought to be"*, and that organisational culture consists of three distinct levels; artefacts & behaviours, espoused values and assumptions.

1. *Artefacts & behaviours:* At the first and most cursory level of Schein's model is the organisational attributes that can be seen, felt and heard to the uninitiated observer. Included here are the facilities, offices, furnishings, visible awards and recognition, the way that its members dress, and how each person visibly interacts with each other and with organisational outsiders.
2. *Espoused values:* The next level deals with the professed culture of the organisational participants themselves, this level often reflect what a group wishes ideally to be and the way it wants to present itself publicly. At this level, company slogans, mission statements and other operational creeds are often expressed, as are local and personal values widely expressed within the organisation.
3. *Assumptions:* At the third and deepest level, the organisation's tacit assumptions are found. These are the elements of culture that are unseen and not cognitively identified in everyday interactions between organisational members.



2-2 Schein's three levels model of culture

2.5. Kotter

According to Kotter, the methods that the management historically have used in their attempts to transform their companies into stronger competitors have routinely fallen short due to the fact that the management have failed to alter the behaviour in their organisations. Through the findings of his research, John Kotter argues that there are in general eight reasons why many of such change processes fail (Kotter, 1996).

1. *Allowing too much complexity*
   - It is easy to overestimate how much you can change the organisations and underestimate how hard it is to change its people. This is because the management do not recognise how their actions can inadvertently reinforce the status quo. The management often lack patience, wanting to skip over preliminaries and get on.
2. *Failing to build a substantial coalition*
   - It is often said that major change is impossible without the head of the organisation as an active supporter. But Kotter argues that the support needs to go deeper, involving a numerous of people, other than management, with a commitment to drive the change. Efforts that lack a sufficiently powerful guiding coalition can

make apparent progress for a while but sooner or later countervailing forces will undermine their initiative.

3. *Understanding the need for a clear vision*
   - Urgency and a strong guiding team are necessary but insufficient conditions for major change. Of the remaining elements a sensible vision is one of the most important ones. *"Whenever you cannot describe the vision driving a change initiative in five minutes or less and get a reaction that signifies both understanding and interest, you are in for trouble"* (Kotter, 1996).
4. *Failing to clearly communicate the vision*
   - The staff will not make sacrifices and change behaviour, even if they are unhappy with the present situation, unless they think the benefits of change are attractive. That requires credible communication, to capture the employees' hearts and minds. Three patterns of ineffective communication are common
     a. In the first, the vision is developed by a group who then try to sell it by holding meetings or writing memos. This way they only use a fraction of the organisation's communication channels.
     b. In the second pattern, the head of the organisation spends a considerable amount of time making speeches to employee groups but most of the groups' managers are virtually silent.
     c. In the third pattern, effort goes into newsletters and speeches, but the visible behaviour of the organisation breaches with the vision, resulting that the belief in the new message goes down.
5. *Permitting roadblocks against the vision*
   - Occasionally the roadblocks are only in people's heads and the challenge is then to convince them that no external barriers exist. But in many cases, the blockages are for real. In these cases they include factors as organisational structure, job categories, or compensation and performance appraisal systems.
6. *Not planning for short term results, and not realising them*
   - Transformation takes time. Short term goals that are met and celebrated are thus important to keep the people motivated to work towards the long term goals.
7. *Declaring victory too soon*
   - With reference to the previous point, it can be tempting to declare victory after the first major performance improvement. However, this could prove hazardous on the change process as it can take years for a change to sink down deeply into the culture of the entire organisation.
8. *Fail to anchor changes in corporate culture*
   - In the end, change only sticks when it becomes the norm in the organisation, *"the way the things are done around here"*. Until the new behaviours are rooted in social norms and shared values, they can degrade as soon as the pressure from the change effort is lifted.

To prevent making these mistakes, Kotter summed up eight steps. He also noted that it is crucial that these eight steps are followed in the same sequence as shown below.

1. Establish a sense of need and urgency
2. Create a coalition
3. Develop a clear vision
4. Share the vision
5. Empower people to clear obstacles

6. Secure short-term wins
7. Consolidate and keep moving
8. Anchor the change

2.6. Beckhard & Pritchard

Beckhard & Pritchard (1992) outline the basic steps in managing a transition to a new system. They argue that any major organisational change involves three distinct conditions:

1. *The present state:* Where is the stage of the organisation at the current stage?
2. *The transition state:* These are the conditions and activities that the organisation must go through in order to move from the present state to the future state. It is the period during which the actual changes take place.
3. *The future state:* Where does the organisation want to be?

Based on the above assumptions, they developed a model for managing the change process. First; set goals and define the future state or the organisational conditions desired after the change. Second; diagnose the present state in relation to those goals. Third; define the transition state. This implies developing strategies and action plans as a way to reach the future state.

Beckhard & Pritchard (1992) identified five themes that could be used to drive the change effort. These are mission, way of work, culture, relationship to key stakeholders, and identity or outside image. Beckhard and Pritchard argue that all these five themes are interconnected, and that changes in one of them will lead to changes in the others. However, they further argue that change will be facilitated if the management can identify and manage the change with one of these perspectives as a pulling force.

Resistance is a part of the natural process of adapting to change, according to Beckhard & Pritchard (1992). Managers should therefore not be surprised when resistance occurs. Beckhard and Pritchard termed it a universal condition that whenever there is a change effort, there will be resistance. Managers should realise that resistance represents energy. Rather than trying to get rid of the negative energy to smoothen things over, management's real challenge is to find ways to convert the negative into positive and productive energy (op.cit.).

2.7. Bolman & Deal

Bolman & Deal developed a very useful organisational typology for viewing and studying leadership in the eighties. They synthesised existing theories of leadership and organisations into four traditions, which they labelled as *frames*[5]. Bolman & Deal's (1984) four-frame theory prescribes a multi-dimensional or multi-frame approach, in understanding the attributes and situational contexts of organisational behaviour. The theory consists of a structural, human resource, political, and symbolic frame. The structural and human resource frame is related to management, while the political and symbolic frame is related to leadership. Bolman & Deal's theory holds that successful organisations are those that understand and utilize a multi-frame orientation of thinking in assessing situational and environmental characteristics and anomalies. The theory assumes that these four organisational frames represent the diverse accentuation and nature of organisations, and in turn, shape how organisational leadership within the respective frames perceive organisational situations. Each frame provides a different way of interpreting events and actions, and each implies a very different focus on effective management. Together, they offer a comprehensive view, leading to a greater freedom of choice for remedial measures when faced with resistance towards the organisation. The structural frame focuses on communication and adjustments, the human resource frame emphasises training, participation and involvement, the political frame creates arenas where important issues can be negotiated, and the symbolic frame creates change-over rituals that allows the people to honour the past and embrace the future. Bolman & Deal claimed that in an increasingly complex world, the ability to use more than one frame should increase the ability to act effectively and make clear judgments (Mosser & Walls, 2002).

A summary table of Bolman & Deal's four frames is given in table 5.

Table 5 Bolman & Deal's four frames

Frame	Assumptions
Structural	The organisation exists primarily to accomplish goals Structure should fit goals, environment and technology Rationality should be maximised Specialisation and structure are basic Coordination through hierarchy and rules
Human resource	Responsibility, hierarchy, structure, standardisation, rules, feedback, deviation control, organisational goals
Political	Decisions are about allocating scarce resources Coalitions between groups with different values, beliefs and realities; bargaining and negotiation

[5] Frames are considered to be both windows on the world, and lenses that bring it into focus. Frames help to order experience and allow people to gather information and to make judgments.

	Power and conflict are central issues
Symbolic	Events and processes in organisations are ambiguous and not subject to only one rationality Interpretation and meaning are crucial Symbols reduce uncertainty and release creativity Strong cultures get results

2.7.1. Structural frame

The structural frame attempts to look at the social context of work and not just simply at the individual. This frame postulates that effective leaders define clear goals, establish specific roles for people, and coordinate activities through the use of rules, policies, and a chain of command. Once an organisation designates such specific roles for employees, the next decision is to form or group them into working units. Coordination and control of these various groups are achieved either vertically[6] or horizontally[7]. The best structure depends on the organisation's environment, goals and strategies. *Structure,* in this context, is understood as "*the total sum of the ways in which an organisation divides its labour into distinct tasks and the coordination among them*" (Hovden, 2003).

To get a clear structural picture of an organisation an identification of the organisation's boundaries is needed. Sometimes this determination is not so clear cut because of complexity trough aspects such as temporary workers, contractors, consultants, etc. One often used criterion for defining the boundaries is one that emphasises the activities and where they take place neglecting whether they are done by the very organisation itself or a contractor, as the main purpose of organisations is to fulfil goals.

In addition to setting guidelines for the members of the organisation, the goals provide a rationale for the organisation's existence, and they provide a set of standards against which the performance of the organisation can be measured. Since an organisation constitutes a number of stakeholders, levels and layers of people affected by the success or failure of the organisation, the result is multiple goals. Some of these may be in conflict with each other, and will eventually threaten the rational choice foundation for decision-making, understood; important aspects of goal setting are covered by the other frames. In evaluating the structure

[6] Vertical differentiation refers to the division of work by level of authority, hierarchy, or chain of command and is in some literature referred to as the scalar process.

[7] Horizontal differentiation refers to the division of work to be done into tasks at the same organisational level, and is sometimes referred to as specialisation.

and patterns of goals in an organisation two aspects are especially important for safety management (Hovden, 2003):

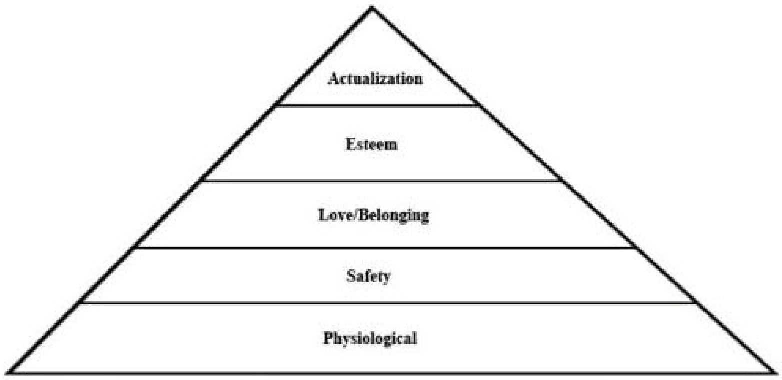
1. Goal *harmony*: penetrate the goals and their patterns for inconsistency, hidden or revealed, especially middle management is known as being exposed to that type of cross-pressure between productivity and safety
2. Goal *acceptance:* are they known by those concerned; are they perceived as faire and consistent; what is the real purpose of the goal; what can the goal development process tell?

2.7.2. Human resource frame

As a result of pre-war research on human relations in the US, the Americans began developing training programs through the decades of 1940s to 1960s focusing on how to make managers more sensitive, better listeners, and more effective in communication. Traditional lectures on the subject had proved not successful, and this gave birth to the idea of experimental learning or "human relations laboratories". The basic idea was that trainers and participants were joined in a common task of working in a group and learning from that work at the same time.

The human resource frame focuses on human needs. It views an organisation like a large extended family. From this perspective, an organisation is inhabited by individuals. These individuals have needs, prejudices, feelings, limitations and skills. The goal of the leader is to mould the organisation to meet all these needs of the personnel. The leader will seek to merge the peoples' need to feel good about what they are doing with the ability to get the job done. Bolman & Deal (1997) state that the key to this window is a *"sensitive understanding of people and their symbiotic relationship with organisations*".

There is a difference in assumptions on the human nature between the structural and the human resource frame. Whereas the structural approach tries to compensate for human failures, imperfection, unreliability, self-interests and limited rationally, the human resource frame focuses on the different aspects of needs of the human nature; coping, learning, adaptation, competence, responsibility, and social and caring values (Hovden, 2003). The most influential theory on human needs is Maslow's (1943) pyramid of needs.



2-3 Maslow's pyramid of needs

Maslow grouped needs into a hierarchy of five basic categories, physiological needs, safety needs, belongings and love needs, esteem needs and needs for self realisation. Higher needs become important only after the lower needs have been satisfied.

Participation is a means for giving the employees more opportunity to influence decisions that affect their work. According to Hovden (2003) some findings of subsequent research about the effects of participation show:

- Many studies of participation at work have found significant improvements in both morale and productivity, and in safety performance. Participation has been one of very few measures that have demonstrated positive effects on a number of objectives at the same time.
- Participation can fail, even when it is working, because it creates a need for changes that are resisted by other parts of the organisation.
- Many safety research studies give evidence for the importance of participation for successful development and implementation of safety measures.

2.7.3. Political frame

The political frame traces its heritage back to the Italian political philosopher Niccolo Machiavelli, by many described as the father of modern political theory (Kreeft, 2003), and his works from the 16th century[8]. The political frame assumes a continuing competition among different constituencies for scarce resources, and emphasises individual and group interests. A political perspective provides a powerful correction to the possibilities of improving organisational decision-making through just rational or human resource approaches. However, a one-eyed power perceptive can be too cynical, underestimating the

[8] N. Machiavelli published *"The Prince"* in 1513, a book where he described the means by which individuals have tried to seize and to maintain power. The book is often associated with cynicism, but it is also an example of an objective, analytical approach to power.

possibilities for effective decisions, balanced communication, dialogue and meaningful preventive actions.

The focus of the political frame is not on the resolution of conflict. Conflict is viewed as inevitable in the organisation, and simply resolving the many conflicts that arise in an organisation therefore only temporarily treat the effect of the conflict, and not the cause. For example, horizontal conflict may exist between divisions or departments, vertical conflict may occur within levels and cultural conflict may exist between groups with diverse values. The management should thus not focus their efforts merely on resolution of conflict but instead on strategies and tactics.

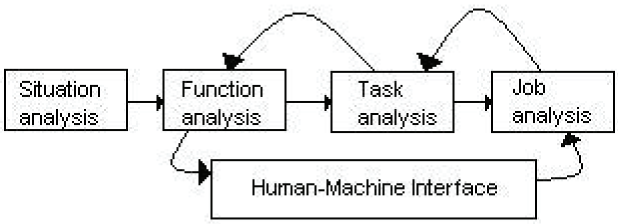
2.7.4. Symbolic frame

With the last frame, the symbolic frame, the management develop symbols and culture within the organisation to provide a shared sense of mission and identity. It is a powerful window that builds on cultural and social anthropology. Symbols clarify an organisation's culture (Mosser & Walls, 2002). This culture is a collection of values, beliefs, and practices that define to its members who they are and how they are expected to do things. An organisation may possess a number of symbols or symbolic activities to find meaning and direction. Problems develop when symbols begin to loose their meaning. Using the framework of the symbolic frame, the management may recognise the need to alter existing practices. This allows the organisation to stage a new drama called "change". If an organisation is deficient in symbols or rituals, the organisation could then create meaningful new symbols. These actions may help bridge the gap that exists between various groups or individuals within the organisation who lack a common purpose.

3. HUMAN FACTOR (HF) ANALYSES

HF analyses are part of the risk assessments within occupational health and the working environment. The analyses are relevant with the design and procurement of new systems, with modifications to existing systems, or it can be applied to assess existing work situations. HF analyses should be applied when the system reaches a certain complexity according to the interaction of MTO-aspects, or when the system has an impact on occupational health and the working environment. According to Statoil’s governing document WR1279 “Human factors analysis", the line management is responsible for ensuring that relevant HF analyses are carried out. Occupational health and working environment personnel with HF expertise are the ones that will assess the need for implementing these analyses, and also determine which of the different analyses that is relevant, describing the scope and plans. The team that carries out the analyses should as a minimum compromise an analysis facilitator with knowledge of and experience in HF methodology, employee representative and personnel who know the system from an operational perspective. All this are to be carried out at the start-up of design and modification projects. WR1279 define start-up as concept evaluation and pre-engineering phase.

There are in general five different methods regarding HF analyses. The relation between them is illustrated in figure 3-1. The HF analyses can be applied independently, but consideration should be given to applying several relevant HF analysis methods in a systematic manner.



3-1 Inter-relationship between the HF analyses

Situation analysis

The situation analysis is a systematic approach in order to evaluate the current condition compared to the stated requirements relating to HF concern. The analysis is intended to provide a status overview based on existing conditions, summarise any non-conformities and describe what is functioning well and what is not. "Crisis intervention and operability analysis" (CRIOP) is a method designed for use in situational analysis, and it is used to evaluate conditions in existing control rooms and proposals for new control rooms, validating and verifying the HF of a control room (Homepage of CRIOP[9]).

Function analysis and function allocation

Function analysis and function allocation is a systematic method for identifying and documenting the function of a system. It is subsequently divided into sub-functions in order to document what the system is intended to accomplish. A systematic review of a system's

[9] http://www.criop.sintef.no/

function is then carried out in order to determine whether the functions can best be dealt with by human or machine. The CORD methodology is a method developed in collaboration between several of the biggest O&G companies on the NCS. It can be used to manage HF aspects in the early design phases of new control rooms/operating rooms, modifications of existing ones, or in situations where it is desirable to challenge current function allocation and work processes. CORD is the methodology that I will focus on in this thesis, and a more close description will be given later.

Task analysis

Task analysis is a systematic review of what the employees must do to carry out a task; physically or mentally. Task analysis is a common term that covers several methods. The aim of task analysis is to ensure that the tasks are understood, and that the employees' needs and limitations are addressed.

Job analysis

The job analysis is a systematic review of the scope of job categories with regard to work tasks, workload, communication lines and necessary support functions. Workload assessment means analysing the workload systematically in order to ensure that personnel are not under or overloaded.

Human-machine interface (HMI)

The purpose of analysing the HMI[10] is to ensure that the written, symbolic or oral communication is both not ambiguous and correctly understood. It is carried out based on ergonomic standards and functional requirements in order to facilitate the integration of all the specialist domains, and applying a system-oriented approach enhancing the usefulness, ergonomics and working environment.

3.1. ISO 6385

ISO 6385 establishes the fundamental principles of HF as basic guidelines for the design of work systems and defines relevant basic terms. It describes an integrated approach to the design of work systems where HF specialists will cooperate with others involved in the design

[10] HMI is the front end interface where technology and material handling by humans come together. This people-technology intercept can be as simple as the grip on a hand tool or as complex as the flight deck of a jumbo jet.

with attention to the human, the social and the technical requirements in a balanced manner during the design process. The standard offers a route to improving the interface between individual users and the components of their working situation; tasks, equipment, workspace and environment.

3.2. ISO 11064

The ISO 11064 is a generic framework for applying requirements and recommendations relating to HF in designing and evaluating control centres with the view to eliminating or minimizing the potential for human errors. The ISO 11064 standard was developed by the Technical Committee ISO/TC 159 in the early nineties. It consists of seven parts[11]:

1. Principles for the design of control centres
2. Principles for the arrangement of control suites
3. Control room layout
4. Layout and dimensions of workstations
5. Displays and controls (see footnote 11)
6. Environmental requirements for control rooms
7. Principles for the evaluation of control centres

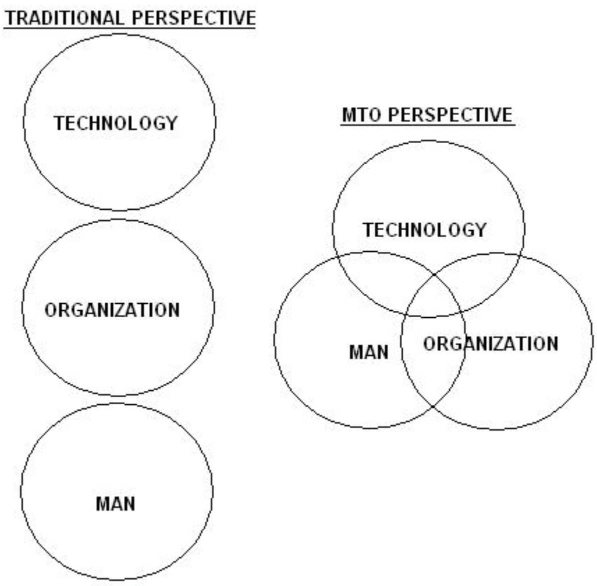
The overall strategy for dealing with the user requirements is presented in ISO 11064-1. ISO 11064-2 provides guidance on the design and planning of the control centre in relation to its supporting areas, while ISO 11064-3 gives all the requirements and guidance on control room layout. Requirements for the design of workstations, displays and controls and the physical working environment are presented in ISO 11064-4 and ISO 11064-6, and ISO 11064-7 establish ergonomic requirements, recommendations and guidelines for evaluation of control centres (ISO, 2006). See appendix D for a more detailed description of the different parts of the ISO 11064 standard.

3.3. Man – Technology – Organisation (MTO)

The term Man-Technology-Organisation (MTO) has its origin from Sweden where it has been widely used by Swedish utilities and regulators to describe knowledge and analytical techniques that focus on human and organisational factors and their relationship with nuclear safety (Andersson & Rollenhagen, 2002). MTO was introduced in Sweden in the mid eighties

[11] The ISO 11064-5 does not any longer figure as an ISO-standard on the homepage of the ISO-organisation, http://www.iso.org, indicating that it might have been withdrawn as an official ISO-standard.

after the Three Mile Island accident[12] as a concept similar to the Human Factors/Ergonomics (HF/E) concept[13] developed in the USA. The intent was that the explicit mention of the three interrelated elements in the concept; Man, Technology and Organisation, would stimulate a comprehensive system-view on nuclear safety. This view should go beyond a strict technological perspective to recognise and highlight human and organisational factors as important moderators of risk.



3-2 The integrating focus of MTO

MTO methods require a system perspective if they are to be applied successfully, something which makes the difference between the three domains difficult to grasp at first (Andersson & Rollenhagen, 2002). Experience shows that misunderstanding and neglect of the necessary system perspective are not uncommon when MTO methods are applied. A result of this may be a further neglect of the organisational context in which MTO methods are used (op.cit.).

There are many different MTO methods available, and the selection all depends on the topic in question. The methods range from MTO analysis in accident investigations such as root-cause analysis[14], to methods designed for accident prevention by identifying hazards in the design phase, to others that focus on organisational learning through carrying out

[12] A brief introduction to the Three Mile Island accident is given in chapter 2.1
[13] HF/E: HF/E is the scientific discipline that attempts to find the best ways to design products, equipment, and systems so that people are maximally productive, satisfied, and safe. Historically the term Human Factors has been used in the US, while Ergonomics is a European used term. HF is the term that will be used in this thesis.
[14] The tern root-cause is used to describe basic causes supposed to be under control of the own organisation.

organisational assessments, for example as part of periodical safety reviews. See Appendix E for further details of the range of methods.

3.4. The CORD-methodology

The CORD-methodology was developed as a response to changes in the HMI. The CORD-project was started in 1997 by SINTEF – Energy Research. After a slow start the project was brought back to life in 2000. The main focus was new ways of doing technical operation and maintenance, with emphasis on challenges and opportunities.

The CORD-collaboration consisted of three sub-projects:

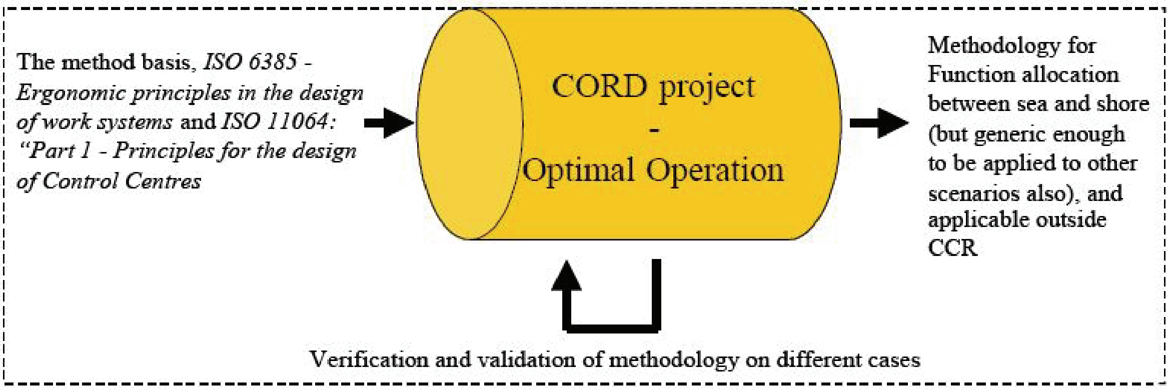
1. Optimal operation and control of offshore installations
2. Technical condition
3. Safety-critical equipment

The first project focuses on remote control of offshore installations, and goes deeper into work processes related to central control room. The objective is to develop important means that can contribute to more optimal operations of these installations. The second project looks at how one can supervise the technical condition on equipment in remote controlling. Knowledge of technical condition is decisive for upholding of safe and effective operation and maintenance of the offshore installations. The third project aims at developing common criteria for safety-critical equipment, and how this can be followed up.

As stated in chapter 1.10, "limitations of the study", I will focus on the first of the three projects considering the Statoil case has control rooms and function allocation as primary issue, and the first out of these projects focuses on optimal operation in combination of use of control rooms and remote operating.

Other standards and guidelines with HMI as a central issue do exist, with the ISO 11064 standard as the traditionally used standard. However, introduction of new integrated operations paradigm over the last years has introduced situations not fully handled by the older standards. For instance, ISO 11064 has a single-mind perspective towards control rooms and its layouts. It does not include new work collaborations embracing VOs and remote team working over the boundaries of companies (CORD, 2006). CORD is developed as a continuance to international standards like the ISO 6385 and ISO 11064. CORD uses existing international standards and MTO-analyses as a basis to develop a structured method for the function analysis and allocation of functions between sea – shore and man – machine (CORD, 2006).

But CORD goes further than the older standards in the description of a practical introduction to data gathering and analyses. The methodology seeks to capture the phase of analysing and allocating functions as something more than just separate processes; it seeks to couple international standards like ISO 6385, ISO 11064 and other guidelines and recommendations to make a whole; a methodology that includes all relevant aspects of the function analysis and allocation phase. To achieve this, CORD has more focus on the organisational aspects in a project than the older standards, in an attempt to cover the whole MTO-area. It follows an iterative approach with development, verification and validation as illustrated in figure 3-3.



3-3 CORD Optimal Operation; high level illustration

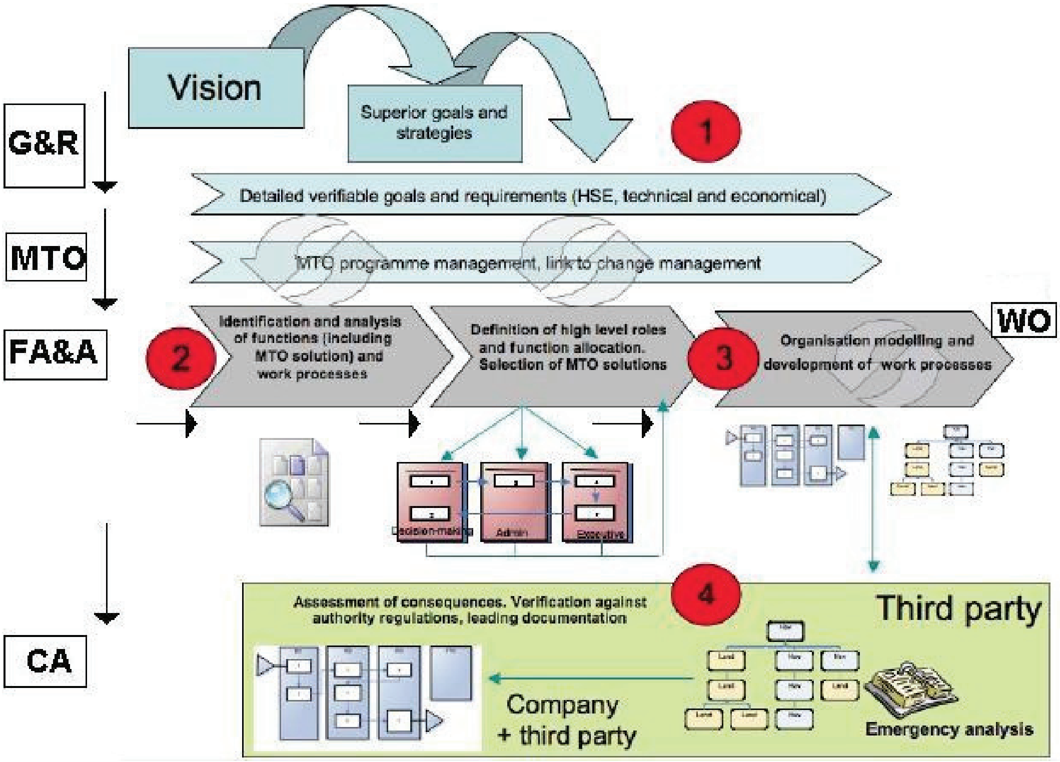
The framework of the method reflects a top-down approach for conducting necessary activities to ensure an optimal allocation of functions, seeking that individual topics may be seen in relation to the overall high level goals of the new design.

The methodology itself does not provide the client with any solutions. The solutions are actually found by the client through guidance and help from an analysis team that facilitates the client by using the methodology in a structured way identifying problem areas and possible solutions.

The method has a five level approach:

1. Goals & Requirements (G&R)
2. MTO Programme Management (MTO)

3. Function Analysis & Allocation (FA&A)
4. Work organisation (WO)
5. Consequence Analysis (CA)



3-4 Five level approach in the CORD methodology

3.4.1. G&R

Here the organisation's visions and goals for the implementation are identified at several levels. The aim is to make visions and goals concrete, uncover internal inconsistencies and identify requirements from the different stakeholders. All project goals identified should be listed and continuously updated. As the other phases of the method are closely linked to the G&R, the formulation of visions and goals will greatly influence the end result. The analysis is guided towards solutions by strategies that provide ideas and concepts necessary to formalise structured solutions. Visions will in this way be transformed into more concrete and verifiable goals. Consideration over whether some goals should be revised should be taken in case of divergences between the visions and verifiable goals.

Table 6 Description of the G&R level

Analysis step	**Description**
Goals & Requirements	
Visions	The main, high level goals that govern the project

Superior goals and strategies	Goals formulated in a general way, but more specific than visions. Strategies is the plan of actions designed to achieve the superior goals
Verifiable goals and requirements	G&Rs stated in a way possible to verify. Thus, they are concrete goals and requirements that give specific criteria for the work system

3.4.2. MTO

The ideal situation is that the analysis team either are integrated into the organisation, or have team members from the organisation that are subject to the analysis. The analysis team should be composed of a manager with knowledge about both the technical aspects of the organisations operations, and HF analysis techniques. The team should also consist of personnel with specific knowledge for the analysis domain. The team will in this way have motivated team members, and the operational phase will have personnel that understand and communicate design premises. The scope of the analysis will very much depend on the depth of the next level; the function analysis and allocation. It is thus important for the analysis team and the client to have a discussed this issue, and agreed upon a common understanding before making a detailed plan for the analysis activities based on the method described in the CORD-methodology. In situations where the project results influences HSE, a plan for employee representation and information has to be established for the project.

Table 7 Description of the MTO level

Analysis step	**Description**
MTO Programme Management	
Analysis team composition	To select an appropriate group of people that will perform the MTO analysis, and one facilitator that will be in charge of the process
Point of contact (POC) identification	To identify one key contact person within the organisation, that can open doors and promote the project to create interest for the analysis. Ideally a person with operational insights and technical and organisational system-knowledge should be identified. Responsibilities: * door opener in the organisation * identification of stakeholders in the organisation under study
Identification of scope and objective	Define scope and objective for the data gathering and MTO analysis
Activity plan development	To produce a detailed project plan for all method activities to be accomplished within the scope of the analysis. MTO analysis and activity plan: * Identification of client plan and already performed activities * project and resource plan

	* project objective and assumptions * team composition
Initiate G&R tracking	To start G&R identification and establish the G&R documentation system
Coordination with change management activities	To ensure employee representation where relevant

3.4.3. FA&A

An FA&A encompasses an analysis of functions within a defined scenario. The analysis starts out by identifying how the existing functions interact with each other. To obtain the goals of the project; the needs concerning data, technology and organisation has to be collected. Secondly; activities and functions are analysed in terms of constraints and preconditions. And thirdly; findings are structured into a matrix that forms the basis for the allocation work. Functions are analysed iteratively to find solutions for how functions, activities and roles can be reallocated or changed in an optimal way to achieve the visions and goals that are stated for the project. It is also important to involve the users in this phase.

Table 8 Description of the FA&A level

Analysis step	**Description**
Function Analysis	
Identification of problem areas for scenario selection	Identify problem areas within the project that are suitable for analysis and that have a significant potential for achieving the identified goals and requirements
Definition of analysis approach	To achieve an agreement between analysis team and the client on how the analysis best can be performed relative to the availability of personnel for workshops and ongoing activities within the client company
Selection and construction of scenarios	Agree upon the scenarios with respect to one or more of the identified problem areas. Further, detail the description of the scenarios with respect to objectives, main activities, required tools, actors involved and how they communicate
Work process/tasks modelling	Talk through work tasks, scenarios and/or create work process models (create new models or modify existing models). Gather enough data to carry out the analyses
Goals means task analysis (GMTA) modelling	To create a GMTA model based on the Scenario talk-through. Focusing on sequence of tasks and their preconditions.
Identification of constraints and tools	This activity is one of the main reasons to carry out a GMTA. It gives the guidelines on allocation opportunities and constraints
Function Allocation	
Definition of high level roles and function allocation	Allocating functions between onshore and offshore or between man and machine agents
Definition of high level roles	To develop role categories suitable for analysis of the superior goals according to the strategies chosen to obtain them

Analysis of constraints, tools and MTO issues	To analyse the results from the function analysis phase and structure the findings in a function analysis table
Preliminary allocation by Work Process Modelling (WPM)	To perform a preliminary hypothetical allocation, based on output from the previous step, G&Rs and mandatory requirements arising from legislations
Allocation to automation, onshore and offshore staff.	To perform the real and detailed allocation of functions based on the hypothetical WPM and function analysis table

3.4.4. WO

WO consists of designing the organisation and the work processes. This phase will ensure that tasks are assigned to each actor in a systematic way. An important issue for organisation design is to incorporate organisational challenges in traditional and new organisations. In this phase the "new" organisation is analysed based on the scenarios selected in the previous phase. The new organisation is created from the output of the FA&A phase and based on the identified preconditions and constraints. The result will be work process models showing functions, relationships and their associated tasks, decision-making processes, actors, and technology and tools necessary to facilitate the new organisation.

Table 9 Modelling of new work processes

Analysis step	Description
Work organisation	
Definition of roles and identification of requirements	Development of work process models based on the function allocation and temporary work process models
Definition of roles to fulfil defined activities Put forward the requirements for roles Identify available resources in the organisation Settle the need for reorganisation	Identify and detail roles and related requirements and identify gaps in organisational structures and competences in order to fulfil requirements for the new organisation, The steps are repeated until gaps between available resources and the demands from the planned organisation are closed

3.4.5. CA

The consequences of the proposed work process models are analysed with respect to requirements for communication, information, decision-making and time for response. It acts as verification against authority regulations and leading documentation. It is recommended that this part is handled by a neutral third party investigation.

Table 10 Overview of the consequence analysis level

Analysis step	**Description**
Consequence analysis	
Verification against performance criteria and organisational constraints	Evaluation or test of proposed work process models against project goals and requirements.
Verification against internal company standards	Identification of gaps between new work process models and internal standards
Verification against HSE, authorities, leading documentation	Identification of gaps between new work process models and authority regulations

PART THREE: SCIENTIFIC APPROACH

4. SCIENTIFIC METHODOLOGY

While the previous chapter introduced the theoretical framework that constitute the basis for answering the research questions in chapter 1-10, this chapter will present the scientific methodology and its processes used to approach and answer the research questions. The intention of the scientific methodology chapter is to make the ideas of the researcher transparent to the reader, making the reader able to judge the validity and reliability of the results presented in this master thesis. This is done by presenting the evaluations and criteria for selection of the research design, the analysis processes and an evaluation of the validity.

4.1. Methodology

A scientific methodology is defined by Ringdal (2001) as *"plans and techniques used to give answers to research questions"*. The answering is done through collecting and analysing data, and methodology is of high importance when doing this research. In order to be able to answer the research questions it is necessary to take advantage of known methods and techniques. One cannot simply trust own abilities and base the work on intuition. It is also crucial to have knowledge about different methods to make it possible to gain insight in work already done by other researchers. Ringdal describes the total research process as the six stages presented in table 11, and these are further presented in this chapter.

Table 11 The research process

1	Rough definition of the theme
2	Research question(s)
3	Selection of design
4	Data collection
5	Data analysis
6	Report

4.2. Rough definition of the theme

A first limitation regarding the theme was given through my background and my professional interests as an HSE-student at NTNU. Further, the theme for this thesis was a continuance from the theme in my project thesis; "Integrated Operations on the Norwegian Continental

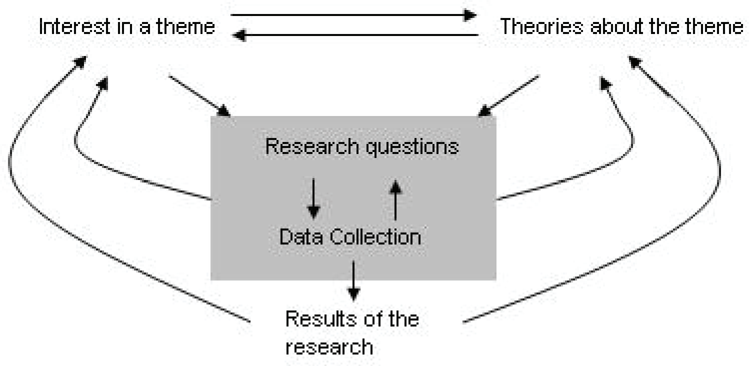
Shelf", written in cooperation with SINTEF during the autumn of 2005. IO was a highly discussed theme within the Norwegian O&G industry at the moment this thesis was written (spring of 2006). Given the focus on the theme from the O&G companies, authorities and research institutions such as SINTEF, combined with my professional background, earlier work and the interest and desire from Statoil to look into the specific case given, led to the topic of this master thesis; new work process through the use of IO solutions, visualised in the case by the new cooperation solution between Statoil and ABB at Snøhvit. A specific case was vital for the limitation process of this thesis as IO in general is a complex and very broad theme stretching from technical aspects one end, to organisational and strategic aspects at the other.

The thesis description in chapter 1.6 is given as a condition for the study. The process connected to the modelling of this description was done in cooperation with both the teaching supervisor and Statoil, making it an iterative process where the selected areas and issues were adjusted and consecutively evaluated.

4.3. Development of research questions

When the topic for the thesis was settled, it was time to further develop the intention of the paper. Research projects often start with unspecified research issues like areas of interests or ideas (Ringdal, 2001). The first step in a research process is to transform these ideas to professional and suggestive research issues; what is the objective, and how should it be reached?

At this point it was useful to divide the task in different parts; hence: R1 and R2. The thought behind this was not to work separately on the research questions, but rather to make it more lucid. However, it is often more difficult to ask the right questions than to answer them (Tjora, 2005), and the first drafts were based more on assumptions than actual knowledge. The content and formulation of the research questions were thus changed iteratively during the first period.



4-1 The development of research questions

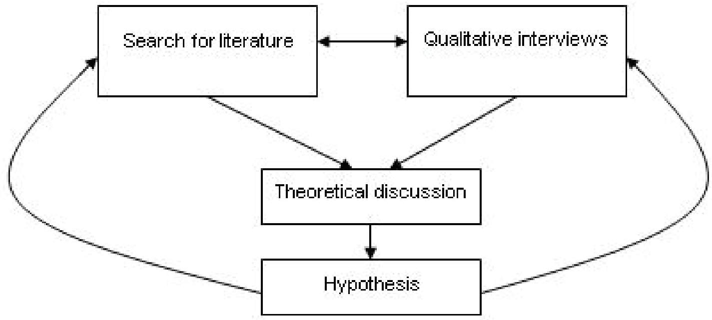
Systematic search for literature and articles, giving the researcher information about former research projects and their results, can be of high usefulness when developing research issues. This was done to better fit the needs as the approach to the problem became clearer through such reading. But discussion and conversations with others that had knowledge about the theme in question also contributed to the adjusting of the research questions presented in chapter 1-9.

4.4. Selection of research design

There are many different methods available when it comes to data collection, and the selection of research design is dependent of the topic that is being examined (Tjora, 2005). One basic separation is between quantitative and qualitative methods. The major distinction between these two design methods is that the quantitative research seeks to gain comprehensive knowledge, while the qualitative method seeks to gain in-depth knowledge about a specific issue (Ringdal, 2001). The quantitative method is hallmarked by exact quantifying; one way of describing it could be the phrase *"if you can't count it, it doesn't count"*, and it is common to analyse the data to find patterns and systems, whilst the qualitative method is of a explorative nature where the researcher starts out with general issues, and then through research and in-depth analysis develops new theories and definitions (Ringdal, 2001; Tjora, 2005).

The research design can first be decided when the researcher has evolved the research issues and objective with the study (Kvale, 1997). The objective in this thesis has been of a theoretical character, and in-depth understanding was thus a key word with the data being a mix between an explorative and describing kind. Based on this thesis' objective and type of data needed to answer the research questions, a qualitative approach was chosen.

The overall sketch of the scientific methodology is given in figure 4-2.



4-2 Sketch of the scientific methodology

4.5. Data collection

When the researcher has selected an appropriate research design, the next step is to select the different methods for data collection (Ringdal, 2001). There exist several methods for such acquisition, and with the qualitative approach chosen for this thesis, the following data collection methods were used to ensure the best possible outcome:

- Research literature
- Governing documents from Statoil regarding both general operations and the Snøhvit plant in special
- Interviews
- Pre-evaluations by the researcher

As Snøhvit is situated far north in Norway, the accessibility is limited. Further, the plant has a planned start of operating during 2007, and test phase is scheduled to start around 1st of May 2006. These two aspects thereby ruled out the possibility of direct observation at the plant.

Using different methods of data collection is called triangulation (Ringdal, 2001). According to Tjora (2005), triangulation of methodology is a powerful way of giving synergic perspectives on the results of the thesis. To make sure that the best possible outcome of the data collection were sought, the triangulation approach were chosen through the use of documentation; earlier research literature and governing documents from Statoil, and qualitative interviews with different stakeholders.

4.5.1. Research literature

While the expression IO and its strategies concerning new work processes and collaboration solutions might be relatively new, the research area of change management and its connected processes have existed for many years. Earlier works on different themes than IO, and in other industries than the O&G, can be altered to make it suitable for the new thinking in the O&G industry. Discussions with my teaching supervisor at SINTEF, plus the work on my project thesis, gave the rough direction to which topics of earlier research that would be best suited for use in this thesis. The two online science archives sciencedirect.com and bibsys.no[15] were thereafter made use of as search engines in the chase for relevant literature. In addition, the CORD-methodology has been used as a link between earlier research works and the Statoil case.

4.5.2. Statoil documents

Relevant documents inside Statoil have been used as input and frameworks as the master thesis has been carried out in cooperation with Statoil. The documents in question were identified through discussion with my teaching supervisor at Statoil, and these documents include both documents of a general kind (Statoil governing documents) and documents and presentations tailored specially for the Snøhvit plant. The Statoil governing documents form a platform that the material handling concerning the research questions further builds on. Thus, including both aspects; general and specific, is of importance to focus on the whole picture. The governing documents used in this thesis consist of the following:

1. WR1279, "Human factors analysis"
2. WD0603, "Human Factors Analysis Methods"
3. AR12, "Operation, maintenance and modifications"

4.5.3. Interviews

According to Ringdal (2001) the main objective with interviews is to gather important information about the identified research issues. Ringdal further states that the researcher can choose between a flexible or a rigid structure[16] of the interview. A flexible approach has been

[15] Sciencedirect is an online collection of science, technology and medicine full text and bibliographic information, while Bibsys is an online library database containing the bibliographic data of all the Norwegian universities, all college libraries, the National Library and a number of research libraries.
[16] The rigid structure does not allow the researcher to change the questions during the interviews, nor can the researcher substitute the selected informants.

chosen for this thesis, as it is an iterative process that gives room for changes as the interviews are carried out.

Preparations for the interviews and the actual interviewing were mainly done as teamwork with Siri Andersen. Both parts gained profit on working together on these tasks as it gave us the opportunity to join forces and supply each other with information during the processes of selecting informants, developing the interview guide, and accomplishing the interviews.
The interviews were partly structured with the interview guide consisting of both strict formulated questions and predefined topics with a more guideline aspect. The informants were allowed to talk free, giving them an opportunity to include digressions and anecdotes to better express their opinions. The intention behind this structure was that the informants, given the opportunity to speak more freely, could come up with thoughts and ideas that had not been covered by the interview guide and thus could have been missed out if I had stuck to a strict interview guide. As such new issues arose; new questions and topics were added to the interview guide for use in later interviews. As the interviews were carried out, it also became obvious that some of the questions were of less relevance to some of the informants regarding their background or knowledge about the IO theme. As the intention of the interviews was of a qualitative perspective; gathering information about IO and enhancing the knowledge about the case and its aspects, it was considered as not a problem. However, this was sought minimized by shifting around the order of the questions to better fit the respondents' background and knowledge area of the IO theme.

Development of the interview guide

Through the work on the project theses during the autumn of 2005, both Siri Andersen and I had focused on IO related aspects[17]. A draft for an interview guide was thus made on the basis of experiences from those project theses. An interview guide has different functions. It can range from thematically arranged entries to complete formulated questions (Ringdal, 2001). It also acts as a support to ensure that the researcher covers the whole terrain of topics within the theme. It should establish channels for the direction and scope of the discourse (McCracken, 1988), and finally, it should lead the more informal interview in the right direction when choosing a partly structured design (Ringdal, 2001). The importance of avoiding leading

[17] The theme of Siri Andersen's project thesis written at NTNU during the autumn of 2005 was "Experiences with remote monitoring and operations in the rail way industry, aviation industry and with Emergency Centrals", whilst my title was "Integrated Operations on the Norwegian Continental Shelf".

questions should also be highlighted as the answers then will be influenced by the interviewer's opinions (op.cit.).

Informants

The informants were chosen in three ways:

- By teaching supervisors
- By recommendations from informants
- Through earlier project works

The teaching supervisors gave several recommendations of persons who could be useful to contact. The persons were then screened; checking their background and professional position. Further, when contacting those we found relevant, some of them recommended other persons that could be of interest to our work. This latter identifying method is called *snowball technique*[18].

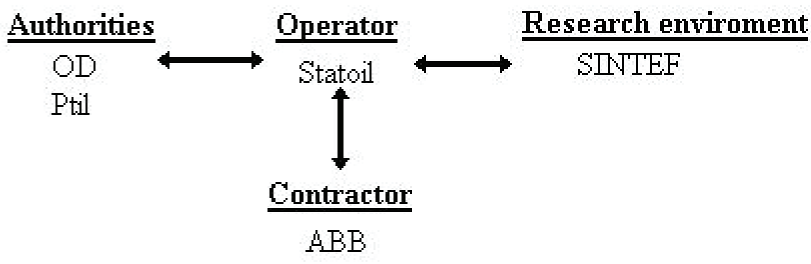
In total, a number of 15 persons have participated as informants in my thesis. Table 12 gives an overview of these persons; their position, company and whether they were interviewed by telephone or through a personal interview.

Table 12 Informants used in interviews

Position	Company	Telephone	Meeting
Process leader	Statoil	**X**	
Head engineer marine	Statoil		**X**
Head engineer	Statoil	**X**	
Chief engineer	Statoil	**X**	
Leader process control	Statoil		**X**
Head engineer automation	Statoil	**X**	
Head engineer	Statoil	**X**	
Advisor refrigeration	Statoil		**X**
Head engineer	Statoil		**X**
Head of section	ABB	**X**	
Head engineer	ABB		**X**
Senior researcher	SINTEF		**X**
Researcher	SINTEF		**X**
Chief engineer	Norwegian Petroleum Directorate (OD)	**X**	
Chief engineer	Petroleum Safety Authority Norway (PTIL)	**X**	

[18] Referrals are made among people who know others with relevant knowledge or characteristics for the research.

The IO theme involves many different stakeholders with differs in both opinions and focus. By including different stakeholders I have tried to grasp this diversity in the informant's responses. Figure 4-3 seeks to show the stakeholders and the relation between them.



4-3 View of stakeholders with the relations among them

Accomplishment of the interviews

All interviews were recorded to help the analysing process. The informants were asked for permission to use a recorder before the interviews. The informants were also assured of anonymity in the paper. The use of a recorder is one of the most usual ways to log data, according to Ringdal (2001). The disadvantage by using a recorder is that the respondent might feel tied up and therefore be restrictive when it comes to information sharing (op.cit.).

The informants were first given a short introduction of the scope of the thesis before the actual interview was carried out. As it is in the opening stages that the informants sets his or hers defences (McCracken, 1988), I felt that by starting with an introduction, and then informal opening questions about the informants professional position and background, I would establish a good relationship of trust and willingness of cooperation between the informants and my selves.

4.6. Data analysis

Analyses of the collected information have been performed persistently, but because of a delay in getting the actual case, the data analysis could not be started until mid April. This was because of the domino effect the delay had on the interview process considering the difficulty of identifying all the target informants without clear cut knowledge about the case. A lot of time and effort has been put into the analysing phase as this process is of vital importance to the quality of the results and findings.

All the interviews were held in Norwegian. The interviews where then transcribed into text files where the main aspects of the informants were highlighted. In a process with several different informants it is important to filter the information to avoid information overload. These aspects were finally grouped into categories to be used in the analysing process. Allowing the informants to talk freely sometimes led to the informant mentioning aspects that were supposed to be answered later, but since this approach secured a good flow in the interview, it was considered a better approach than a more rigid structure. However, the talk freely-approach did make it more difficult to structure the answers afterwards.

4.7. Report

Kvale (1997) claims that the writing-style of a report holds a key position in the communication with the reader; it forms the basis for the reader's evaluation of the validity of the presented material. Kvale further states that the fear of subjective interpretations could lead to the report consisting of many quotations instead of coupling the interview material with theoretical reflections, something which could make the report both tiresome to read and less convincing. I have therefore tried to keep the use of quotations to a minimum, and instead summarised the key aspects and connected it to the theoretical framework presented in part two of this thesis.

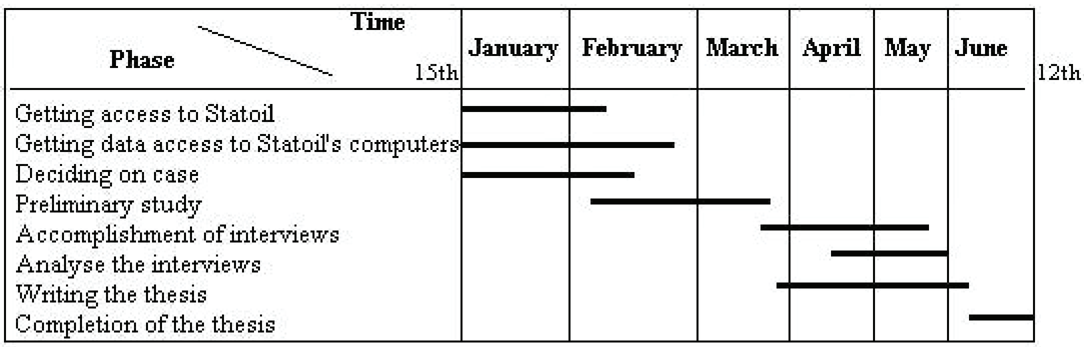
Issues regarding morality could be raised when research results are publicised. The publication should be seen in relation to ethical guidelines such as informed approval, confidentiality, and consequences. The informants were all informed of the intention behind the interview; to use the interview material in this thesis. Getting approval from the informants was done orally, and I chose to make them anonymous to make it possible for the informants to answer the questions without being afraid that the answers could be held against them later.

Personal experiences from earlier works have shown me that the data gathering phase often takes longer then anticipated. The writing of the report therefore started before all of the interviews had been carried out. Notes, drafts and summing ups was written and discussed on a continuous basis with my teaching supervisors during the work on this thesis.

The next part, part four, presents the results of the research together with a discussion of the results. The main findings of R1 are summarised in the start of chapter 5, while a thorough reflection of the findings constitute the rest of the chapter. Chapter 6 does the same for R2. Part five constitute of the conclusions of the study, recommendations to future studies, and a bibliography of the references used in this thesis.

4.8. Time summary of the work on this master thesis

The education regulations of NTNU limit the general timeframe of a master thesis to 20 weeks plus 1 week as Easter holiday, making it 21 weeks in total. Further, NTNU has the 15th of January as a fixed start-up date. As a consequence of the time limit of 21 weeks and the fixed start-up date, it is vital that the work on the thesis gets started as soon as possible in order to complete the work within the given time limit. The work on this thesis, however, experienced a delay due to some difficulties. To be able to sit close to Statoil's R&D environment regarding IO, it was decided that I would be given access to Statoil's R&D centre at Rotvoll in Trondheim. Getting access to the centre took several weeks because of changes in the Statoil organisation that altered the distribution of responsibility related to who was in charge of giving this access. In addition, getting the actual case also proved time consuming as Statoil did not finally decide on Snøhvit until mid February. Finally, getting data access to Statoil's computers took even longer because of some misunderstandings in the hierarchy of Statoil's IT division. These three delays brought along consecutive delays because of the domino effect the initial three delays had on the interview process considering the difficulty of identifying all the target informants without clear cut knowledge about the case. Something which again led to the fact that the analyses of the interviews had to be moved to late April.



4-4 Time summary of the work on this thesis

4.9. Self-evaluation of the scientific methodology

The scientific approach to this thesis has been presented in the previous sections of this chapter. In this section I will give a personal evaluation of the scientific approach based on the notions of *validity* and *reliability*[19]. The intention behind writing the "scientific methodology" chapter is to make the reader of the paper able to reflect on the research approach and whether the results could be generalised or not. Through his or hers reasoning, the researcher should make it understood for the reader how the conclusions are reached, even if the reader doubts the findings (Ringdal, 2001).

Validity can be divided into *internal validity* and *external validity*. The internal validity is a measurement against which the research results are judged. To be internally valid the results of a research are considered to be accurate indications of the attitudes or knowledge of the informants in the research, whilst external validity refers to the accuracy of the scientific results when generalised beyond the survey situation and into the real world (Ringdal, 2001).

Reliability is generally used about measuring errors (Ringdal, 2001). It can be described as *"the extent to which the research gives the correct answer"* (Kirk & Miller, 1986). In qualitative studies, reliability is related to the researcher's reflections upon how the data collection was carried out, and especially with focus on possible sources of errors. The evaluation will often be vaguer for qualitative research than for quantitative approaches as the approach and research conditions are less static for qualitative than with quantitative research (Ringdal, 2001). The method description is thus especially important for the qualitative research method as it is through the researcher's reasoning that the reader will be able to reflect upon the validity and reliability of the study.

The most important criterion for internal validity in interviews is privacy (Polkinghorne, 1991). This was sought ensured for by making the informants anonymous in the analysis phase. Is should also be stressed that the researcher should be conscious about his or hers role and expressions, and how this may influence the informants (Ringdal, 2001).

[19] It should be mentioned that the relevance of using the notions *validity* and *reliability* qualitative research is something of which is much debated. Some prefer to use the concepts *verification* and *trustworthiness* instead of validity and reliability, respectively.

The biggest threat against the internal validity with qualitative interviews is, according to McCracken (1998), over-reporting. This happens if the researcher perceives the interview as a possibility of guiding the attention towards some specific topics and therefore focus' especially on those topics. Over-reporting could also occur if the researcher presents the study in such a way that the informants try to give the researcher what they think he/she are looking for rather than telling their fully opinions. Over-reporting was tried avoided in this thesis by presenting the core of the study as an introduction to the interviews; emphasising the thesis' goals of differentiating rather than generalising.

As stated, the external validity refers to which degree the scientific results can be generalised in the real world. This study is conducted within a given frame of time, linked towards one specific organisation and a small part of this organisation's staff by a relatively independent researcher. All these aspects are conditions that affect the results of this study. In order to obtain the best possible basis of information, the interviews were carried out with various stakeholders.

Reliability can be described, as earlier mentioned, as *"the extent to which the research gives the correct answer"* (Kirk & Miller, 1986). While working on this thesis I was given the opportunity to have access to Statoil's IO Division at their research centre at Rotvoll in Trondheim. The possibility of locating me so close to the people in Statoil that does the strategic thinking concerning the future IO solutions is something I regard as a huge advantage. Being part of the organisation's research environment gave me valuable information and knowledge with little or none delay through informal talks and referrals. However, being so close to a research environment also creates challenges related to nearness to the sources of information. During my work on this thesis I have had two teaching supervisors, one from Statoil and one from SINTEF, that both have IO as their daily work subject. My work is obviously been influenced by their opinions and views, but I have tried to be aware of this trough the selection of informants. By including different stakeholders, I have tried to get the necessary distance, and instead embrace the diversity of opinions regarding the IO theme; minimizing the possibility of being too influenced by the views of the research environment and my teaching supervisors. Figure 4-3 in chapter 4.5.3 illustrates the stakeholders and the relations between them. I have also tried to cut short the influence by using both earlier relevant research literatures that was not directed especially towards the O&G industry, combined with governing documents from Statoil.

Most of the interviews were performed by telephone. This is no ideal interview setting because of lack of direct communication. Direct communication gives a higher flexibility both due to the possibility of using body language as a communication tool, and using visual tools like drawings and sketches (Ringdal, 2001). Nevertheless, personal interviews are a resource-demanding method, and this is why most of the interviews had to be performed by telephone, even though it may invite to superficial questions and answers, as the respondents were located geographically all over Norway. The exception was with personnel from SINTEF and some from Statoil. The interviews were held in Norwegian as all of the informants were Norwegians, while the thesis is written in English. In addition to avoid the report from being tiresome by consisting of many quotations, the use of quotations has also been sought minimized due to the chance of misinterpretation when translating the quotations from Norwegian to English. Instead, the material from the interviews has been written as summaries to grasp the key aspects.

To summarise I would stress that I have sought to find the right balance between nearness and distance. I have spent a great amount of time at Statoil's location at Rotvoll in Trondheim, but have also tried to minimize the influence of this nearness by selecting a range of stakeholders as informants, and used independent research literature as part of the basis for this thesis.

PART FOUR: RESULTS AND DISCUSSION

5. R1: THE SNØHVIT CASE

In this part the findings of the study will be presented and discussed. The findings have been identified through the interviews and will be discussed on the basis of the theory presented in part two of this thesis; the theoretical framework. This chapter is related to R1, while chapter 6 concerns R2.

R1:

Investigate the activities and plans at Statoil with regard to the case:

a) **Is the function analysis and function allocation at Snøhvit attended to in such a manner as recommended in the CORD-methodology?**
b) **What are the potential pitfalls of the selected design concept in the Snøhvit case?**

5.1. Main findings

The findings concerning R1 can be summarised as the five main elements given below. A more carefully discussion of the findings will be given after the summary.

- The study has identified a need for the development of methodologies such as CORD.
    - The informants expressed an opinion that they demanded a tool or method that can act as a package deal that combines several existing methods to create a whole as it today can be hard to keep track of all the regulations, standards, guidelines, practices, methods, etc.
    - Historically, the NCS has seen several major cost overruns on O&G-projects, and figures presented to the Norwegian Parliament by OED[20] have ranked Statoil as the worst of the companies on the NCS at more than one occasion. Further, a committee appointed by OED concluded in 1999 that *poor planning* was the main reason for the cost overruns on the O&G-projects during the nineties. In the work of improving the planning phase, better methods and methodologies, such as CORD, hold a key position.
- However, the research has found that the CORD-methodology is not very well known; only a few of the informants had heard about CORD. The CORD-project is not very easily accessible, and even informants with background as HF specialists regarded CORD as *almost a secret*.

[20] OED: The Norwegian Ministry of Petroleum and Energy

- Earlier research has shown that the later in a project a problem area is identified, the more costly it will be to change the selected solutions to deal with the problem. It was identified that the HF-analyses regarding the control room at Snøhvit was not conducted at start-up of the project as recommended by the CORD-methodology, and also later in Statoil's own governing documents. During the interviews it was stated that at the time the Snøhvit project was started, the practice had traditionally been that HF analyses were not always carried out. Instead, solutions were then selected more on the basis of presumptions from earlier projects.
- The Snøhvit field is a totally new design solution on the NCS; no surface installations and the production is 100% remotely controlled by personnel located 150 km away from the field. With no personnel on-site to observe and report any divagations the demands on HMI and HF aspects increases. Efficient fetching of information and good interactions will thus be vital for safe operating. History has shown examples of accidents were poor HF design has contributed to the scale of the outcome, and the importance of a good HF design to avoid that mishandling makes a divagation escalate into an accident, must be highlighted.
- When establishing the Onshore Support Centre at Stjørdalen, the work group in Statoil that focused on organisational development were faced with a tough task when they wanted to alter the work processes at that time. Changing the mindset of people that had worked in a certain way for years took a long time. In addition, the control rooms also proved challenging as the contractor had his focus on budgets and time limits; limiting the OSC-projects possibility of influencing the architectural choices.

5.2. A need for the development of methodologies such as the CORD-methodology

The ISO 11064 standard was first developed over ten years ago. The standard has then seen adjustments during the years towards the new practices of the O&G industry. Before the ISO-standard was developed, the O&G industry used demands from the authorities and from NORSOK-standards[21] as guidelines. The development in the industry had been marked by a continuous increase in the use of control rooms and new allocations of functions during the eighties. The authority demands and NORSOK-standards came as a response to a growing need to look into HF aspects of the control rooms as the design solutions at that time was

[21] The NORSOK standards are standards developed by the Norwegian petroleum industry to ensure adequate safety, value adding and cost effectiveness for petroleum industry developments and operations.

characterised by ad hoc-thinking. As the use of control rooms continued to increase during the nineties and after the millennium, the need has developed further.

5.2.1. A need in the future Statoil organisation

The introduction of the new IO paradigm over the last years has resulted in some situations not fully handled by the current standards and guidelines. The increased use of control rooms over the last decades has increased the technical complexity and changed the function allocations; creating new challenges that needs to be addressed. The standards and guidelines of these decades do not fully include the new work collaborations of today where the function allocation embraces the possibilities of VOs and remote team working over the boundaries of companies. For instance, the ISO 11064 is a good standard; it is the standard that up until now has constituted the basis for analysing and designing control rooms. However, it has some limitations related to today's practice as it has a single-mind focus on control rooms that does not fully handle the new ways of working and cooperating.

As a result of the increasing use of control rooms; new instructions, practices, governing documents, regulations, etc have been developed; almost creating "a jungle" of methods. Identifying which method is the best in each case is not an easy task. To cope with this development, some of the informants stated that new methodologies that could act as package deals are needed, and this was the reason for developing the CORD-methodology; to address the challenges and provide well-established mechanisms for close cooperation between the operators and their vendors on the NCS. CORD tries to be such a package tool as the methodology includes all the phases from visions, through analysing and allocating, to consequence analyses in retrospect. It couples international standards, as the ISO 10064 and ISO 6385, with other guidelines to seek the best from each of the various one and meld it all together to a best practice. Performing analyses with CORD as the superior framework supported by standards and guidelines that each looks into aspects at detail level will thus better ensure that best possible solutions are being sought through the analyses.

5.2.2. A need in Statoil based on historical experiences

The construction phase of a project has budgetary frames to act in accordance with estimated in the planning phase, and any considerable cost overrun is regarded as unacceptable. Yet, the

O&G industry has historically seen numerous of such overruns. The obvious reason for this is the difficulty connected to estimating the real future costs as no project is identical to previous ones; problem areas such as geology and technology varies from one project to another. Economical theory holds that the estimations should be done in accordance with the expectation principle that takes risk into account; stating that costs could both rise or sink compared to the estimated value (Research Council of Norway, 2004). Not having overruns to a certain degree could just as well be an indication of conservatism than good finance management. As the major O&G companies generally have several projects in progress at the same time, they reduce the risk by spreading it out on those projects, and a budget overrun could be a sign that the company follows the established principle for profitable operations (op.cit.).

Still, the number of overruns compared with the total number of projects, or the difference between total real costs compared to the total estimate, should be sought minimized. In 2003, OED presented figures to the Norwegian Parliament showing the differences between investment estimates and updated estimates for the ongoing projects on the NCS at that time. The figures ranked Statoil and bp[22] as the worst companies on the NCS with respect to budget overruns (Aftenposten, 2004).

[22] bp: formerly known as British Petroleum

Investment estimations for ongoing projects

Operator	Budget	New estimate	Change
STATOIL			
Sigyn	2138	2057	421
Vigdis utvidelse	2739	2667	-72
Kvitebjørn	9467	9802	334
Snøhvit med LNG anl.	40 506	46264	5757
Kristin	16593	16940	347
Kvitebjørn oljerør	668	572	-96
Mikkel	2627	2104	-523
Visund gasseksport	2623	2643	20
Sum	**77361**	**83049**	**6188**
HYDRO			
Tune	2936	2984	48
Grane	17918	15901	-2017
Oseberg J Struktur	1453	1453	0
Fram Vest	4627	3805	-822
Sum	**26934**	**24143**	**-2791**
BP			
Valhall Flanke	4506	4928	421
Valhall Vaninnjeksjon	5116	7329	2276
Sum	**9622**	**12257**	**2697**
ESSO (EXXON)			
Ringhorne	9555	8819	-736
Ringhorne Jurassic	1376	1401	25
Sum	**10931**	**10220**	**-711**
TOTAL			
Skirne Sybve	1872	2102	230
Sum	**1872**	**2101**	**230**
GASSCO*			
Net 1 (Kårstø)	1178	821	-357
Kollsnes - LNG anlegg	2554	2195	-350
Røgass sjørør	382	307	-75
Sum	4114	3323	-782
Totalsum	**130 934**	**135157**	**4320**

All numbers in mill NOK

*** Statoil: technical operator**

5-1 Investment estimations for ongoing projects, 2003

Snøhvit has later seen further overruns, and had in September of 2005 an investment estimate of 58.3 billion NOK (Teknisk Ukeblad, 2005). OED presented new figures to the Norwegian Parliament in 2005, again ranking Statoil as the worst of the companies on the NCS (OED, 2005)[23].

[23] PUD: Plan for development and operation (in Norwegian: plan for utbygging og drift)
PAD: Plan for plant and operation (in Norwegian: plan for anlegg og drift)

Investment estimations for ongoing projects

Operator	PUD/PAD estimat	New estimations	Change
Statoil			
Kollsnes NGL	2626	2577	-49
Kristin	17064	20674	3610
Kvitebjørn	9622	10048	426
Kvitebjørn oil pipes	686	486	-200
Skinfaks / Rimfaks IOR	3478	3478	0
Snøhvit LNG *	41656	60174	18518
Statfjord senfase	13651	13651	0
Urd	3489	3571	82
Volve	1963	1963	0
Sum	74545	93371	22387
Hydro			
Fram Øst	3927	3927	0
Njord	1073	1073	0
Ormen Lange, including Langeled	67869	66191	-1678
Oseberg J-structure	1496	1848	352
Oseberg Vestflanken	2217	2272	55
Vilje	2103	2116	13
Visund	2700	2676	-24
Sum	81385	80103	-1282
Gassco			
Tampen Link	1488	1460	-28
Kep 2005	5808	4187	-1621
Sum	7296	5647	-1649
Paladin			
Enoch	786	851	65
Blane	1650	1870	220
Sum	2436	2721	285
ConocoPhillips			
Ekofisk Vekst	8290	8148	-142
Sum	8290	8148	-142
Marathon Oil Ltd			
Alvheim	8235	8062	-173
Sum	8235	8062	-173

All numbers in mill NOK
* Includes investments in LNG ships

5-2 Investment estimations for ongoing projects, 2005

The two OED presentations show that two projects in general, Snøhvit and Kristin, contributes to Statoil's poor score. However, these two projects are not the only major cost overruns in the history of Statoil. Over the period of the last 20 years, Statoil has spent a total of over 49 billions NOK[24] above the initial investment estimate on their five worst projects (Dagens Næringsliv, 2004; Teknisk Ukeblad, 2005; OLF, 2005).

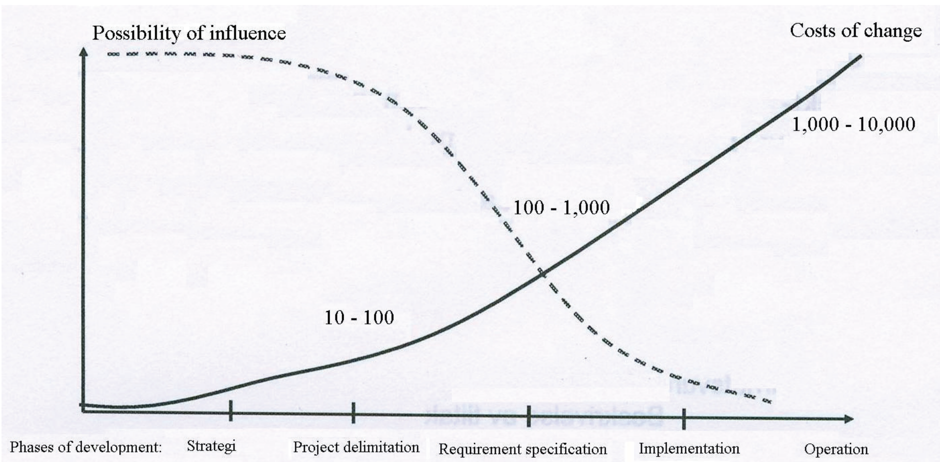
[24] The figures represent the value of the NOK at the time each project was completed, and is thus not equivalent to 2006-NOK.

Table 13 Major cost overruns in Statoil

Name of the project	Time	Cost above initial estimate
Mongstad	1987	5.4 bill NOK
Kalundborg	1995	1.25 bill NOK
Åsgard	1999	20 bill NOK
Kristin	2005	3.7 bill NOK
Snøhvit	2006	18.8 bill NOK

A committee[25] appointed by OED, known as “Kaasen-utvalget”, evaluated in 1999 thirteen of the overrun projects on the NCS during the nineties. The committee’s conclusion was that *poor planning* was the main reason for the cost overruns in the projects (Aftenposten, 2004). When questioned about the conclusions of the committee connected with the overruns at Snøhvit, the acting chief executive of Statoil, Erling Øverland, admitted that although it would be wrong to say Statoil had not learned anything from the committee, Statoil had not been good enough and thus still had work to do, referring to the recommended actions by the committee (op.cit.).

In the work of improving the planning, it is obvious that better analysis methods and methodologies in the pre-engineering phase hold a key position. The analyses shall identify problem areas that have a potential for affecting the goals and visions. They shall also describe the requirements for performing the functions. The later such problem areas are identified, the more costly it will be to make changes to the organisation and the function allocation, and the possibility of influencing the selected solutions decreases (Samset, 2001). This is illustrated in figure 5-3[26].



5-3 Costs of change connected with the development phases of a project

[25] NOU 1999:11
[26] The numbers on figure 5-3 are selected to indicate the scale of the graph.

The CORD-methodology alone cannot accomplish this, but it could contribute to a needed improvement of the planning phase by its aspect of being developed as a continuance of earlier standards; improving the analysis phase as it melds current standards and guidelines into a whole to make a best practice.

5.3. CORD, not a known methodology

The interviews, however, identified that the CORD-methodology is not a well known method. Only a few of the informants had knowledge about the methodology, let alone ever to have heard of it. The first HF analyses on Snøhvit's control rooms were carried out in 2002 – 2003. The HF team used the traditional ISO 11064 as basis for their analyses as the CORD-methodology was still under development at that time. While the CORD-methodology is relatively new, developed after the millennium, the ISO 11064 standard is over ten years old, and has up until now constituted as the traditional basis for conducting HF analyses on control rooms.

With the challenges discussed in the previous section still in mind, Statoil should work towards making the CORD-methodology better known to its personnel, and especially those that potentially could be part of such analysis teams. CORD itself is not an answer book that provides final solutions. It is a tool for how to structure, approach and perform analyses of problems. It should therefore be rooted in the organisation for ensuring safety, improving efficiency, cutting costs and optimising operation. The best way to achieve this is by making process owners and project responsible people leading and taking part in the practical work. The challenge with the CORD-methodology is to get this done. At the time this thesis was written the methodology was not very easily accessible. To get access to official documents of the CORD-project one had to sign up and then be granted access at the homepage of the CORD-project[27]. During the interviews, it was stated that CORD was considered *"almost a secret"*.

The reason for not promoting the CORD-project could have to do with the costs related to the development of the project. As the CORD-project has lasted over several years, and the financial funding has come from the O&G operators involved in the project (CORD, 2003),

[27] http://prosjekt.marintek.sintef.no/cord/

the companies involved could therefore be reluctant to share the documents and recommendations of the CORD-methodology to avoid giving competitors a free ride. The verification and validation tool named CRIOP, initially created in the late eighties, has managed to get recommended as the preferred method within the O&G industry. In addition to obviously being a good method, CRIOP has accomplished its status by being a public method allowing the actors to actively use it.

The CORD-methodology is mentioned in Statoil's governing document WR1279 "Human factors analysis" as a tool that *"can be used to manage the human factors in the early design phases"*. However, the follow up document to WR1279; the governing document WD0603 "Human Factors Analysis Methods" that goes into detail about the selection and execution of such HF analyses, does not mention CORD when describing the different phases of HF analyses; it only names ISO 11064 as an alternative.

5.4. The function analysis & function allocation at Snøhvit

The CORD methodology starts out with visions and goals. The Snøhvit field is located far north in Norway, making it harder to access than the other fields on the NCS who in general are located on either the west coast or outside the mid part of Norway[28]. One of the goals of the Snøhvit project was therefore to keep the manning low; to create a lean organisation to improve the efficiency. The methodology then moves to identifying requirements and opinions from the stakeholders. With regard to the goal of lean organisation, Statoil and ABB saw a possibility of moving some of the functions and connected staff away from Snøhvit. Allowing ABB to do the job remotely from Bergen, instead of having to fly the personnel to the Snøhvit field every time something needed to be done, would limit the time spent on the job and thus improve the efficiency and cutting operating cost.

It is vital that the cooperation is based on analytical considerations when establishing the cooperation and its technical solutions. This to ensure that the solutions have highlighted technical, organisational and HF related aspects. The first step consists of creating an analysis team. To identify and analyse the functions, and then allocate them, an analysis team is required. The function analysis and function allocation shall be done in the light of MTO thinking and HF design, and CORD thus states that the analysis team shall include team

[28] A map showing the NCS can be found here: http://217.68.117.237/website/NPDGIS/viewer.htm

members with knowledge of these aspects. By using different analysis techniques like "goals means task analysis" (GMTA) and "work process modelling" (WPM), functions are analysed iteratively to find solutions for how functions, activities and roles can be allocated or changed in an optimal way to achieve the visions and goals that are stated for the project. The GMTA technique is an analysis tool used to identify functions and their associated preconditions and constraints against allocation, and finally identify tools that could help overcome the constraints, while the WPM is an alternative approach to GMTA that identifies how the work process and functions interact with each other. The WPM is suitable for analysing work processes when performing modifications in existing organisations, whilst the GMTA approach is more suitable when no previous organisation or work processes exist.
The GMTA model drawn is not a result in it self. The results from the GMTA analysis are the identified constraints and tools.

The CORD methodology states that analyses shall be done at start-up of a project. However, the interviews identified that HF analyses had not been carried out at start-up at Snøhvit, but rather been included in the projects after a certain time. Many of the design solutions were already chosen when the HF team was assembled. It was stated that these solutions had been selected on the basis of presumptions from earlier projects, and were therefore in many occasions not specifically tailored towards Snøhvit. With reference to figure 5-3, the HF team was thus faced with a challenging task when analysing and recommending changes as they had to defend each change they recommended since all these changes had aspects regarding cost and time related to them. The reason for not carrying out a HF analysis at start-up were said to be due to the fact that such analyses had not traditionally been done before on a regular basis in Statoil, and it therefore took some time to establish such a HF team. This aspect is sought addressed with the development of new governing documents in Statoil.

The two Statoil governing documents; WR1279 "Human factors analysis" and WD0603 "Human Factors Analysis Methods", were made valid on the 5th of September 2005. Before this date no governing document in Statoil had explicit stated that HF analyses had to be carried out. The intention behind the development of these two governing documents were to ensure that such analyses were given the proper attention in the design phase to prevent situations where selected solutions needed to be altered as a result of analyses had not been carried out in advance of the solution decision. WR1279 states that the line management is responsible for ensuring that the relevant HF analyses are carried out, and that the analyses must be carried out at start-up of projects relating to either design of new installations, or modification or upgrading of existing installations. Start-up is further defined as concept evaluation and pre-engineering.

The first HF analysis were not conducted at start-up, but it was stated in the interviews that the introduction of the WR1279 and WD0603, in addition to the practical experience of having conducted such analysis, has now made it much easier to start the process of analysing, than earlier. During the last years, several more analyses have been conducted at Snøhvit such as task analysis, workload analysis, communication analysis and function analysis & allocation. These analyses have been continuously revised in order to include new aspects, update already existing ones and as verification on findings and corrections from earlier analyses, but they have been performed independently and has not taken fully advantage of the recommendations of the CORD-methodology.

5.5. Potential pitfalls of the selected design

Snøhvit is a new design solution not only in Statoil, but on the NCS too. There exist no surface installations, and the production is 100% remotely controlled by personnel located more than 150 km away from the field. This brings along some challenges, obviously. The fact that there will be no one on the field to observe and report any occurrences of divagations or hazards implies a need for automation of the alarm detection. HF principles must be in focus to ensure that such systems and its HMIs are designed in a way that focuses on safe operating.

History has shown that poorly ergonomic designed solution can lead to disaster. For instance, at the Three Mile Island accident where the operators were faced with over a 100 alarms during the first minutes (TMI, 1979). Far from all of these alarms were critical, in fact many of them were secondary alarms that came as a response to the critical alarms, but the system had not been designed in a way that provided the operators with a way of suppressing the unimportant ones and identifying the important ones. The critical alarms thus disappeared as a “needle in a haystack”. The danger of having too many alarms was recognised during the design stage, but the problem was never resolved. In addition, the arrangement of controls and indicators was not well thought out as some key indicators relevant to the accident were on the back of the control panel, and several instruments went off-scale during the course of the accident. The results were that the Three Mile Island got a worser outcome than if the issues above had been dealt with (op.cit.).

As described earlier in this thesis, the CORD-methodology, and the ISO 11064 and ISO 6385 that CORD partly builds on, has such HF aspects as focus area. Using these tools and methods is thus of importance to address the challenges related to the HF design to avoid similar faults as on the Three Mile Island plant. Efficient fetching of information and good interactions are vital due to Snøhvit's low manning. Use of large-screens, and designing HMIs and computer interfaces that highlights HF thinking and the need for fast and correct information can accomplish this.

In addition, an report in Statoil states that there is a desire to connect Snøhvit to an expertise centre in a different area due to the low number of engineers at Snøhvit within the segment of rotating equipment. Building organisational redundancy is vital in an industry such as the O&G as the consequences of divagations or accident could have a catastrophic outcome.

However, in the Government Proposition no. 38 it is referred to a report by McKinsey[29] that states that it takes an average of 30 years from the idea phase to the new technology is introduced to 50% of the O&G market, something which is two to three times longer than other markets (OED, 2002). Even though the ISO 11064 is over ten years old, it was still not fully exploited in the design phase of O&G projects when Snøhvit was in that phase. The importance of a good HF design to avoid that mishandling evolves a divagation to an accident must be highlighted, and as a response to this, Statoil has developed governing documents in order to root such analyses into the design phase in their future projects.

5.5.1. Experiences from Stjørdal

Although Snøhvit as a whole is a new design solution in Statoil, the establishment of control rooms onshore is not. The Onshore Support Centre (OSC) at Stjørdal just north of Trondheim was completed in December 2003. Here it all started out with an idea about how to better improve the geology work using 3D visualisation onshore to increase production. As the project elapsed, it snowballed from a relatively minor establishment to a major project as

[29] McKinsey is a worldwide management consulting firm that advises companies on issues of strategy, organisation, technology and operations.

other divisions, mainly from the "underground" environment[30], hooked up on the principles and ideas leading to the development of the OSC. The Operations & Maintenance (O&M) division got influenced by the thoughts in the aftermath of the OSC-project, and have built operating rooms of their own at Stjørdal for installations[31] at the Halten/Nordland area.

The OSC-project experienced various challenges during the establishment of the centre. They created a work group that focused on organisational development as the people connected to the project early saw that in order to optimise the utility of the centre they needed a focus on MTO to alter the organisation and its current work processes. Simply improving the technical solutions would not be enough. The group had to argue hard to convince people of the opinions of the work group as they were faced with an environment were the operations had roughly been done the same way over a number of years, and anchoring the MTO-view took a long time. In addition, the OSC-project was also faced with a tough task in the design of the actual rooms. The contractor in charge of constructing the building that should house the centre had his concern on the budgets, financial aspects and time limits, making it harder for the crew of the OSC-project to influence the architectural choices. The result were that the control rooms had to be modelled based on predefined sizes and not in relation to what would be the best possible solution. During the interviews one operator stated that the design of the control rooms has limitations regarding unfortunate placing of the operators due to lack of space.

5.5.2. Utilizing the experiences

The OSC and the following operating rooms of the O&M division were pioneer projects in Statoil, making their experiences from the development phases of the projects valuable to similar establishments, such as Snøhvit. The interviews identified that the experiences from the establishment at Stjørdal is not fully taken advantage of by Snøhvit. Statoil's research centre at Rotvoll in Trondheim has been involved to a certain degree, but as with the HF analyses, many of the decisions regarding the technical equipment had already been made when the research centre was involved, limiting the utility of the experiences from Stjørdal.

[30] Underground: The operations at the seabed and below; drilling, reservoir, work on the wells, etc.
[31] Halten/Nordland installations: The Kristin, Heidrun and Åsgard field.

However, Statoil has set up a database in the IO corporation initiative that has the function of gathering all experiences related to the projects connected with the initiative to make it easier to share the experiences throughout the Statoil organisation.

6. R2: THE FUTURE OF IO

R2:

Evaluate the future of IO:

a) **How will an increase in vendor involvement and cooperation affect Statoil's operations?**
b) **How should Statoil work to ensure that new IO solutions and concepts are analysed and designed in a best possible way?**

6.1. Main findings

The findings concerning R2 can be summarised as the three main elements given below. A more careful discussion of the findings will be given after the summary.

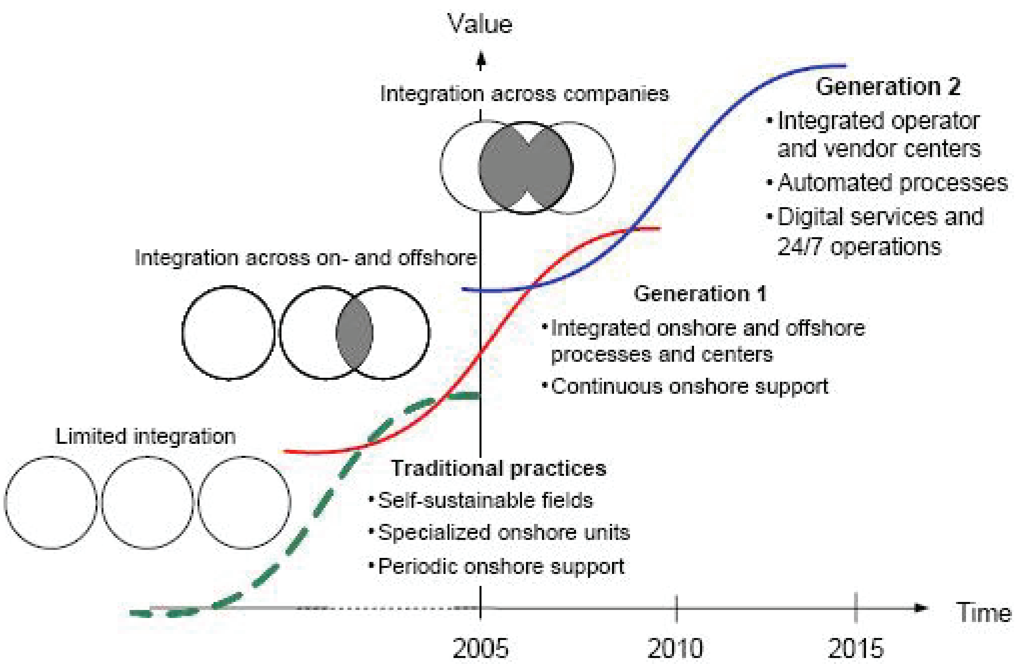
- The vendor involvement will increase in the future, bringing the vendors closer to the decision-making and the design of the solutions. The vendors are the specialists within their fields, and better utilization of this expertise will result in better solutions. An increased involvement will also result in a closer integration of the work processes of the operators and the vendors. In the future, the O&G fields will be operated by operators and its vendors located in operation centres onshore, and the vendors may even have taken over some of the daily work and decision-making processes.
- The organisations will embrace the possibilities of VOs, and the vendors will establish control rooms and centres of their own, resulting in organisations and divisions working and interacting virtually with each other in a geographically dispersed setting. Such a development will increase the complexity and tighten the couplings of the O&G industry, and to ensure that the aspects of Perrow are addressed, the organisations should highlight the recommendations and principals of the HRO thinking.
- To anchor the mission of Statoil's corporation initiative and its following change processes, Statoil must focus on Kotter's pitfalls and recommendations to avoid making mistakes that could make the work on the initiative and its vision fail. Success hinges on everyone pulling together in the same direction, and to create the motivation, enthusiasm and drive that is necessary to realise the initiative, good communication are needed to create a common understanding and joint efforts.

Listening to the views of the stakeholders to make everyone work together is essential to form the basis needed for creating smart solutions.

6.2. Increased vendor involvement

Based on the input from the interviews the vendors will only get more influence in the future. Their involvement in Statoil's processes will increase; bringing them closer to the decision-making and the design of the solutions. The continuing improvement of the ICT technology, combined with the fact that a vendor is the specialist within its field, constitute the basis for this development. The desire to better utilize the knowledge that the vendors possess to build better solutions is regarded as the driving force.

A work group in OLF concluded in their report that the integrated work processes of IO most likely will be implemented in two stages; first by Generation 1 (G1), and then by Generation 2 (G2) processes. Both generations are said to change the existing work processes profoundly (OLF, 2005).



6-1 Implementation through G1 and G2

6.2.1. G1

At this level, OLF states that all major operators active on the NCS are investigating the improvement potential associated with IO, and most of the companies have built onshore drilling centres. Some companies will have onshore operation centres that integrate onshore and offshore drilling, completion, production, maintenance and logistics functions. The implemented practices differ amongst the companies, but some will be common; the practices are built around onshore centres that are integrated with operations offshore through collaboration facilities and solutions, and the centres are staffed by personnel who have specific knowledge about the field and its processes. With reference to Statoil, Snøhvit and the operation rooms on Stjørdalen offers the best examples of Statoil's work towards G1 and G2, and Statoil are pushing hard towards G2 when allowing ABB to work remotely on Snøhvit from Bergen.

6.2.2. G2

Implementation of the G2 processes will lead to a closer integration of the work processes of operators and vendors. It will also offer the development of operational concepts that have as an aim to make it possible to offer a large portion of the services required to operate a field "over the net". O&G fields will be operated by personnel located in operation centres belonging to both operators and vendors, and the vendors may have taken over some of the daily work- and decision-making processes like monitoring, analysing and optimizing tasks.

6.3. Embracing the possibilities of VOs

This increased involvement of the vendors will lead to organisations forming VOs; embracing the possibilities and benefits of the VOs' structure. The vendors will start establishing control rooms and centres of their own in collaboration with the operators. Allowing the vendors to work together with their collaborators from separate locations, in this thesis visualised through the cooperation solution between Statoil and ABB, enhances the efficiency by minimising time spent on travelling and other similar factors and thereby reduces the costs. The concept of CE[32] will make its way into the O&G industry giving the actors in a collaboration better possibility of coordinating the planning and performing of activities to

[32] CE: Concurrent Engineering

reduce both time spent on decision-making and lost-time as a result of maintenance operations.

6.3.1. Concurrent engineering (CE)

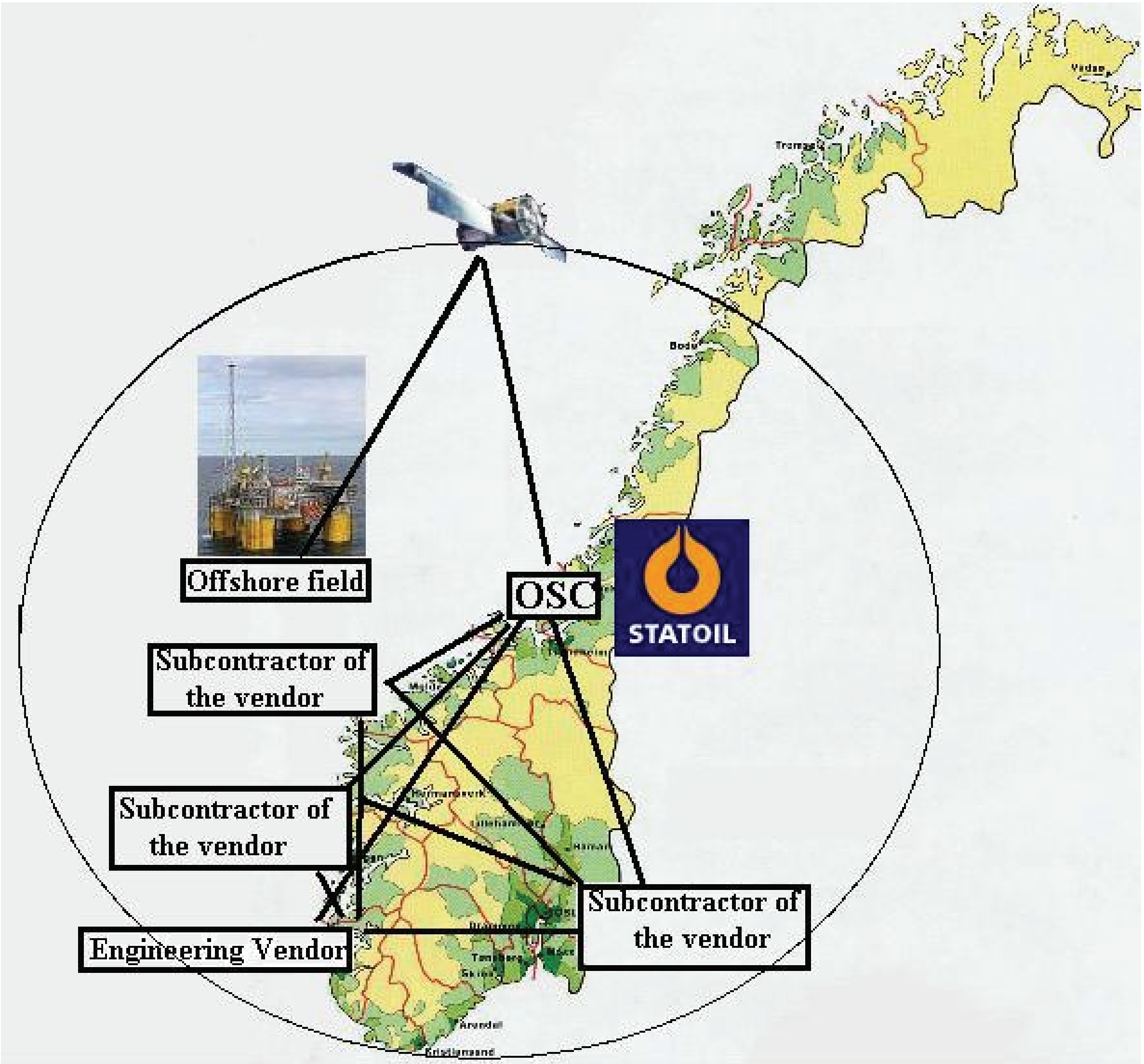
The past two decades have been characterised by important changes in the market. Not only is the NCS getting mature, but the companies have to respond to fierce competition, quicker delivery of new products on the market and growing costs. The time to market (TTM) has become an essential issue, as it enables both quick response to changing market preferences, and the continuous introduction of innovative technology. The vendors are now more and more integrated in the company's strategies (De Lit, 2000).

To face the challenge of the TTM, designers' effort gave birth to CE. Practices in process engineering have steadily evolved from the use of stand alone tools and methodologies to a more integrated and collaborative workflow approach that combines process synthesis and conceptual design with process simulation and detailed design (Howell et al., 2002). CE is a systematic approach to an integrated, simultaneous design of both products and their related processes, including production (Gunasekaran, 1998). Process optimisation has been widely practiced as a means of cutting costs. However, the ability to optimize a plant’s physical assets, coupled with optimising the associated processes, is a relatively new approach. The main principle of CE is to integrate product and process development. By adopting such a multidisciplinary, integrated workflow CE ensures that engineering and operations decisions are based on sound business lifecycle knowledge, reducing the design lead-time and improving both the quality and cost (Howell et al., 2002; De Lit, 2000).

Collaboration and integration of process engineering work results in higher engineering efficiencies with respect to a plant’s design-schedule and budget as well to the day-to-day operations on the plant once it has started operating.

The major challenges with CE, however, are creating the needed trust and ensuring that controllability, operability, availability and equipment reliability for these designs are considered as integral parts of the process-design phase. Aligning incentives takes time and effort, resources that are often scarce, and achieving the effective integration is a difficult task. Efficient communication and coordination among the diverse disciplines are key concepts in ensuring the success of CE (Jagou, 1993).

A CE in the O&G industry could be a collaboration consisting of Statoil, one or more of Statoil's vendors, and subcontractors of the vendors. This collaboration is illustrated in figure 6-2.



6-2 Example of a CE collaboration

The collaboration illustrated in figure 6-2 could have a positive impact on both costs and safety levels. The organisations of the collaboration share monitoring-data of the field and the installation among them giving the actors possibilities of better predicting the needs for modifications and maintenance (MM). For instance, one of the subcontractors identifies that some of their technical equipment on the installation needs MM work in the near future, but due to built-in redundancy the need is not yet critical and it is decided that they will wait until later with the MM. During “the wait” for the need to become more critical the other participators of the collaboration could identify likewise needs, and the CE collaboration would thus improve the production by allowing the organisations to better plan the MM work. This way several MM tasks can be carried out at the same time instead of one by one, and down-time on the installation is thereby reduced.

Instead of having to operate in a setting where such MM needs are not identified until sudden break-downs occur, the possibility of monitoring the need in advance has a positive effect on the safety level, obviously, as the known is in most cases preferred to the unknown, and a reduction in sudden break-downs would limit the risk of experiencing critical divagations as a result of such break-downs.

A McKinsey report found that it takes an average of 30 years from the idea phase of new technology to the technology is introduced to 50% of the O&G industry (OED, 2002). The CE concept has been around for around 20 years, but has only just recently started to make its way into the O&G industry.

A coalition consisting of Statoil, Aker Reinertsen and several other companies including NTNU and SINTEF has initiated a project named “Teknoklynge for olje og gass i Trøndelag” (in English: Technogroup for O&G in Trøndelag) that investigates the possibilities of conducting such MM task with the specialist personnel located in different places (Teknisk Ukeblad, 2006). The CORD-methodology is well suited as the analysis tool during such a project as it includes all the phases from vision, through analysing, to consequence analyses. Having such a tool that can be run in parallel could be vital to validate and verify en route the main project.

Especially the aviation industry has embraced the principles of CE. See Appendix B for a more detailed description of the improvement possibilities of CE, and Appendix C for a brief description of the Airbus Concurrent Engineering concept (ACE). However, as the ICT solutions constantly improve, and the NCS mature, the CE concept will be carefully looked into by the actors on the NCS.

6.3.2. VOs with respect to Perrow

Such a future characterised by increasing vendor involvement and creation of VOs will increase the need for coordination between the actors of the VOs. This will bring along further needs when it comes to designing rigid and time dependent processes in order to seize control of the collaborations, something which again will increase the complexity of the organisations and tighten its couplings.

Perrow's (1984) argument connected to his 'normal accident' theory states that such a combination of complexity and coupling carries along an organisational dilemma; systems with high interactive complexity can only be effectively controlled by a decentralised organisation, whereas tightly coupled systems can only be effectively controlled by a centralised organisation. Since an organisation cannot be both centralised and decentralised at the same time, systems with high interactive complexity and tight couplings cannot be effectively controlled, no matter how it is organised. If again the system in question has catastrophic potential and it is not possible to effectively control the system, the system should be discarded. As Perrow defined oil installations as complex systems with tight couplings the implication is thus that Perrow were of the opinion that the O&G industry should be discarded.

6.4. Applying HRO theory on VOs

As a reaction to Perrow's pessimistic angle of sight, HRO theorists argue that it is possible to operate under the conditions described above. The couplings of the system can be made more flexible than Perrow's rigid classification, and thus make the "rejected" system manageable again. Avoiding accidents is a matter of proper management of prevention and mitigation activities. The HRO practices are critical to reliable performance in complex and changing environments, and they could thus prove vital in risk mitigating work in VOs. With this in mind, a future consisting of increasing vendor involvement and creation of VOs should work on applying the recommendations and theories connected to the HRO thinking.

But transferring these characteristics from the HRO world to the VOs' is difficult. By their nature, VOs are more diffuse than traditional reliability-enhancing organisations as VOs often consists of members with differences in backgrounds and cultures and geographically dispersed operational settings. Insuring that everyone in a distributed VO has a shared vision when it comes to safety and reliability goals is difficult at best. While sheer numbers of persons and job functions in VOs assures some redundancy, it is not obvious that the redundancies are of the form required to assure reliability without careful attention to design. Geographical dispersion of VOs hampers their ability to develop a shared, reinforced culture of reliability, and the lack of a shared culture inhibits the development of interpersonal trust in VOs (Grabowski & Roberts, 1998). Thus, mitigating risk in VOs not only requires attention and knowledge about risk mitigation research and processes in traditionally organisations and HROs, it also requires an understanding about the nature and behaviour of the VOs. With this in mind, there are four key topics that together assemble the core of transferring risk mitigation in HRO theories to VOs (op.cit.):

1. Organisational structuring and design
2. Communication at the interfaces of the VO
3. Develop a shared organisational culture of reliability across the VO’s members
4. Development of trust among the members of the VO

6.4.1. Organisational structuring and design

As said in chapter 2.3, *structuring* is the organisational process for solving the two fundamental problems: *"the division of labour into various tasks to be solved, and the coordination of these tasks to accomplish the activity"* (Lucas & Barudi, 1994). While HROs use the principle of redundancy, the problem is that redundancy in VOs can cause difficulties if duplicate tasks are executed in geographically dispersed operational settings. Determining the point at which the different groups should cease parallel activities and begin joint cooperation is challenging in geographically and culturally diverse settings, particularly if members of the VO do not share each others’ values or roles and responsibility, i.e. understand how the response process works, or who is in charge (Harrald et al., 1992). The challenge for VOs is thus to harness whatever redundancy that exists to affect needed slack. As in the example with the aircraft carriers, the low-level personnel on these carriers may only make decisions in one direction, they may only abort landings. This to manage the processes and making it possible for distributed groups to work together (Grabowski & Roberts, 1998).

The example of the HRO aircraft carriers also illustrated how organisational structures may vary from low to high tempo operations as a response to environmental changes. Building an organisation that has the ability to provide varied structures in response to such changes in the environment is thus critical to the success of the VO. Distributed ICT solutions that ties the members of the VO together provides the basis to building such a fluid organisational structure (Grabowski & Roberts, 1998).

But VOs should also focus on fluidity in their organisational structures as well as redundancy to ensure that the needed flexibility in response alternatives exists. Organisations that should be reliability enhancing often fail to restructure in the face of change because the cognitive frameworks of their managers fail to adapt to meet changing situations. VOs face frequent changes in requirements, their environments, and in resources, and flexibility to respond in different ways to varied conditions and situations, are critical for VOs. This flexibility may reduce the risks of miscommunication, misunderstanding, or inconsistency in organisational goals by providing multiple paths through which structuring and communications can occur (Weick, 1993; 1996).

Through the interviews it was identified a concern from ABB that Statoil's own IT-division, IT Operation (in Norwegian: IT Drift), shall intervene in ABB's operations. ABB's concern is that Statoil, and their IT Operation, over time will try to seize more control over the control systems. ABB have manufactures the control systems used on the Snøhvit plant and thus holds the expertise on the systems. The fear is therefore that the IT-division shall conduct modifications to the control systems, for instance could this be that the IT-division start running virus programme updates of their own on the servers.

The concern of ABB illustrates the importance of having a structure of the cooperation with clearly defined roles and responsibilities. Such concerns could exists if the communication at the interface between Statoil and ABB is lacking or not good enough, and according to ABB there exist no procedures or governing documents related to this concern aspect. It should therefore be worked on creating carefully procedures to avoid scenarios as the one described above.

The introduction of new integrated operations paradigm over the last years could also have the implication of making the present HSE control system out of date. The current system is based on people reporting unwanted incidents which are then stored in a database such as Synergi. The organisational structure does not necessarily take into consideration the "challenges of tomorrow" by the increased use of control rooms and remote working. It should be considered whether the HSE control system of Statoil needs to be modified so that any incidents that occur as a consequence of instructions given by personnel in a control room are reported and looked into afterwards.

6.4.2. Communication at the interfaces of the VO

According to research within the field of ‘uncertainty reduction theory’ people communicate to reduce uncertainty, thereby making their environments more predictable (Grabowski & Roberts, 1998). One of the distinctive marks of HROs is the use of effective and varied communications as one means of reducing the uncertainty and mitigating risk (LaPorte & Consolini, 1991). Thus, VOs have similar needs for many and varied communication about member responsibilities and relationships. Especially communication at the interfaces of the VO is particular important as that is where the VO defines itself to its members and the outside world (Grabowski & Roberts, 1998). Such communication in distributed VOs can make the links and roles that the VOs’ members assume clearer, making explicit and more understandable the differing levels of autonomy and interdependence present in the VO. It can also provide opportunities for discussion of different approaches and improvements to the organisation (Grabowski & Roberts, 1997). For a geographically dispersed organisation, communication can also serve social support needs and thereby contribute to the development of a shared culture.

In the Snøhvit case both ABB and Statoil stated that they had a clear cut idea about the overall roles of both parties. The development of the procedures has so far been an iterative process, where ABB and Statoil have worked together and shared opinions and views. ABB’s own procedures related to their ARMOR centres has been coupled with Statoil’s governing documents and demands, giving both sides the possibilities of highlighting their needs and desires and thus making the interface between Statoil’s and ABB’s operations visible. There was, however, still some work left to be done at the moment this thesis was written. ABB stated that they cannot do any updates or configuration on the Snøhvit plant without a work order from Statoil. ABB also still did not how Statoil’s procedures on such work orders were, in addition to the above mentioned concern regarding the IT-division of Statoil.

But as with the organisational structuring discussed in the previous section, communication processes in VOs that mitigate risk are different than those of the traditional organisations.

This is so because of the VOs' varied and changing organisational structures. Just as organisational structures change in the VO, so too do communication patterns within and among those structures. In the initiation and integration phases, when the VO is establishing its goals, objectives and responsibilities, the communication will be rich, while at later stages, as in the production stage, information is more solitary (Grabowski & Roberts, 1997). Managing the communication processes among the members of the VO is therefore critical to the development of highly reliable safety cultures.

6.4.3. Organisational culture

As said in chapter 2.4, there exists no single definition of what an organisational culture is. The topic has been studied from a variety of perspectives ranging from disciplines such as anthropology and sociology, to the applied disciplines of organisational behaviour, management science, and organisational communication. Culture in itself is not an empiric quantity, and should instead be regarded as means to interpret an organisation; the behaviour and manner of the personnel and the organisation's surroundings.

Schein's three levels model

However, Edgar Schein's definition is well suited for the HRO – VO paradigm. Schein (1996) defined culture as a set of basic tacit assumptions about how the world is and how it ought to be, and that organisational culture consists of three distinct levels; artefacts & behaviours, espoused values and assumptions. Understanding paradoxical organisational behaviours becomes more apparent by using Schein's model. For instance, an organisation can profess highly aesthetic and moral standards at the second level of Schein's model while simultaneously displaying curiously opposing behaviour at the third and deepest level of culture. An organisation needs to be consistent; what is stated by the management must be pursued down the hierarchy of the rest of the organisation. If the management and the managers do not become conscious of the cultures in which they are embedded, those cultures will manage them. Cultural understanding is desirable for everybody, but it is essential for leaders if they are to lead. The challenge in a VO will be that it most likely will consist of several different cultures that maybe are not even similar.

VOs are a melting pot of several cultures

In conventional organisations, shared assumptions typically form around the functional units of the organisation, and are often based on the members' similar educational backgrounds or experiences (Grabowski & Roberts, 1998). Developing strong organisational cultures in VOs is difficult because they are comprised of several cultures. The various cultures represented in the different members of VOs will almost surely introduce dysfunctional ties and miscommunications as communication and functionality in VOs takes place across organisations that do not share common values, assumptions, or perceptions (Porter, 1993). Thus, developing a single culture of reliability from these many cultures can prove challenging (Grabowski & Roberts, 1998). The risk is a situation where an organisation has several "petty kings" that "defend" their territory by refusing to interact with the rest of the organisation to get experiences and knowledge to avoid remaking mistakes previously made by others.

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"* (HSC, 1993)

The safety culture can be seen as part of the organisational culture. Defining good and bad safety culture is not an easy task, but Reason (1997) argues that good safety culture can be characterised as the following:

- It is informed and just
- Focuses on problem solving rather than condemnation/punishment
- The significance of reporting and responses is emphasised

The trademarks of the safety culture are the elements in the organisational culture that affect the safety in either a positive or negative direction[33]. Hale (2000) and Rosness (2001) therefore suggests that the safety culture term could be described as "recurrent patterns of interaction that have an impact on risk".

Haukelid (2001) identified that the differences in defining *good safety culture* were related to the person's background; the management often focused on the attitude of their staff and the need for organisational changes, while the labour unions were concerned about the degree of

[33] The elements could also affect attitude and behaviour that is not directly linked to safety, but that could be influenced by a shift in the focus on safety.

participation and secure workplaces. He also identified a trust problem between the unions and the companies. Haukelid's (2002) own interpretation of *good safety culture* is *"an environment consisting of safety meetings with active workers"*.

Melding it all together

According to Grabowski (2006), risk propensity in traditionally organisations has its roots in five factors.

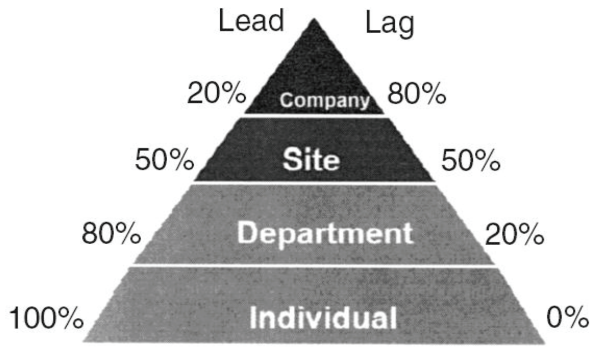
1. The activities performed in the system could be inherently risky
2. The technology is inherently risky, or exacerbates risks in the system
3. The individuals and organisations executing tasks, using technology, or coordinating both can propagate human and organisational errors
4. Organisational structures may encourage risky practices or encourage workers to pursue risky courses of action
5. Organisational cultures may support risk taking, or fail to sufficiently encourage risk aversion.

Risk propensity in VOs is characterised by several of the same factors, but the propensity also has some intriguing dissimilarities. Because of the differences between VOs and traditionally organisations, risk in VOs can migrate between the organisation's members, and thereby making risk identification and mitigation difficult. A VO is a large scale organisation with complex interactions between its members; it consists of members with their own individual goals, policies, and cultures. The members are also connected through temporary alliances, making the development of a shared culture of reliability and commitment to reliability goals difficult, as the presence of simultaneous interdependence and autonomy creates an inherent tension in the VO. Resulting in that precipitating incidents and accidents may have long incubation periods, making identification of a leading error chain difficult.

One way of solving these issues are by being proactive rather than reactive. Traditionally, safety performance has been measured by a "after the loss" type, for instance with accidents or injuries rates. These kinds of indicators are called *lagging indicators*[34] and are of a reactive kind, therefore the indicators do not provide enough information to make a system or organisation safe; *"a low reported accident rate, even over a period of years, is no guarantee that risks are being effectively controlled, nor will it ensure the absence of injuries or*

[34] Lagging indicator: an accident must occur, or a person get injured, before a measure can be made.

accidents in the future" (Lindsay, 1992). The use of *leading indicators*[35] is associated with proactive activities that identify hazards and assess, eliminate, minimize and control risk. Leading and lagging indicators differ by focus and granularity (Bergh, 2003). These differences are illustrated in figure 6-3.



6-3 Units of analysis for leading and lagging indicators

Leading indicators are primarily focused at the individual and only a little at the departmental level, while in contrast, lagging indicators are broader in scope and generally focus on organisational measures. Lagging indicators are seldom focused on individual performance; similarly, leading indicators are most often focused on small units of analysis.

Risk mitigation in VOs requires melding the varied cultures that comprise the system into a cohesive whole in which the deep assumptions and espoused values of the VOs can be built around. Being proactive and establish slack and safe areas in the VO to discuss incentive and control system issues can be a first step in creating an environment and conditions conducive to resolution of these sensitive inter- and intra-organisational aspects, and to reduce risk overall in the VO (Grabowski & Roberts, 1998).

6.4.4. Trust

Trust has been defined as *"the willingness of a party to be vulnerable to the actions of another party based on the expectation that the other will perform a particular action important to the trustor, irrespective of the ability to monitor or control that other party"* (Mayer, Davis & Scoorman, 1995). Successful teamwork requires that each team member

[35] Leading indicator: one type of accident precursor that have some value in predicting the arrival of the event, for instance near hit reporting.

understand their role and how it interconnects to all the others, and in this way build trust, cooperation and team identity. Without trust, the members of the organisation may perceive the network as weak and commitment to the actions and goals of the organisation can waver (McAllister, 1995). VOs with high levels of trust among their members can effectively utilize interactions and communication processes at their interfaces so members can learn together, and can develop shared mental models of reliability and a shared culture of safety. In addition, high levels of trust also contribute to strengthening linkages among member organisations.

As described earlier, the development of the procedures between Statoil and ABB in the Snøhvit case has so far been an iterative process where ABB and Statoil have worked together sharing opinions and views. Merging the procedures of both companies into common rules and guidelines enhances trust. However, a considerable amount of an organisation's real competence is "silent". This competence is knowledge about work methods that are not described in either procedures or documents (Serck-Hanssen, 2002). Kjellén (2000) highlights socialisation as the main way of transferring silent knowledge in an organisation. For instance, by people talking to each other, or by observing how colleagues execute their work tasks. This interaction and the connected development of such silent knowledge are limited in VOs. A VO should therefore work to find remedies that in some way replace the "informal lunch talk". One alternative would be safety meetings where workers are requested to come forward with their thoughts and opinions to promote improvements.

It is the first time that Statoil allows a vendor to operate from another location than the actual plant, something which only increases any possible uncertainty and scepticism. Obviously, this makes it even more important to work towards building trust. The control room of Snøhvit and the ARMOR centre will have a direct link between them through the use of audio and video. The intention behind this is to make the operator feel like they are in the same room, to create a shared working environment despite being located at two separate locations. This is vital for providing the amount of trust that is necessary for such cooperation as between Statoil and ABB where ABB will sit on a separate location far away and conduct configuration on critical parts of the system.

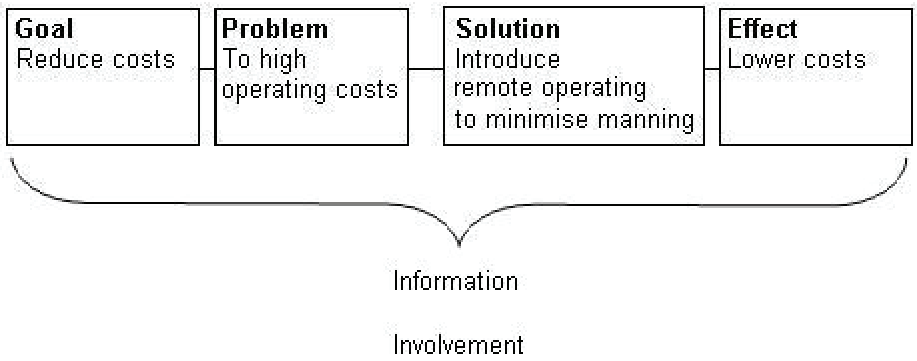
According to Grabowski & Roberts (1998) trust is *"particular important in VOs that require constant and close attention to shared commitments to safety and reliability, as well as shared willingness to learn and adapt"*. When labourers become assets, the underlying contract with the organisation has to change. Trust and commitment inevitably requires some sense of mutuality, of mutual loyalty. VOs are dependent on information, ideas and intelligence, and cannot escape this dilemma. One answer is to turn labourers into members; to turn the instrumental contract into a membership contract. People who think of themselves as members have more of an interest in the future of the business and its growth than those who only see themselves as hired help (Handy, 1995).

An important aspect of building trust is the diversity and quality of communication channels. It is argued that rich communication channels such as face-to-face interaction in general is more powerful than more sparse communication as formal written messages or procedures when in comes to promoting reliability in complex systems (Weick, 1987). In HROs, the symmetricality, intensity and mutuality of linkages among its members are very solid, leading to the development of trust, high quality information transfer, and joint problem solving as effective means of risk mitigation (Schulman, 1993; Uzzi, 1997). However, achieving mutuality and symmetricality among the members of the VO may prove very difficult as VOs seemingly are devised to work against a development of these issues. Developing trust requires fairly constant, small group activities among the members since it is difficult to trust people you do not know well, and VOs consists of varying and changing organisational members in geographically distributed locations with fluctuating degrees of shared goals. This is something which makes the symmetricality, intensity and mutuality of linkages in VOs different than those of the HROs. Statoil and ABB have made the process of developing the procedures iterative, allowing both sides to vent their points of view in order to create a good spirit of cooperation.

6.5. Statoil's IO corporate initiative and future plans

Statoil as a company has stated that they have a goal of being the leading IO company on the NCS by the end of 2006. The goal was initiated after their current President and Chief Executive Officer Helge Lund was appointed in 2004, leaving Statoil with only a few years to their deadline. Statoil has stated that IO solutions will increase the efficiency of exploration, operations and new developments through the use of new work practices.

6.6. The initiative with reference to Bolman & Deal; structural frame



6-4 Rational chain of reasoning (Hvalgård, 1999)

In connection with the reasoning chain in figure 6-4 it can be expected that implementation of IO solutions and such means as remote working will have a basis rooted in a MTO evaluation where all the aspects of the means has been regarded (Hvalgård, 1999). Analyse methods such as the CORD methodology constitute the evaluation method, and it shall give answers to aspects as:

- Comparing remote working to other alternative options
- Ensuring that all impacts as a consequence of the new IO solutions have been considered
- Thorough evaluation of the feasibility of IO solutions such as remote working

In Bolman & Deal's theory of the structural frame, they state that once an organisation has designated specific roles for its employees, the next decision is to form or group them into working units. The coordination and control of these various groups are achieved either vertically or horizontally. The need for vertical coordination increases when the management is planning for changes. Knowledge of the organisation's goals and desires are important to the employees; a need that is amplified in times of uncertainty, i.e. when changes are either discussed or carried out. If employees find themselves in a situation with information shortage, the result can be confusion and rumours based on wrong assumptions. Involving the employees in the planning, decision-making and start-up is thus of vital importance to secure a good attitude amongst the members of the organisations when faced with changes. The feeling of having contributed creates an ownership feeling to the process and its final result (Irgens, 1996).

When the HF team at Snøhvit was assembled it included among other persons an employee representative. This is in accordance with the recommendations of the CORD-methodology which states that such HF teams should be interdisciplinary, compromising members with knowledge about both the technical aspects and human factors, in addition to employee representatives. Statoil has later sought to root this into its organisation by stating the same demands on the staffing of such HF analysis teams in their two governing documents WR1279 and WD0603.

6.7. The initiative with reference to Bolman & Deal; human resource frame

Many organisations either lack a clear ‘human resource’ thinking, or fails to comply with it, even though the organisations’ possibility of success could hinge on having a distinct philosophy on how their personnel’s needs should be dealt with (Bolman & Deal, 1999). The main challenge of the human resource frame is to tailor the organisation to fit their people in order to establish a way that best allows the personnel to do their job and at the same time make the personnel feel happy about what they are doing. But also, a numerous of improvement measures made as attempts to deal with this challenge fails because of the management and the leaders avoids spending time and money on necessary knowledge and skills (Kotter, 1996). A change removes the known and replaces it with the unknown. As it is in the nature of man to be sceptic towards changes; to fear the unknown, it is of vital importance to think through the implementing of such changes to succeed in rooting into the organisation and thus limit the scepticism.

The remote working solution between Statoil and ABB is a pioneer design to Statoil. It is the first time Statoil has allowed a vendor to operate from a different location than the Statoil site. Training and competence will thus be important to ensure that the personnel at both sites have the necessary amount of skills to make them feel confident of their abilities, and to make them trust the performance of the other party. ABB’s procedures states that all of their operators working in the ARMOR must have personal and local knowledge of the site they are working towards; in this case the Snøhvit plant.

As ABB has staff placed locally at Snøhvit in addition to their operators in Bergen, the demands in their procedures are ensured for by implementing a job rotation. Such a rotation could have both positive and negative aspects. It secures an upholding of the knowledge of ABB’s operators; they do not “fall asleep” in the same job routine, but could at the same time be negative as it breaks up the “team feeling” between ABB’s operators and those of Statoil’s at Snøhvit if ABB switches local operators too often.

Another possible problem has to do with the training. Training through practical experience has the problem that every operator then gets different knowledge as the training then is subject to a personal comprehension. The operators will thus form different views and opinions of the processes. Kaarstad and Førdestrømmen (2001) states that an organisation should seek to implement consistent and structured training programmes based on demand analyses with clearly defined criterions. As Snøhvit has a planned start up during 2007 with the test phase scheduled to approximately May 2006, planning concise training strategies might prove difficult at the moment. However, creation of such strategies should still be considered.

6.7.1. The initiative with reference to Bolman & Deal; political frame

> *“There is nothing more difficult and dangerous, or more doubtful of success, than an attempt to introduce a new order of things in any state. For the innovator has for enemies all those who derived advantages from the old order of things, whilst those who expect to be benefited by the new institutions will be but lukewarm defenders”* (Machiavelli, 1513).

Although the statement is nearly 500 years old, it is still of relevance. It implies that getting all the parts involved to pull together in the same direction is a big challenge, especially if one or more of the parts have apparent advantages of the present situation.

IO is a theme that has been subject to focus from not only the O&G industry, but also from the government and research institutions. IO is regarded as a key concept in the work of taking the O&G industry one step further; the Government proposition no. 38 stated IO as one of the central premises for realisation of the long term development path, and the corporate initiative of Statoil embraces this thinking.

The organisation is a political arena where various groups with different interests fight over scarce resources. But these coalitions are also dependent of each other, even if their interests are only somewhat overlapping. The fight over the resources creates conflicts and use of power. *Power* implies the ability to conquer the opponent(s); making them act in a different way than they would normally do. As conflicts are viewed as inevitable, the question is how to best deal with the conflicts. Strategies and tactics are often a better solution than display of power.

The implementation of IO solutions will, in the political frame, be seen as a process governed by the management. Even though Statoil's governing document AR12 "Operation, maintenance and modifications" states that *"manned plants will be manned and equipped in such a manner as to allow day-to-day operation and maintenance to be carried out safely and efficiently"* and further *"taken together, the management team at the plants must have the required/relevant operational, professional and managerial expertise"* and thus do not allow remote operating of manned installations at the moment, a future scenario where IO solutions results in reductions in the workforce offshore is not unlikely, according to the informants. It is also not unlikely that a reduction possibly would mean major changes in the work situation and work processes of those who remaining. Such a scenario would obviously be an area of conflict between the companies and its personnel through labour unions. From a conflict perspective, the interaction between the colleagues would create coalitions; "we" (the personnel) versus "them" (the companies). This collective thinking reduces uncertainty giving the "group" ("we") a feeling of security. Knowledge and respect of each other's roles and views will be fundamental in a conflict solving process. If the parts do not understand or respect the views and opinions of the others, the distance between them could grow so big that constructive talks and negotiations cannot take place. The workers have traditionally been concerned about safety, justice and trust, while the employers often have economical aspects as cost cutting, optimum manning and better utilization of technical solutions as their primary issues. It could then be tempting for the part that wants to establish the new order to seize to use of power, but the result could very well then be a "winning a battle, losing the war".

6.7.2. The initiative with reference to Bolman & Deal; symbolic frame

The symbols clarify and express the culture of the organisation. The interwoven patterns consisting of values, practises and objects that tell the members of the organisations about "who they are" and how the things are done. The symbols are developed over time, and are used to guide and aid in chaotic times.

Presenting the conditions quantitatively has become near to an ideal in the O&G industry (Haukelid, 2001). This also applies for the results of various organisations mappings. Statoil has an internal scoreboard designed as a traffic light with red, yellow and green colours relating to the IO corporate initiative. The idea behind this is to make the personnel design and implement solutions that are in accordance with the initiative. Such quantifications can be useful with technical analyses, but quantifying organisational and man related conditions may prove much more problematic. The problem with this way of thinking is the possibility of focusing too much on conditions that are easily quantified, for instance economic aspects, and forget or overlook those that are not. The result in most cases will be a one-sided focus on a few areas (op.cit.).

In addition, a change process has a symbolic effect too. As a result of the reasoning from the management; communicating their value base and visions, the people of the organisation will be influenced and start to see the value of the changes. But the personnel will at the same time also see problems and negative aspects related to the changes and thus could be reluctant to the very same changes. This paradoxical difference can be seen as two parallel processes by considering the problem through the symbolic frame (Gillund, 2002). They are, as said, influenced by the management and their visions, but also by interaction with their colleagues promoting basic rules and norms that bring forward the attention to the negative aspects of the changes.

The corporate initiative of Statoil has a symbolic value in its own. By stating that Statoil has a desire of being the leading IO company on the NCS, Statoil sends a signal towards their competitors that they keep a sharp eye and are aware of technical improvements and new developments in work processes and organisational design. It also has a symbolic value towards Statoil’s personnel; the signal from the corporate management is that they are aiming for first place; being a follower is not good enough, Statoil want to be the leading company. Even though the initiative focuses only on IO, the initiative can be interpreted by Statoil’s personnel in a more general way making the vision of the management a desire to be the leading company overall. This could further create an extra will in the personnel pushing them to give an extra effort.

6.7.3. The change processes of IO

To reach their goal Statoil must avoid several pitfalls. As presented in chapter 2.6, Kotter states that there are a total of eight such main pitfalls. Statoil must work hard, and keep Kotter's theories in focus, in order to anchor the initiative and its following changes in their operations. Kotter presented eight steps to avoid making the mistakes that leads to the failure of change processes. Beckhard & Pritchard (1992) hold that the overall changes in an organisation are described by a process consisting of three stages; a present or current state, a transition state and a changed state. They further stress that change processes should be connected with Senge's *learning organisation*. This view can be coupled with Kotter's steps. Kotter gives a summarisation of his steps: "The first four steps in the transformation process help defrost a hardened status quo. Phase five to seven then introduce many new practices. The last stage grounds the changes in the corporate culture and helps make them stick" (Kotter, 1996).

Beckhard & Pritchard (1992)	Present state	Transition state	Changed state
Kotter (1996)	Phase 1-4 sense of need, coalition, develop and share the vision	Phase 5-7 clear obsticales, short-term wins, consolidate and keep moving	Phase 8 anchor the change into the organisation

6-5 Beckhard & Pritchard combined with Kotter

By understanding these steps as sequential phases, Kotter gives a recipe for the change process to succeed. Kotter states that *"skipping steps creates only the illusion of speed and never produces a satisfying result"* (Kotter, 1996). Kotter states, in other words, that skipping steps creates pitfalls too, in addition to the eight main ones. But it can still be useful to discuss the sequence of Kotter's steps. The steps are:

1. Establish a sense of need and urgency
2. Create a coalition
3. Develop a clear vision
4. Share the vision
5. Empower people to clear obstacles
6. Secure short-term wins
7. Consolidate and keep moving
8. Anchor the change

The change must be driven by a strong vision; the desire to be "the best" IO company on the NCS. The main message of Kotter (1996) is that an explicit vision shall give direction for the changes; it shall be a vision of the future illustrating the future state of the organisation and their operations. But it shall also act as a commitment (Beckhard & Pritchard, 1992). Beckhard & Pritchard argues that the vision shall give the fundament for planning and guiding towards the overall goal for the changes, and will thus be of importance to understand the differences and the distance between the present and the visionary situation.

"Significant organisational changes create a decline in self esteem… the decline has an impact on performance" (Carnall, 1995). To deal with the decline, a sense of need for the change is necessary to achieve cooperation. It will be difficult to create a coalition with enough power and credibility to lead the change project if the need for change is too weak. It could also prove difficult to persuade key persons to spend time on developing and communicating the vision if that is the case.

As IO is subject to focus from both the O&G companies as well as from the authorities and research institutions, the foundation for establishing the sense of need exists. The NCS is getting more and more mature, and by declaring IO as a corporate initiative, Statoil sought to materialise the need into its personnel to make them realise and understand the importance of developing new ways of operating, utilizing the potential IO gives.

The *need* captures the attention of the people, and coalitions are needed to maintain the change processes and establish a common understanding. Kotter stresses that investing enough time on developing the vision and its connected strategies and then communicating it is crucial to the success of the change project. The communication serves as means both to inform the people of the organisation about the future; what the organisations wants to accomplish, and also as a means to limit the resistance and remove the obstacles. No changes are carried out without any resistance. There is always a certain level of conflict involved, and the changes are often met with alternative suggestions. Even innovative changes that are wanted will affect some of the involved people in a way that threatens their security and thus creates uncertainty (O'Connor, 1993). Sometimes the vision and its connected changes need to be adjusted because of the resistance, but good communication and discussions are often good remedies. Kotter (1996) states that a two way-communication is better then a monologue; letting the affected parts lift their opinions, while Beckhard & Prichard (1992) stress that one-way and passive communication often is employed to inform about changes, but that this form of communicating not necessarily contributes to a commitment from the staff.

It is herein the main challenges to Statoil lie; Kotter's pitfall of roadblocks and how to empower the people of the organisation to clear the obstacles. A majority of the informants stated that the main driving force for IO is economic related; cutting costs, expanding the life time of the fields and in a longer view reduce the number of people working on the installations offshore by moving the functions onshore. Statoil's long-view plan regarding IO presented in figure 1-7 includes remote operating from onshore locations and transferring personnel from offshore to onshore. It is obvious that Statoil's employees and their labour unions will have views on these aspects, and Hjellestad (2005) identified opinions stating that a reduction in the workforce offshore could increase the risk as a result of a reduces amount of experience and competence offshore. By moving people onshore the organisation will loose some of the "hands on" experience, there will be fewer people on the installations to observe any potential hazards, and it can bring along increased number of work tasks on those workers that remain offshore. In addition, as some of Statoil's installations are 20-30 years old, they are build for a different manning regime than if IO; constructed in such a way that demands a certain number of people onboard. Modifying these "dinosaur" installations could prove such an expensive and complex task that it would be an unprofitable process.

All these issues, and any others, must be debated and agreed upon, and a process characterised by communication and constructive discussions will benefit both the parties involved and the change processes itself; removing the obstacles that could hinder a development towards the vision and the future. Beckhard & Pritchard (1992) argue that change removes the known and replaces it with the unknown, which someone thinks will be better. The resistance can be greatly reduced by being specific about the future state, specifying not only what will change, but also what will not change.

Alteration means transition; from something to something different or new, and it means changing and developing the organisation. As an organisation is a complex organism, changing it is a demanding task that takes time, and often lots of time. Since it is such a demanding task, it is important to highlight the little victories to keep the moral and motivation sharp. Ambitious goals are important for development, but aiming to high could ruin a process that in any other way had all the necessary premises. It should also be stressed that there is a basic difference between creating short-term wins and hoping for such wins. While the former is active, the latter is passive. According to Kotter (1996) a successful transformation manager actively looks for ways to obtain clear performance improvements, establish goals in the yearly planning system, achieve these objectives, and reward en route.

Making people produce short-term wins could cause complaints, but under the right circumstances this kind of pressure can be a useful element in a change process. If it becomes obvious that the change efforts will take long time, urgency levels usually drop. Commitments to produce short-term wins can help keep complacency down and encourage the detailed analytical thinking that usefully can clarify or revise transformational visions. The ambitious goal of Statoil's IO corporate initiative, in addition to their long-view plans, implies that Statoil need to divide the strategies regarding the overall goal of the initiative up into smaller projects so as to "learn how to walk before they run"; taking the time to consolidate the growth and take advantage of the confidence in the organisation. One should celebrate the success whenever possible, but also try to avoid the feeling of being let down if the pace of accomplishment slows. Commitment to change management strategies generally involve rewarding the personnel for accomplishments, consolidating the progress achieved, and taking advantage of new opportunities by setting new and more challenging goals when the previous ones are reached.

Beckhard and Pritchard (1992) argue that most companies measure results, but that the majority also overlooks measuring the process of improvement. The measurements and rewards should thus not only be results-oriented, but also learning-oriented. It should also be stressed that Statoil should not progress too quickly. Statoil must ensure that the new work processes are anchored in their organisational culture as changes in general are as good as worthless related to future operations if they are not rooted into the corporate culture.

Applying Kotter to make a change process succeed is not only important to solely accomplish the goals of the changes. Having a change process that fails could prove dangerous within a safety frame. By changing the current operations and work processes at some levels but not succeeding in altering the organisation as a whole, could lead to complications with a catastrophic potential. For instance, having two different organisational cultures as a result of changing some of the personnel's mental models but not everyone's could lead to disaster. As an example; two airplanes are on collision course. The flight computers in the planes will read this and give responses in recommending changes in the course (i.e. height) of the two planes. At the same time, traffic control on the ground can also intervene and give contrary recommendations. If the pilots on one of the planes have a background from a culture where the traffic control is superior, while the other pilots are trained to trust the flight computer the risk for a collision will not only still exist, but in fact increase.

Kotter's theories can thus very well be read as a safety guide for how to create common understanding and joint alliances in the organisation. With respect to Kotter's recommendations; his step of *empowering people to clear the obstacles* to accomplish such creation of common mental models and mutual thinking is the most important one to Statoil and their long-view plans of IO. According to Schein (1996), we cannot understand Organisational Learning, development and planned change, unless we consider culture as the primary source of resistance to change. Statoil thus need to communicate, discuss and listen to their employees, the labour unions and other stakeholders in order to establish good coalition with solutions and strategies that everybody agrees upon.

PART FIVE: CONCLUSION AND FURTHER RESEARCH

7. CONCLUSION

Through the work on this thesis it has been identified a need for tools and methods, such as the CORD-methodology, that can improve the planning and carrying out of projects in Statoil. A committee appointed by the Norwegian Ministry of Petroleum and Energy found that the main reason for cost overruns in oil and gas projects on the Norwegian Continental Shelf during the nineties were due to poor planning, and the ministry has further ranked Statoil as the worst company on the Norwegian Continental Shelf with respect to cost overruns at more than occasion. By including new aspects and situations introduced by the new IO paradigm, and melding other standards, guidelines and practices into a whole, CORD can improve the planning phase and contribute to reducing the risk of cost overruns in Statoil's project.

In addition, by taking advantage of methods like the CORD-methodology, human factors design and its aspects will be better highlighted, and stronger design solutions can be achieved. The importance of focusing on human factors must be stressed as the history has shown examples of accidents where poor human factors design has played a contributing part to the outcome of the accident.

However, the study has also identified that the CORD-methodology neither has been fully exploited on Snøhvit nor is very well known. CORD should be made public in order to get the methodology and its benefits known in the HF environments to make them start using it.

As fields on the NCS mature and production declines, new thinking and new ways of operating are needed in order to reduce cost and increase production. In the future, Statoil and its vendors will work closer together with each other by increased use of control rooms, operation centres and concurrent engineering; bringing the vendors closer to the decision-making. The challenge is to optimise the interaction and cooperation between Statoil and its collaborators with respect to safety and performance. With reference to Perrow, such a development of the Statoil – vendor interaction will increase the complexity and tighten the coupling of the oil and gas industry; increasing the risk of accidents. Statoil and its collaborators should include the thoughts and ideas of the HRO theory to create collaborations that build organisational redundancy in order to address the challenges of Perrow.

In order to embrace the potential of IO Statoil has commenced an IO corporation initiative that states that Statoil shall be the leading firm on the NCS by the end of 2006 when it comes to implementing IO solutions. The organisational redundancy, that in a HRO perspective is fundamental for safe operating, can be affected either positively or negatively by how changes to the organisation are carried out. The change process connected to the IO initiative must highlight the pitfalls and recommendations of Kotter in order to anchor the initiative and its following changes in their operations.

8. RECOMMENDATIONS FOR FURTHER RESEARCH

Through the work on this master thesis new and interesting issues have occurred. However, the predefined scope of the thesis has restricted the amount of subjects that could be handled, so the following are issues that are considered as interesting for further research:

- The research has identified that the O&G industry most likely will embrace the possibilities of VOs in the future. By establishing VOs, companies with differences in safety culture and background will be connected with the intention of working together. More research should be carried out to identify more about the impact of such collaborations, and especially the concept of CE should be looked close into. Practices from other industries as the aviation industry or the car assembling process could give valuable feedbacks and experiences so to avoid mistakes already made by these industries.
- The HRO theory should be further investigated as the new paradigm of IO makes it way into the O&G industry. Because of the complexity and tight couplings of the O&G industry any divagations and accidents could have a catastrophic outcome. The thoughts and ideas of the HRO theory are interesting in a safety frame. How HRO can best be exploited as risk mitigation with respect to Perrow's pessimistic view on any system characterised by the combination of complex interactions and tight couplings.
- Although the theme IO is a relatively new notion in the O&G industry similar concepts already exists. The interaction between an almost countless number of airplanes and the many air traffic control centres that exists is one example of this. To improve the solutions with respect to HF design and organisational redundancy experiences and views from other similar concepts should be researched and used to form recommendations and best practices.
- Through the interviews it was found that the CORD-methodology is not very well known although such a method that could act as a package deal at the same time is demanded. The McKinsey report referred to in the Government Proposition No. 38 states that it takes on average 30 years for the O&G industry to fully use "new" technology. Research on how to make the O&G companies on the NCS to react faster to new technology and methods should be carried out in order to get them to more easily take advantage of innovative thinking.

9. BIBLIOGRAPHY

Aftenposten (2004) *Snøhvit kapper hoder I Statoil*.
Article published June 11th 2004. [Online] Located at: http://n24.no/arkiv/article808075.ece Last visited: May 31st 2006

Andersson, Ol, Rollenhagen, C. (2002) *The MTO Concept and Organizational Learning at Forsmark NPP, Sweden*.
Presentation held at the IAEA International Conference on Safety Culture in Nuclear Installations, Rio de Janeiro, Brazil, 2-6 December 2002.

Bandecchi, M., Melton, B., Gardini, B., Ongaro, F. (2000) *The ESA/ESTEC Concurrent Design Facility*.
Presentation held for the European Space Agency.

Beckhard, R. & Pritchard, W. (1992) *Changing the Essence: The Art of Creating and Leading Fundamental Change in Organizations.* San Francisco, CA: Jossey-Bass Inc.

Bergh, V.D. (2003) *Leading and Trailing Indicators: Occupational Safety.*

Berniker, E. & Wolf, F. (2001) *Managing Complex Technical Systems: Working on a Bridge of Uncertainty*, Proceedings of the Tenth International Association for the Management of Information Systems, Vol. 18, No.4.
[Online] Located at:
http://www.plu.edu/~bernike/ManComSys/Managing%20ComplexSystemsIAMOT.doc Last visited: May 31st 2006.

Bierly, P.E. & Spender, J.-C. (1995) *Culture and High Reliability Organizations: The case of the nuclear submarine*. Journal of Management, Winter 1995.
[Online] Located at: http://www.findarticles.com/p/articles/mi_m4256/is_n4_v21/ai_17586339 Last visited: May 31st 2006.

Bolman, L., Deal, T. (1984) *Modern Approaches to Understanding and Managing Organizations.* John Wiley & Sons Inc, New Jersey, USA.

Bolman, L., Deal, T. (1997) *Reframing Organizations*. John Wiley & Sons Inc, New Jersey, USA.

Bolman, L., Deal, T. (1999) *Nytt perspektiv på organisasjon og ledelse: strukturer, sosiale relasjoner, politikk og symboler*. 3 utg, Oslo, Gyldendal akademisk, Norway

Carnall, C. (1995) *Managing Change in Organizations. 2nd* Ed. Prentice Hall, Uk.

CORD (2003) No title
Statement made by CORD's former chairman, Knut Heim.
[Online] Located at: http://prosjekt.marintek.sintef.no/cord/ Last visited: May 31st 2006

CORD (2006) *A Guideline to best practices for Function Analysis and Allocation in Integrated Operations*.
CORD-document, published January 27th 2006.

Dagens Næringsliv (2004) *Utbyggingsskandalen i Statoil*.
Article published June 11th 2004. [Online] Located at:
http://www.dn.no/forsiden/energi/article255832.ece Last visited: May 31st 2006.

De Lit, P.G. (2000) *A comprehensive and integrated approach for the design of a product family and its assembly system*, Université libre de Bruxelles, Faculté des sciences appliqués, Brussels, Belgium.
[Online] Located at: http://cfao.ulb.ac.be/cfao/documents/PhDPierreDeLithyp.pdf Last visited: June 6st 2006.

Eede, G.v.d., Walle, B.v.d., Rutkowski, A.-F. (2006) *Dealing with Risk in Incident Management: an Application of High Reliability Theory.* [Online] Located at: http://csdl.computer.org/comp/proceedings/hicss/2006/2507/02/250720037c.pdf Last visited: June 6st 2006.
FAD (2001) *Stortingsmelding nr. 7 (2001-2002) Om helse, miljø og sikkerhet i petroleumsvirksomheten*. [Online] Located at: http://odin.dep.no/fad/norsk/publ/stmeld/002001-040012/index-dok000-b-n-a.html Last visited: June 1st 2006.
Gillund, Ø. (2002) *Hvorfor forståes informasjon forskjellig? En analyse av informasjonsmottakernes tolkning av informasjon i forbindelse med et endringsprosjekt*. [Online] Located at: http://www.apertura.ntnu.no/bra/LarsGillund-oppgave.html Last visited: June 1st 2006.
Grabowski, M., Roberts, K.H. (1997) *Risk Mitigation in Large Scale Systems: Lessons from High Reliability Organizations*. California Management Review, Vol. 39, No. 4.
Grabowski, M., Roberts, K.H. (1998) *Risk Mitigation in Virtual Organizations*. [Online] Located at: http://jcmc.indiana.edu/vol3/issue4/grabowski.html Last visited: June 1st 2006.
Grabowski, M. (2006) *Leading indicators of Safety in Virtual Organizations.*
Gunasekaran, A. (1998) *Concurrent engineering: a competitive strategy for process industries.* Journal of the Operational Research Society, Vol. 49, No. 7. [Online] Located at: http://www.palgrave-journals.com/jors/journal/v49/n7/pdf/2600549a.pdf Last visited: June 1st 2006.
Hale, A., (2000) *Culture's confusions*. Safety Science 34.
Handy, C. (1995) *Trust and the virtual organization*. Harvard Business Review, no. 73. [Online] Located at: http://visionarymarketing.com/handytrust.html Last visited: June 1st 2006.
Harms, U. (1998) *A look at the Concurrent Multidisciplinary Engineering Conf.* [Online] Located at: http://www.hpcwire.com/hpc-bin/artread.pl?direction=Current&articlenumber=13483 Last visited: June 1st 2006.
Harrald, J.R., Cohn, R., Wallace, W.A. (1992) *We were always reorganizing: Some crisis management implications of the Exxon Valdez oil spill.* Industrial Crisis Quarterly, no. 6.
Haukelid, K. (2001) *Oljekultur og sikkerhetskultur*. Work note by Centre for technology, innovation and culture (TIK), University of Oslo [Online] Located at: http://www.risikoforsk.no/Publikasjoner/Oljekultur%20og%20sikkerhetskultur.pdf Last visited: June 1st 2006
Haukelid, K. (2002) *Oljekultur og sikkerhetskultur – notat nr 2*. Work note by Centre for technology, innovation and culture (TIK), University of Oslo [Online] Located at: http://www.risikoforsk.no/Publikasjoner/Oljekultur%20og%20sikkerhetskultur%20notat%20nr%202.pdf Last visited: June 1st 2006
Hjellestad, K.I. (2005) *Integrerte Operasjoner i petroleumsnæringen på norsk sokkel.* Project thesis autumn 2005, NTNU, Norway.
Hovden, J. (2003) *Safety Management of Organisations: DIFFERENT APPROACHES AND FRAMES*
Howell, A., Hanson, K., Dhole, V., Sim, W. (2002) *Engineering to Buisiness: Optimizing Asset Utilization Trough Process Engineering*, CEP magazine, Vol. 98, No. 8.

HSC (1993) *Advisory Commitee for Safety in Nuclear Installations.*

Hvalgård (1999) *Sikkerhet ved nedbemanning offshore – en kvalitativ studie*. Master thesis, Institutt for industriell økonomi og teknologiledelse. Norges teknisk-naturvitenskapelige universitet (NTNU), Trondheim.

Irgens (1996) *Den dynamiske organisasjon*. Abstrakt forlag, Norway.

ISO (2006) *ISO 11064-7:2006 Principles for the evaluation of control centres*.

Jagou, P. (1993) *Concurrent Engineering,* Hermès, Paris, France.

Kirk, J., Miller, M.L. (1986) *Reliability and validity in qualitative research.* Qualitative research methods series 1, A Sage University Paper.

Kjellén, U. (2000) *Prevention of accidents through experience feedback.* Taylor & Francis, London, Uk.

Kotter, J. (1996) *Leading change*. Harvard Business School Press, USA.

Kreeft, P. (2003) *Socrates Meets Machiavelli: The Father of Philosophy Cross-Examines the Author of the Prince.*

Kvale, S. (1997) *Det kvalitative forskningsintervju.* Gyldendal AS, Norway.

Kaarstad, M., Førdestrømmen, N. (2001) *Fjernstyring av offshore installasjoner – hovedrapport,* IFE/HR/F-2001/1173, Norway.

LaPorte, T.R. & Consolini, P.M. (1991) *Working in Practice but not in Theory: Theoretical Challenges of "High Reliability Organizations.* Journal of Public Administration Research and Theory, vol. 1, no. 1.

Lindsay, F.D. (1992) *Successful health and Safety Management, The Contribution of Management Audit.* Safety Science, no. 15, 387-402.

Lucas, H.C. & Barudi, J. (1994) *The role of information technology in organizational design*. Journal of Management Information Systems, Vol. 10.

Machiavelli, N. (1513) *The Prince*. Oxford University Press, Uk

Maslow, A.H. (1943) *A Theory of Human Motivation.* Psychological Review, no. 50.

Mayer, R.C., Davis, J.H., Schoorman, F.D., (1995) *An Integrative Model of Organization Trust*. Academy of Management Review, Vol. 20.

McAllister, D.J. (1995) *Affect and cognition based trust as foundations for interpersonal cooperation in organizations.* Academy of Management Journal, Vol. 38.

McCracken, G., (1988) *The long interview.* Qualitative research methods series 13, A Sage University Paper, USA

Mosser, N.R., Walls, R.T. (2002) *Leadership Frames of Nursing Chairpersons and the Organizational Climate in Baccalaureate Nursing Programs.* Southern Online Journal of Nursing Research, Vol 3, No. 2.

Nielsen, P.E. (2005) *Integrated Operations: a corporate initiative in Statoil.* Power point presentation. [Online] Located at: http://www.posc.org/meetings/may05WITpub/may05WITpub_statoil.ppt Last visited: June 1st 2006

NPD (2005) *Petroleumsressursene på norsk kontinentalsokkel 2005.* Report. [Online] Located at: http://www.npd.no/Norsk/Emner/Ressursforvaltning/Ressursregnskap_og_-

analyse/Ressursrapport_2005/coverpage.htm Last visited: June 1st 2006

O'Connor, C.A. (1993) *The Handbok for Organizational Change. Strategy and skill for trainers and developers.* McGraw-Hill Book Company, London.

OD (2005) *Petroleumsressursene på norsk kontinentalsokkel 2005*.
[Online] Located at: http://www.npd.no/Norsk/Emner/Ressursforvaltning/Ressursregnskap_og_-analyse/Ressursrapport_2005/coverpage.htm Last visited: May 27th 2006

OED (2002) *Stortingsmld nr. 38, 2001-2002: Om olje- og gassvirksomheten*.
[Online] Located at: http://odin.dep.no/oed/norsk/publ/stmeld/028001-040009/index-dok000-b-n-a.html Last visited: June 1st 2006

OED (2005) *Stortingspropsisjon nr. 1 (2005-2006) For budsjettåret 2006*.
[Online] Located at:
http://www.statsbudsjettet.dep.no/2006/dokumenter/html/fagdep/oed/index.htm
Last visited: June 1st 2006

OilCamp (2006) *OilCamp secures 3 year contract with ABB*.
Article published [Online] Located at: February 21st 2006
http://www.oilcamp.com/portal/Home/tabid/93/ctl/Details/mid/465/ItemID/4/Default.aspx Last visited: May 27th 2006

OLF (2002) *Statsbudsjettet*.
Article. [Online] Located at: http://www.olf.no/nyheter/oljeindustrien/2002/?12512 Last visited: June 1st 2006

OLF (2003a) *eDrift på norsk sokkel - det tredje effektiviseringsspranget.*
Report. [Online] Located at: http://www.olf.no/?15204.pdf Last visited: June 1st 2006

OLF (2003b) *eDrift på norsk sokkel.*
Theme document. [Online] Located at: http://www.olf.no/?18389.pdf Last visited: June 1st 2006

OLF (2005) *Integrated Work Processes: Future work processes on the Norwegian Continental Shelf*.
Report published by the Norwegian Oil Industry Association October 20th 2005
[Online] Located at: http://www.olf.no/?28867.pdf Last visited: June 1st 2006

Perrow C. (1984) *Normal Accidents: Living with High-Risk Technologies.* Basic Books, New York, USA.

Polkinghorne, D. E. (1991) *Generalisation and Qualitative Research: Issues of External Validity*. Paper presented at the American Educational Research Association 1991 Annual Meeting, Chicago.

Preston, S.M. (1991) *Virtual Organization as Process: Integrating Cognitive and Social Structure Across Time and Space*.

Porter, A.L. (1993). *Virtual companies reconsidered.* Technology analysis and strategic management, No. 5.

Reason, J. (1997) *Managing the Risks of Organisational Accidents*. Ashgate, Kent, UK.

Rasmussen, J., Svedung, I. (2000) *Proactive Risk Management in a Dynamic Society.* Swedish Rescue Services Agency, Karlstad, Sweden.
[Online] Located at: http://www.mie.utoronto.ca/labs/cel/research/frameworks/risk.htm Last visited: June 1st 2006.

Research Council of Norway (2004) *Årsrapport 2004 fra programmer I Divisjon for store satsinger*.
[Online] Located at:
http://www.forskningsradet.no/CSStorage/Flex_attachment/Satsinger%20Nettversjon%20-Sammensydd.pdf Last visited: June 6st 2006.

Ringdal, K. (2001) *Enhet og Mangfold*. Fagbokforlaget, Norway

Roberts, K.H. (1990) *Managing High Reliability Organizations.* California Management Review, Summer 1990.

Rosness, R. (2001) *Safety Culture: Yet another buzzword to hide our confusion?* SINTEF-note. [Onsline] Located at: http://www.risikoforsk.no/Publikasjoner/Safety%20culture.pdf Last visited: June 6st 2006.

Rosness, R., Guttormsen, G., Steiro, T., Tinmannsvik, R.K., Herrera, I.A. (2004) *Organisational Accidents and Resilient Organisations: Five Perspectives*. [Online] Located at: http://www.sintef.no/upload/Teknologi_og_samfunn/Sikkerhet%20og%20p%C3%A5litelighet/Rapporter/STF38%20A04403.pdf Last visited: Last visited: June 1st 2006.

Samset, K. (2001) *Prosjektvurdering i tidligfasen*. Tapir Akademisk Forlag, Norge.

Schein, E.H., (1992) *Organisational Culture and Leadership*. Jossey-Brass, San Francisco, USA.

Schein, E.H. (1996). *Three cultures of management: the key to Organizational Learning.* Sloan Management Review, Vol. 38, No. 1.

Schulman, P. (1993) *The analysis of high reliability organizations. New challenges to understanding organizations*, Macmillan, New York.

Senge, P.M. (1990) *The Fifth Discipline: The Arti & Practice of The Learning Organisation.* Currency Doubleday, New York, USA.

Serck-Hanssen, C. (2002) *Safe Change. Methodology on Change in Norwegian Oil Industry*. DNV, Høvik, Norway. [Online] Located at: http://risikoforsk.no/HMS/Publikasjoner/Safe_Change.pdf Last visited: June 6st 2006.

SINTEF (2003) *Fortellinger fra I fjor.* SINTEF's Annual report for 2002 [Online] Located at: http://www.sintef.no/upload/Teknologi_og_samfunn/Stab/Teknologiledelse%C3%85rsrapport2002.pdf Last visited: June 1st 2006.

Statoil (2005a) *Integrerte Operasjoner*. Power point presentation presented to OLF by Statoil. [Online] Last visited 27th of May 2006. Located at: http://www.olf.no/?26573.pdf Last visited: June 1st 2006.

Statoil (2005b) *Snøhvit*. Presentation of the Snøhvit field. [Online] Located at: http://www.statoil.com/snohvit Last visited: June 1st 2006.

Tecpress (2003) *I pose og sekk*. Article published October 21st 2003. [Online] Located at: http://www.teknologiforlaget.no/art.asp?id=167 Last visited: June 1st 2006.

Tecpress (2005) *Tar teten I 2006?* Article published 23rd of August 2005. [Online] Located at: http://www.teknologiforlaget.no/art.asp?id=298 Last visited 10th of May 2006.

Teknisk Ukeblad (2005) *Snøhvit-sprekk på 160 prosent*. Article published September 16th 2005. [Online] Located at: http://www.tu.no/nyheter/offshore/article40439.ece Last visited: May 31st 2006

Teknisk Ukeblad (2006) *Norges fremste innovasjonsmiljøer*. Article published April 4th 2006. [Online] Located at: http://www.tu.no/nyheter/offshore/article40439.ece Last visited: June 7th 2006

Tinmannsvik, R.K., Sklet, S., Jersin, E. (2004) *Granskningsmetodikk: Menneske-teknologi-organisasjon, En kartlegging av kompetansemiljøer og metoder.* SINTEF, Trondheim, Norway.
Tjora, A.H. (2005) *TIØ7 Kvalitativ metode + TIØ8 Kvantitativ metode.* Department of Industrial Economics and Technology Management, NTNU, Trondheim, Norway. Handouts from lectures in TIØ7 + TIØ8 Methodology Autumn 2005.
TMI (1979) *Report of The President's Commission on the Accident at Three Mile Island.* The official investigation report of the Three Mile Island accident.
Uzzi, B. (1997) *Social structure and competition in interfirm networks: The paradox of embeddedness.* Administrative Science Quarterly, no. 42.
Weick, K.E., & Sutcliffe, K.M. (2001) *Managing the unexpected: Assuring High Performance in an Age of Complexity*, Jossey-Bass (Wiley) San Francisco, California.
Weick, K. E. (1987): *Organizational culture as a Source of High Reliability*, California Management Review, no. 29.
Weick, K.E. (1993) *The collapse of sense making in organizations: The Mann Gulch disaster.* Administrative Science Quarterly, no. 38.
Weick, K.E. (1996) *Drop your tools: An allegory for organizational studies*. Administrative Science Quarterly, no. 41.
Zack, M.H. (1999) *Managing Organizational Ignorance.* Knowledge Directions, Vol. 1.

APPENDIX

APPENDIX A – INTERVIEW GUIDE (IN NORWEGIAN)

Generell regel: avgrense og fokusere på problemstillinger knytte til grensesnitt.

Introduksjon

1. Litt om meg/oss og oppgavene og målsetting med intervjuet.
2. Informasjon om intervjuet: båndopptaker, 30 min, fokus på oppg, samarb. Statoil)

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. Hva konkret er ABB sine oppgaver mot Snøhvit?
    - Hva er rollen/arbeidsoppgavene?
    - Klare ansvarsforhold? *
    - Er det noen som verifiserer at ansvarsforhold er godt ivaretatt? (CRIOP?)
    - Kan en for integrert deltakelse mellom operatør og leverandør, hviske ut ansvarsgrenser og danne grobunn for uoverensstemmelser?
8. Hvilke former for kommunikasjon eksisterer mellom Statoil og ABB? (flyttet fra 32)
9. Hvordan jobber ABB sine underleverandører mot Snøhvit?
10. Er ARMOR i Bergen 1. eller 2.linje, og hva ligger i dette?
11. Hva er drivkreftene bak/hva ønsker man å oppnå med IO? *
12. Har IO operasjoner økt eller senket sikkerhetsnivået, hvordan?
13. Stilles det krav fra Statoil med tanke på sikkerhet når ABB skal ta seg av oppgaver?
    - Er disse kravene forstått?
    - Har det vært problemer med dette?

Fremtidig bruk av IO

14. Hvilke suksesskriterier må oppfylles?
15. Hvilken utvikling ser du for bruk IO?
16. Hvilke ulemper og muligheter har IO for sikkerhetsnivået?
17. Hvilken organisering av oljefelt vil IO gi?
    - Hav og land
    - Operatør og leverandør
18. Hva vil IO si for samarbeid med operatør (pos og neg)?
19. Vil utfordringene ligge på tekniske, menneskelige eller organisatoriske forhold?
20. Kan du peke på konkret forslag til forbedringer (MTO)?

Organisering, kommunikasjon og grensesnitt i organisasjonen

21. Er organisasjonens struktur og design lagt til rette for sikker samhandling ved:
    - Bygger man tillit og felles kultur/forståelse, hvordan? *
    - Promoteres sikkerhet likt i alle ledd av operatør og leverandør? *
    - Blir det tatt tak i at ansvarsforholdene er uklare (av hvem)? *
22. Hvordan bør man ivareta læring og erfaringsoverføring (system) mellom:
    - Aktører? *
    - Hav og land? *

23. Med tanke på informasjonsdeling og -systemer:
    - Hvilket system for rapportering av hendelser brukes, og fungerer det som et bra læringsverktøy og til erfaringsutveksling? (S.O)
    - Trengs det felles standarder og informasjonsrutiner når det gjelder rapportering av uønskede hendelse og lignende? (S.O)

Økt tjenesteutsetting

24. Hva er de størst mulighetene og truslene tjenesteutsetting gir?
25. Har man pr i dag sett noen sikkerhetsmessige ulemper med tjenesteutsetting?
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?
    (operatører eller underleverandører? Bør ansvarsfordelingen omstruktureres?)
28. Hvem tar ansvar for sikkerheten og sørger for at det blir implementert?
29. Blir underleverandører nå mer/tidligere involvert i fordeling av ansvar?
30. Er samarbeidet pr i dag mellom leverandør og operatør tilfredsstillende?
31. Hvordan er dagens ordning med operatør som overordnet ansvarlig sett i lys av en situasjon med økt leverandørinvolvering? (Bør ansvarsfordelingen omstruktureres?) *

32. Har dere benyttet erfaringer fra andre bransjer eller selskaper ved utforming av sentral og arbeidsprosesser?

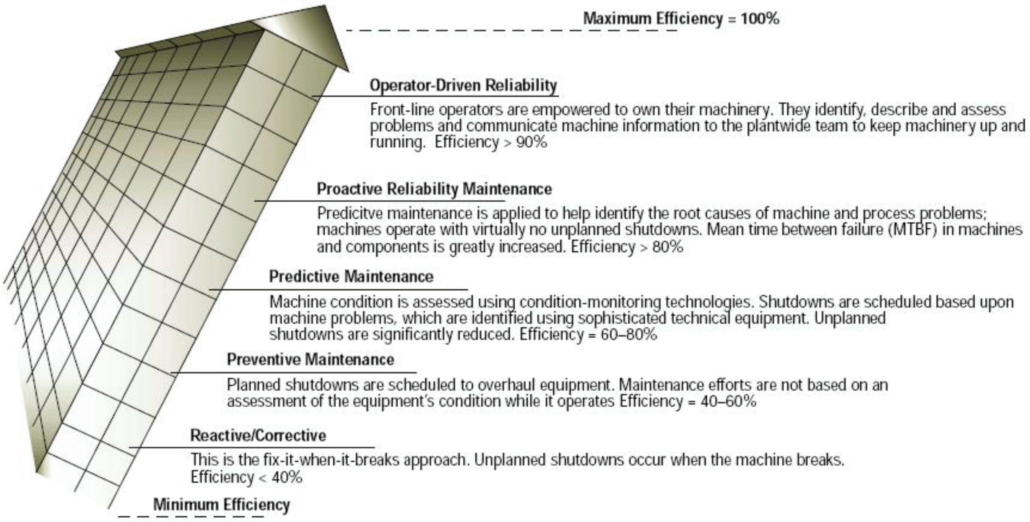
Eventuelt

33. Andre problemstillinger eller innspill fra intervjuobjekt..?

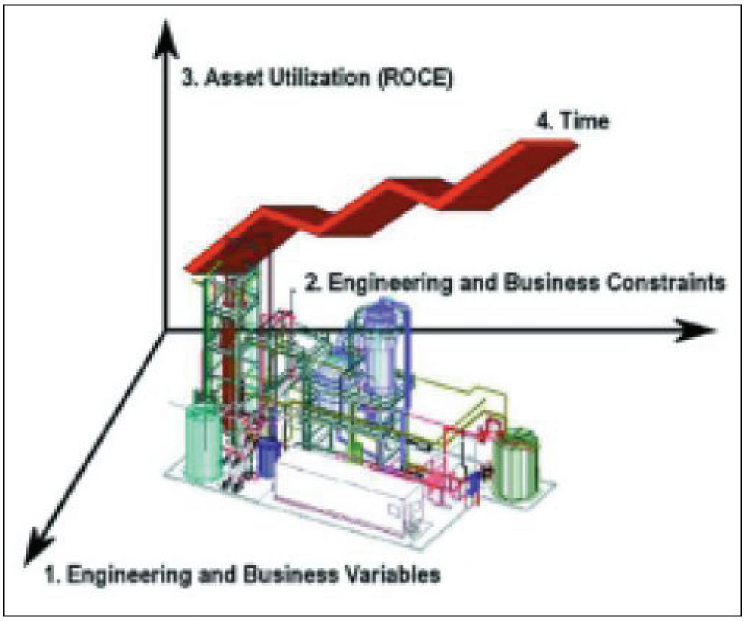
APPENDIX B – CONCURRENT ENGINEERING

CE's main principle is to integrate product and process development, and by adopting such a multidisciplinary, integrated workflow ensuring that engineering and operations decisions are based on sound business lifecycle knowledge, reducing the design lead-time and to improving both the quality and cost.

Especially the maintenance strategy is essential. The maintenance strategy process identifies the right tasks to be performed at the right time on the right equipment and includes a proper mix of reactive/corrective, preventive, predictive and proactive tasks (Howell et al., 2002). By addressing four key reliability processes; maintenance strategy, work identification, work control and work execution, management and the operation personnel can optimise a plant's physical assets for greater equipment productivity, efficiency and cost savings (op.cit.).



Howell et al.'s (2002) vision for the process industry is *"model centric virtual facilities with a unified and consistent, multi period based asset simulation deployed at the centre of a host of workflow based application and data exchange modules".* The process engineering, operations and business lifecycles all utilize the same virtual asset model (VAM) as illustrated in the figure above, which allows for a consistent understanding of the cause-and-effect relationships in the physical plant.



Mapping both engineering and business parameters over time to yield historic, current and projected business performance enhances decision-making. In this manner, the effect of the plant variables and business profitability constraints can be easily communicated to the various disciplines. As a result, the process engineering, operations and business lifecycles become an interconnected, engineering-to-business virtual asset. By transcending the process engineering, operations and business lifecycles, model centric tools transform plant based data into knowledge at the boardroom level, and concurrently drive a focused strategic vision back down to the business managers and plant personnel (op.cit.).

The integrated approach permits to face the problems of interdependence in designing solution and the corresponding production and operation processes. Instead of looking upon a decision chain as merely a baton, it embodies team values of cooperation, trust and sharing in such a manner that decision-making is by consensus, involving all perspectives in parallel, from the beginning of the product life-cycle (Bandecchi et al., 2000).

APPENDIX C – AIRBUS CONCURRENT ENGINEERING (ACE)

The ACE was started by Airbus-Industries and partners in 1995.

MISSION:
Providing Airbus with a competitive advantage by establishing integrated and efficient processes, methods and tools along the whole product lifecycle (Le Roy, 2005).

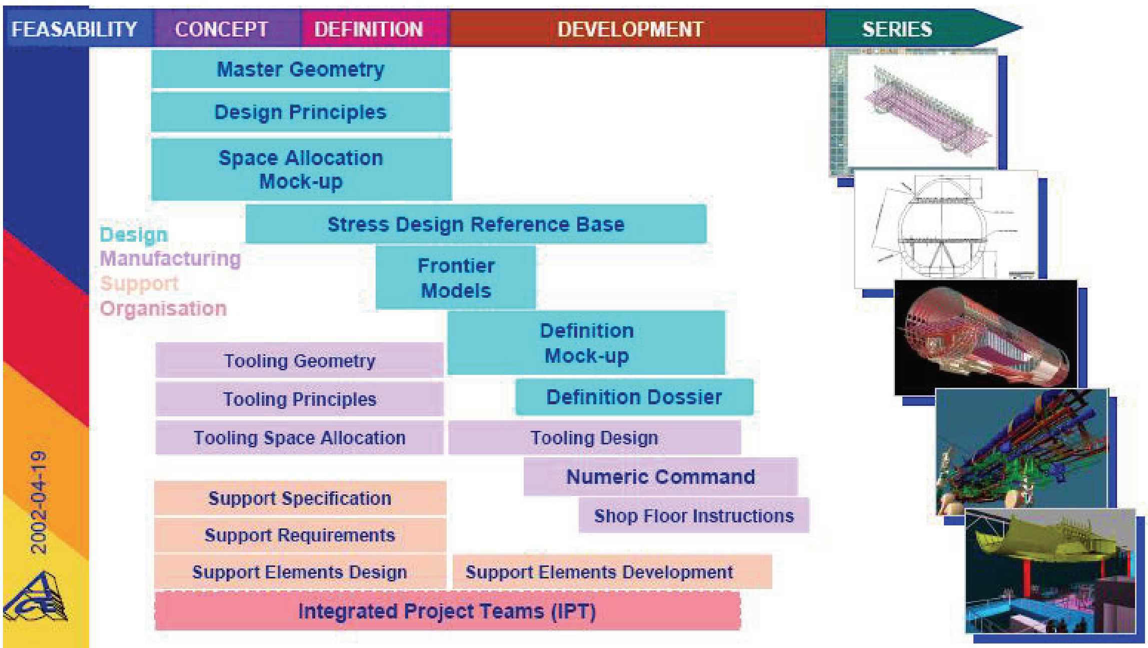
SCOPE:
Integrate data and information related to the Airbus development process in the trans-national organisation. Major focus on new aircraft programs (op.cit.).

The project manager of ACE, Wilfried Rieckmann, states: *"The costs of developing a new aircraft were growing, so new methods and tools had to be developed to make Airbus more competitive"* (Harms, 1998). The development costs of the basic aircraft had to be reduced by 30%, and the lead time could not exceed 50% of the A340 according to Rieckmann.

The ACE project team concentrated on three topics:

- Common Business Reengineering (harmonised, parallel processes, establishing principles of Concurrent Engineering, using new methods based on Master Models)
- Optimised CAx-Tools (efficient design and development in 3D)
- Implementation of Product Data Management Systems (synchronisation of data exchange between concurrent engineering tasks).

The objective was reducing the lead time, reducing the costs and improving the quality of the final product (ACE, 2002). This was done by implementing the principles of CE; continuously delivering data to the next stages and thus making the whole process parallel.



APPENDIX D – ISO 11064

The ISO 11064 is a generic framework for applying requirements and recommendations relating to ergonomics and human factors in designing and evaluating control centres with the view to eliminating or minimizing the potential for human errors. It consists of seven parts.

ISO 11064-1:2000
Specifies ergonomic principles, recommendations and requirements to be applied in the design of control centres, as well as in the expansion, refurbishment and technological upgrades of control centres. It covers all types of control centres typically employed for process industries, transportation and logistic control systems and people deployment services. Although this part of ISO 11064 is primarily intended for non-mobile control centres, many of the principles specified in this document could be applicable to mobile control centres, such as those found on ships and aircraft.

ISO 11064-5
Concerns the design of equipment interfaces, which are influenced by environmental factors. As 11064-5 no longer is listed on the official homepage of the ISO-organisation, http://www.iso.org, it might indicate that 11064-5 is withdrawn as an official standard.

ISO 11064-2:2000
Covers ergonomic design principles for control centres and, more specifically, the various arrangements of rooms and spaces in a control suite. The principles are based on an analysis of functions and tasks that have to be supported by the control room and functionally-related rooms. They include identifying functional areas, estimating the space provisions for each functional area, determining operational links between functional areas and developing preliminary layouts for the control suite to facilitate the transition between all the activities conducted in the control suite.

ISO 11064-3:1999
Gives requirements and guidance concerning the ergonomic design of the control room layout, describing how this phase should be carried out.

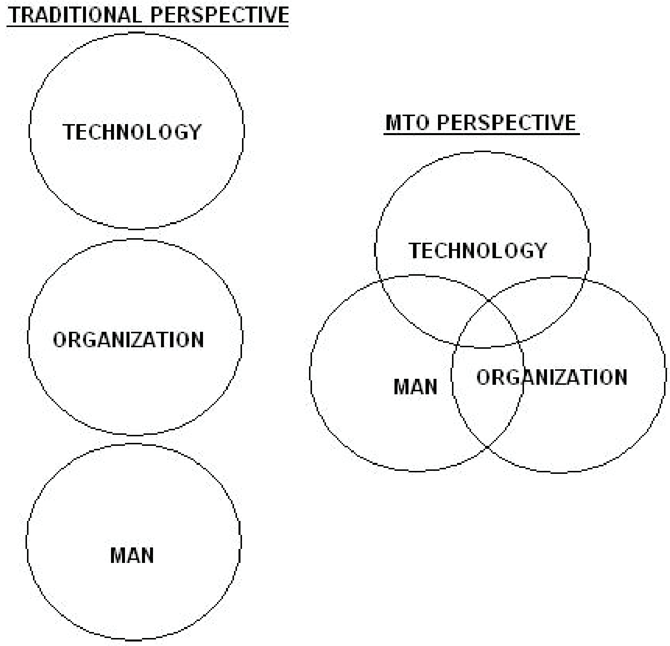
ISO 11064-4:2004
Specifies ergonomic principles, recommendations and requirements for the design of the workstations found in control centres. It covers workstation design with particular emphasis on layout and dimensions. This standard covers primarily seated, visual-display-based workstations although sit/stand workstations are also addressed. These workstations are to be found in applications such as transportation control, process control and security installations.

ISO 11064-6:2005
Gives environmental requirements as well as recommendations for the ergonomic design, upgrading or refurbishment of control rooms and other functional areas within the control suite. The following aspects are covered: thermal environment (temperate regions); air quality; lighting environment; acoustic environment; vibration; aesthetics and interior design. It is applicable to all types of control centres, including those for the process industry, transport and dispatching systems and emergency services. Although it is primarily intended for non-mobile control centres, many of the principles are relevant to mobile centres such as

those found on ships, locomotives and aircraft. It does not cover the influence of electromagnetic fields.

ISO 11064:7-2006
Establishes ergonomic principles for the evaluation of control centres. It gives requirements, recommendations and guidelines on evaluation of the different elements of the control centre, i.e. control suite, control room, workstations, displays and controls, and work environment. It covers all types of control centres, including those for the process industry, transport systems and dispatching rooms in the emergency services. Although this part of ISO 11064 is primarily intended for non-mobile control centres, many of the principles could be relevant/applicable to mobile centres, such as those found on ships and aircraft.

APPENDIX E - MTO



The MTO concept can be looked upon as three domains; as methods, as a specialist domain, and as an overall system thinking that includes organisational learning.

1. MTO as a set of *analytical techniques*. In this domain the MTO concept focuses on the methods that analyse the relationships between humans, their activities and the organisational and technological context in which these activities take place.
2. MTO as a *human factors specialist domain*. In this domain the MTO concept is foremost perceived as a specialist domain, supported by knowledge in human factors, psychology and other human related sciences.
3. MTO as a *metaphor for system thinking* about safety. In this perspective the MTO concept is viewed neither as a set of specialist domains, nor as a set of specific methods, but rather as a general attempt to develop a safety culture that focuses on the entire socio-technical system.

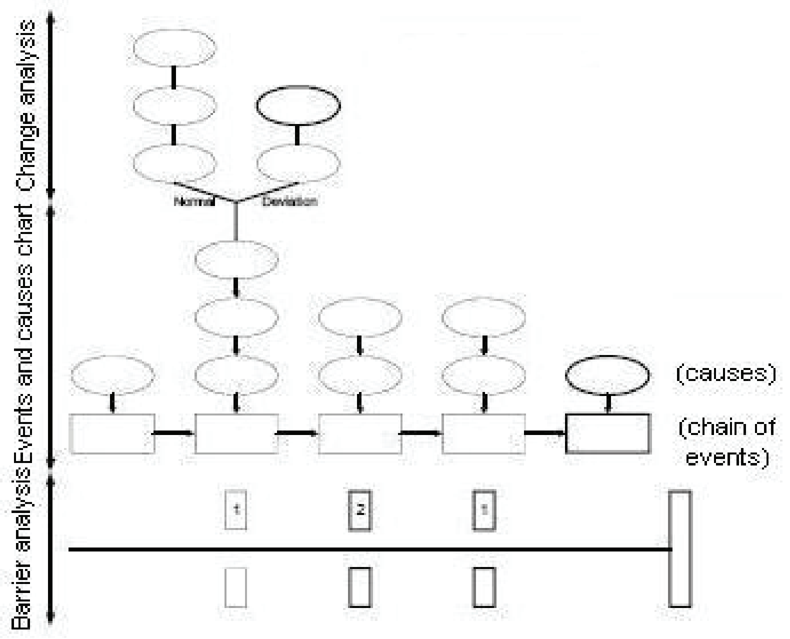
There are many different MTO methods available, and the selection all depends on the topic in question. The methods range from MTO analysis in accident investigations such as root-cause analysis[36], to methods designed for accident prevention by identifying hazards in the design phase, to others that focus on organisational learning through carrying out organisational assessments, for example as part of periodical safety reviews.

Root-cause analysis
The basis for the MTO-analysis is that human, organisational, and technical factors should be focused equally in an accident investigation. The basic questions in the analysis are:

- What may have prevented the continuation of the accident sequence?
- What may the organisation have done in the past in order to prevent the accident?

The worksheet for the MTO analysis is presented below.

[36] The tern root-cause is used to describe basic causes supposed to be under control of the own organisation.



The MTO-analysis is based on three steps:

1. Structured analysis by use of an event and cause-diagram. Develop the event sequence longitudinally and illustrate it in a block diagram. Then identify possible technical and human causes of each event and draw these vertically to the events in the diagram
2. Change analysis by describing how events have deviated from earlier events or common practice, i.e. to assess how events in the accident progress have deviated from normal situation, or common practice.
3. Barrier analysis by identifying technological and administrative barriers which failed or were missing during the accident progress.

Retrofit design process analysis
Another set of MTO methods and tools is used in the design process for control-room retrofits and modernisation's. One of the lessons learned, according to Andersson & Rollenhagen (2002) is that the organisation of retrofit projects, such as the modernisation of control rooms, is highly dependent on the establishment, organisation and utilisation of different competence's, such as operator experience, instructor competence, HF competence, IT competence etc. However, there is sometimes a tendency to overly separate ergonomic issues from the broader context. The application of MTO methods in the design process are therefore in order to facilitate the integration of all these specialist domains and applying a system-oriented approach enhancing the control room's usefulness, ergonomics and working environment (op.cit.).

Organisational assessment analysis
MTO methods regarding organisational assessment focus on organisational learning. An example of application of such methods and tools is the structured assessments made before organisational changes are performed. Another example is organisational assessments performed as part of mandatory periodic safety reviews. But the most important use is the extension of the root-cause analysis. The catch with the root-cause analysis is that it does involves anything that really forces the analytical process to include higher management levels since much is up to the judgement of the person(s) performing the analysis (Andersson & Rollenhagen, 2002).

Organisational methods as guidelines for *identification of contributing factors* develop the concept of event analysis further. It provides the standardisation of the analysis process. As soon as possible after an event has occurred the whole event must be described. The description aims at separating the process of information-gathering from the interpretation of this information. Every single action identified in the description of the situation should be analysed by asking the question "why", and every contributing factor is complemented by adding further contributing factors (Tinmannsvik et al., 2004). And finally, all possible contributing factors are transferred into general questions. An example of such a question would be “could there have been an influence of the working conditions on the operator performance?” These questions seek to find if the organisation itself are to blame for accidents or events that have occurred, rather than just looking upon them as the results of human errors.