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Uncoupling Safety and Design
- Designing Large Screen Displays for Petroleum Control Rooms

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Abstract

In complex organizations as in the oil industry, it is crucial that safety is adequately addressed at every point of the design and production process. This industry operates with a highly dynamic and tightly coupled technological system, which requires extensive safety assessments in order to avoid malfunctions and prevent accidents. Unfortunately, there are many examples of how things can go wrong: the loss of Sleipner A in 1991, the Alexander Kielland disaster, and several others.

When engineers design a subunit of a complex system it is necessary to consider how each component is integrated with the rest of the system both in loosely and tightly coupled situations. In the development of a new system, the design task is divided into subunits which companies with special expertise are engaged to manufacture. In these companies there are different actors and different situational demands which contribute to form the result of the subtask. This means that in most companies there is some deviation between the project set by the operator of the system, and the subcontractor’s actual result.

In complex systems which consist of many components made by different subcontractors these deviances can affect each other in unexpected manners when they interact. In order to decrease this tendency there are regulations and industrial standards to regulate the interaction, but these static tools do not always correspond to the task at hand and may therefore be inefficient. This is the problem of central concern in this thesis.

Keywords: Safety, design, system, large screen display, uncoupling, practical drift.
Abbreviations

IFE- Institute for Energy Technology
ABB- Asea Brown Boveri Ltd.
PSAN- Petroleum Safety Authority Norway (Petroleumstilsynet)
NPD- Norwegian Petroleum Directorate (Oljedirektoratet)
LSD- Large Screen Display
OW- Operator Workstation
VDU- Visual Display Unit
CCN- Central Control Room
LNG- Liquefied Natural Gas
Table of Contents

ACKNOWLEDGEMENT.................................................................................................................... I
ABSTRACT ....................................................................................................................................... II
ABBREVIATIONS .............................................................................................................................. III

1.0 SAFETY AND DESIGN................................................................................................................ 1

1.1 INTRODUCTION .......................................................................................................................... 1
1.2 RESEARCH QUESTION AND STRUCTURE .............................................................................. 3
1.3 STUDYING SAFETY AND DESIGN IN THE STS- FIELD ............................................................ 4
1.4 METHOD ..................................................................................................................................... 9

2.0 DESIGNING THE LARGE SCREEN DISPLAY.............................................................................. 12

2.1 BACKGROUND: STATOIL ......................................................................................................... 13
2.2 SAFETY IN THE LNG- PRODUCTION ....................................................................................... 14
2.3 BACKGROUND: IFE AND THE START OF THE LSD- DESIGN.................................................. 16
2.3.1 Organizational Structure ....................................................................................................... 17
2.4 THE HUMAN FACTOR APPROACH .......................................................................................... 18
2.5 DESIGNING THE LARGE SCREEN DISPLAY AT IFE ................................................................. 21
2.5.1 What to include in the design? ............................................................................................... 22
2.5.2 How to make a good design? ............................................................................................... 26
2.5.2.1 Change Blindness: ........................................................................................................... 26
2.5.2.2 Key- Hole effect .............................................................................................................. 27
2.5.2.3 Alarm System ................................................................................................................ 28
2.6 THE PURPOSE OF THE LARGE SCREEN DISPLAY ................................................................. 28

3.0 UNCOUPLING IN THE DESIGN PROCESS .............................................................................. 31

3.1 NORMAL ACCIDENT THEORY .................................................................................................. 31
3.2 INTEGRATING THE ORGANISATION ......................................................................................... 33
3.2.1 Theory of Practical Drift ....................................................................................................... 35
3.3 APPLYING DRIFT TO THE DESIGN PROCESS ......................................................................... 38
3.3.1 Regulations ......................................................................................................................... 38
3.3.2 Drift at IFE ......................................................................................................................... 39
3.4 ACTORS IN THE DEVELOPMENT OF AN LNG- PRODUCTION ................................................ 44
3.4.1 The actors in the development of the LSD ......................................................................... 45
3.4.2 Uncoupling Actors ............................................................................................................. 47
3.5 LACK OF WORKING PROCEDURES ......................................................................................... 48
3.5.1 Inconsistency between the Visual Display Unit and the Large Screen Display ..................... 50
3.5.2 Procedures in complex systems ......................................................................................... 52

4.0 CONCLUSION.............................................................................................................................. 56

4.1 SUMMARY .................................................................................................................................. 56
4.2 COUPLING THE ANALYSIS ...................................................................................................... 57
4.3 IMPLICATIONS ............................................................................................................................ 59

APPENDIX A: LIST OF INTERVIEWEES ....................................................................................... 63

LIST OF FIGURES ............................................................................................................................ 64

REFERENCES: ................................................................................................................................... 65
1.0 Safety and Design

1.1 Introduction

Modern society is a high-tech society. Key institutions like producers of energy, transportation systems, and information-communication systems rely on technologies that are complex and tightly coupled. This makes society more vulnerable to errors, accidents and social disruptions. On the other side the improvement of technology, innovation in safety devices and regulations have also made society safer. Vulnerability is the price we have to pay to live in an innovative culture where the technology of efficiency usually is one step ahead of the technology of safety.

The society in the western world is totally dependent on the energy we get from fossil fuel to maintain the order and lifestyle we experience today. On the Norwegian shelf, some of the oldest oil reservoirs are no longer efficient for oil production and the oil companies have therefore started to exploit the less profitable gas in these wells. To balance the loss of income, and to meet external demands, they have to increase the productivity and automate it, which can be achieved through the adaptation and development of new technology. Since the first American “Texans” came and helped Norway establishing its petroleum business the development of new knowledge and technology has improved dramatically. The technology has moved from manual systems to high-tech e-drift and onshore control rooms like in Statoil’s new “Snøhvit” plant in the Barents Ocean. The safety culture has also gone through changes, it has gone from a rash culture with risk taking actions to a more safety focused and regulated culture. Norway has been a pioneer when it comes to safety in the oil industry. The Norwegian state is concerned with the potential hazards related to the petroleum industry, and
has therefore appointed an institution under the oil-department called Petroleum Safety Authority Norway (PSAN). This institution makes sure that state laws are followed and has developed guidelines and revision-methods to make sure that safety is considered at every level of the complex process of designing technological artefacts and systems for the production of oil and gas. A lot of research has been put into increasing safety for people and environment at oil plants. Even so, there have been some terrifying accidents during the years of production. These cases serve as reminders on how important it is to never ease when it comes to safety issues, and they also serve as hard learned lessons in how to find factors that make the system more vulnerable.

In the gas and oil industry many of the processes are based on subunits that are in complex interaction with each other. These interactions can make the process vulnerable if the subunits are not properly connected with each other, and one has to make sure that all possible connections are appraised. In my thesis I will look at the design of a large screen display (LSD) designed by the Institute of Energy Technology. The display is going to be placed in the central control room (CCR) at Statoil’s new Snøhvit field. I will focus on how to increase safety when one designs a new artefact that is supposed to fit into a dynamic and complex system. To consider the lack of safety functions in just one of the operator-support-tools in the control room may seem like a small fraction of the whole vulnerable system actually involved in this process. The Liquefied Natural Gas (LNG) process at Snøhvit is a complex system and in order to increase the overall safety, engineers have to consider the different subunits and artefacts both separate and in interaction with each other. In the paper I will study how the LSD is connected to the LNG process and criticize the designers and engineers who do not see the LSD as a safety critical monitor, excluding it as an important part of the control room interface and a monitor of the performance criterion of the LNG production. I will not get into the technological details of this system, but I will look at how
the actors involved in the Snøhvit LSD design seem to uncouple the LSD from the system in the design process and the factors contributing to make the formal demands of interaction hard to meet.

1.2 Research Question and Structure

The aim of this thesis is to illustrate how system designers build a process piece by piece, and how they in some cases seem to miss some of the links that should be connecting the pieces when they integrate it back to the system. This tendency seems to be especially present when different contractors make different parts. In this thesis I will look at how Snøhvit’s LSD is connected with the rest of the process of producing Liquefied Natural Gas in the design process. When looking at the empirical material in the thesis one will see that both IFE and Statoil uncouple the LSD from safety related components like the operators and the Visual Display Units (VDU) in the system. STS-scholars like Latour (1979) and Hughes (1987) claims that this distinction is discriminating and uncouples the system. Snook (2000), Law (2003) and Rosness (2003) describes how the integration-process for organization and system units often fail when the organization has been in operation for a while. In this case I will indicate how uncoupling can happen at two levels; first I will claim that there is an uncoupling within IFE in the process of designing the Snøhvit LSD, and second I will claim that the uncoupling in the LSD design process leads to an uncoupling between the actors and components which entire the system. My research question in this thesis will be: how did the design process uncouple the LSD from the LNG production system, and how does this affect the safety in the system?

In order to answer these questions I will start chapter 2 by introducing IFE as the responsible designers of the LSD, and Statoil; the operator at Snøhvit. Then I will look at the LSD designers approach to the Human Factor method which has had an ambiguous affect on the designers; on the one hand influencing them with its framework, on the other hand they
have tried to take distance from it. To open the ‘Black Box’ in the design process I have made a thorough description of what the LSD design team did, thought and decided in the design process. To understand why it is interesting to look at safety in this design process I have written a part on the purpose of the LSD. It may seem like both IFE and Statoil underestimate the effect the LSD will have on the operators; while both of them categorize it as non safety-critical, which seems a contradiction considering its size (16 meters) Further, such an approach compels the operators to learn two different information interfaces. In chapter 3 I use Snook’s concept ‘uncoupling’ and his theory of ‘practical drift’ to analyse my empirical data from IFE. I will discuss how the design process of the LSD in several ways has resulted in uncoupling of the display and the process it is supposed to monitor, and how the different actors that are contributing to make the LSD are uncoupling the development process. The main purpose of the LSD is to improve the operators monitoring capabilities of the LNG production, it is therefore necessary that the LSD is tightly coupled to the rest of the system. Finally, in chapter 4 I summarize my findings, and discuss the relevance of regulation and coupling in making a safe design. In the end I will try to come up with some directions for further research.

1.3 Studying Safety and Design in the STS- Field

In this thesis I will investigate the design and development of a new technology. This is a topic of tradition in the field of Science, Technology and Society (STS). Bijker and Law (1992) argue that:

Technologies do not ... evolve under the impetus of some necessary inner technological or scientific logic ... if they evolve or change it is because they are pressed into that shape (pp: 3).
Rejecting technological determinism which views innovation as a result of factors external to society they believe that technology is shaped by a range of heterogeneous factors, like society and culture. The development of technology has relevance for the society; living in a technological culture is by Bijker implied “to live in a vulnerable world” (2006:1). This vulnerability can not only be seen as something negative, because it also connotes living in an open and innovative culture. The interdisciplinary field of STS which draws on research from philosophy, sociology, economy and innovation studies is trying to show how technology is a part of everyday life. One can not understand the culture today without taking into account the technological diversity that is affecting the society. STS researchers investigate how social factors influence the development of technologies and the construction of meanings that are given to the technological artefacts (Bijker, 2006).

Because we are living in a technological and innovative culture where vulnerability is one of the characteristics (Bijker, 2006), many STS scholars have done fruitful investigations on different technological system accidents in order to gain a deeper understanding of what kind of factors contribute to the vulnerable context prior to the accident. To understand these meanings one has to open the ‘Black Box’ of technology; one has to look at the content of technology and study how it has developed in interaction with society and culture. The aim of my thesis is not to analyse vulnerability by looking back at accidents to describe what went wrong. Instead I want to look forward and try to see where one can improve safety before accidents happen. The STS literature that I will use in this thesis is full of accident analysis, they cover areas from the military (Snook, 2000), NASA’s space program (Vaughan, 1996), train accidents (Law, 2003, Rosness, 2003) and accidents in the oil industry (Haukelid, 2001, Wackers and Kørte, 2003, Wackers, 2004). These researches have inspired me to study which factors should be considered and improved during a design through what Latour (1979) calls a ‘primary process’. The primary process is the actual real time work process prior to the
accident. The secondary process on the other hand, is the activity the constructivist in science and technology investigate after accidents when they look for the causes of errors and loss. There are different people involved in the two processes. Experts and consultants from the outside are often brought in to find the causes of the accidents, and when they find them they can see how the causes have been there all the time, hidden in the complexity of every day tasks. The management, system designers and operators are often blamed for the accidents because they should have seen the obvious errors found in the secondary process. The problem is that they are not obvious at all before they are reconstructed in the post-accident investigation (Wackers, 2004). It is not easy to discover errors with eyes that are adapted to the process. Rasmussen (2000) suggests that many accidents happen because couplings occur between activities that are usually not coupled in functional ways in the daily work. To fully understand the error one has to look at what kind of social and organizational factors that made the designers make this error.

This thesis will focus on the primary process and how systems often are divided into subunits in the design process without being integrated when put back into the system again. When I talk of systems in this thesis I will mostly talk about the whole process of producing Liquefied Natural Gas at the Snøhvit plant. The acknowledged STS scholar, Thomas Hughes claims that technological systems contain messy, complex, problem-solving components which are socially constructed and society shaping (1987:51). The components in the technological system can be physical artefacts, natural resources, organizations or/ and legislative artefacts. Hughes argues that artefacts, physical or non-physical, are socially constructed and adapted in order to function in the system. The components interact with each other, and they contribute directly or through other components to accomplish a common system goal. A characteristic of a good system builder is the ability to construct or to force unity from diversity (Hughes, 1987). In this thesis I will analyse a component or a subsystem
[the LSD] in a complex LNG production. I will try to understand how the designers of the component, and the responsible operator; Statoil, link the component back to the system. To describe how the designers, i.e. IFE and the operator, i.e. Statoil, separate different parts of the system I will use the concept of ‘uncoupling’. This concept is used by STS scholars like Snook, Law and Wackers, to describe how subunits of an organization drift from written procedures where the subunits interact in a coordinated manner to a local optimized procedure where the units interact in a haphazard way. I will explain how this happened with the design process at IFE as well, but I will also draw this concept a little further and use uncoupling to describe how some systems never got coupled in the design and how this can affect safety when these subunits interact with each other. Law (2003) writes about the London Ladbroke Grove disaster where 31 people died when two trains collided. He looks at how systems are developed over time, and how they unavoidable develop practices and routines in safety critical contexts because it is locally efficient. This is the same process that Snook calls ‘practical drift’ which will be used in the further analysis. Law uses the ‘actor network theory’ (ANT) to describe how all elements in a network where geared towards improving safety, but he also shows how small changes in standard alignment collectively may have prompt a disaster. ANT is based on a material- semiotic method; its aim is to map relations that are both material and semiotic. With this method scholars try to explain how material- semiotic networks come together as a whole. ANT assumes that all the units in the network can and should be described in the same terms whether they are human or non- human; a symmetric explanation should be offered both for the social and technical world. This is called the principle of ‘general symmetry’ and an extension of Bloor’s (1981) ‘strong programme’ where he presented a principle of symmetry. Bloor’s principle advocates that true and false beliefs or successful and failing machines are to be explained in the same terms, in this way
he outlaws both technical determinism where society is explained as an effect of technical development, and social determinism, where technology is explained as a result of the social.

As mentioned above there are STS scholars that have investigated the oil industry; Wackers and Kørte (2003) used the concept of ‘drift’ to investigate how an offshore helicopter transport system changed towards a vulnerable state when they started to follow local adapted practices instead of the prescribed protocols. Wackers also investigated the accidents where a concrete offshore production platform (Sleipner A) capsized and sunk. In this analysis he focuses on how a good construction firm could fail at making a condeep structure when it seemed like they did everything by the book. Wackers is looking at the vulnerability in these accidents. The vulnerability concept will also be used in this thesis but not as the main factor for this research. I will mostly look at how safety is considered and factors that improve or decrease safety in the design of the LSD. The term ‘safety’ is used in many different fields, often without any formal definition. The Norwegian Research Council invests considerable funds each year to do research in order to increase safety in the oil/gas sector. They define safety as:”the ability to avoid injuries or loss of human lives, environment and materials caused by acute, unavoidable situations (accidents) or criminal actions” (ROS-definitions- Norwegian Research Council). In this thesis I will propose a definition of safety that is quite similar to the ROS-definition where I will try to cover most of the application even though it may be too general for some purposes. The difference is that I see the situation at the gas plant as unstable and therefore consider that safety should be seen in a dynamic perspective. I will also remove the factor of criminal actions, because this has little relevance for the use of LSD in the LNG production. In this thesis safety is: ‘a dynamic ability to reduce the injuries or loss of human life, environment and property damage, and the ability to limit the consequences when an accident is unavoidable’.

1 ROS (Risiko og Sårbarhet)- Definitions ( 10.06.06) http://www.sintef.no/static/t/projects/ros/defs.html
I will draw on a constructivist approach from the STS field in order to get an understanding of the design and production of a technological artefact. By using the empirical data from interviews with the LSD designers, I hope to show how the design process is influenced by the tendency to divide systems into subunits and the actors’ reluctance to see the units in interaction, results in an incomplete system.

1.4 Method

The empirical basis for this thesis is gathered by means of interviews of the six designers of the LSD design team for the control room at the Snøhvit gas plant. All the interviewees were directly involved in the design process, either as computer experts, project leader or consultants, and they all made some part of the design. The interviews took the form of semi-structured qualitative interviews, which were taped and later transcribed to constitute a written source of the data. The interviews lasted between one and two hours. The aim of the interviews was to explore how safety was considered in the design. As recommended by Rubin and Rubin (2005) a topic guide was made before the interviews were conducted. This was mainly made to make sure that I would remember the most important questions. However, these topics did not make a strict guide on how to structure the interview. I tried to be non-directive, and filled in with questions and comments where I felt that it was natural to do so. It was their story and version I wanted, so what they felt was interesting to tell, was considered good information.

Because Norwegian was the native language for both the interviewees and the interviewer, the interview was conducted in this language. This was done to make the interviewees relax and give as much information as possible without feeling restricted by bad word-account, pronunciation or other related issues. On the other side, the fact that I had to translate other people’s opinions and information to another language can have caused
complications because of the possibility of making wrong translations or misinterpretations. Nevertheless, I do not feel that this had any influence on the outcome of this thesis. Most of the technological terminology was heavily influenced by English and their documents and reports were also written in English.

The interviewees were rather homogenous in their academic background, they where all engineers from technical faculties. I did interviews with all the members of the design team. The different roles in the design process and different backgrounds are therefore possible to detect if there are any. One of the interviewees had work experience from an oil-plant and as a consultant for PSAN, and it was interesting to see how his answers deviated from the others. Five of the six interviewees were men, something that has been typical in technical engineering in Norway. Things are starting to change in this gender distribution, but it takes time to see it in the workplace. All the participants were interested and positive about my thesis, and they all participated willingly and allocated time and recourses needed to conduct the interview. A complete list of the interviewees can be found in Appendix A.

In the thesis I mention that the cooperation between IFE and some relevant actors that contributed with expertise and information to the LSD design has not been problem free. From my side, I experienced some communication difficulties when I tried to get in contact with Statoil, ABB and Linde. Apart from mail exchange with Statoil it was very hard to get information from the other companies. Thus when I speak about the other actors, I will use the information the design team at IFE gave me. Because it is the LSD design process I will focus on, I believe it is the design team’s experience of the interaction with other actors that is the most relevant information.

To understand IFE and their way of selling research I attended their workshop about “Human system Interfaces – Design and Evaluation”. This workshop was mostly about nuclear control room design, but some of it could be attributed to the petroleum research.
Most importantly it gave me insight in how IFE considers guidelines and human factors in what the IFE Snøhvit design team calls a ‘conservative industry’. To give the nuclear researchers some insight in IFE’s other design area, petroleum, they also gave us a tour in the HAMMLAB (Halden Man- Machine Laboratory) where they gave us an introduction about the function oriented interfaces in LSDs.

To get better insight in how the oil and gas process works I attended a conference in process understanding at the “Industrial Association for Electronics and Automation”. Here we had an introduction in the main processes at an oil production plant, the building of a plant and an introduction about the running and maintenance of process equipment. Even though I write mostly about the LSD which is a support product in the gas and oil production, it was useful to get an overview of the whole system in order to understand how this product can increase the safety of a complex production. This conference also introduced me to some of the main actors in the Norwegian petroleum industry, Aker Kværner, Hydro and Statoil, and I got in touch with one of the safety managers at Snøhvit who helped me with some information about Statoil’s philosophy for the LSD.
2.0 Designing the Large Screen Display

Figure 1. The control room with the LSD, the Snøhvit plant at Melkøya and the Snøhvit field in the Barents Ocean (Illustrations by IFE).

Snøhvit is an onshore receiving and landing plant situated on Melkøya Island outside Hammerfest in northern Norway. The estimated production period at this plant is from 2007 to 2035. The main product from the Snøhvit field is Liquefied Natural Gas (LNG), which is natural gas that has been processed to remove impurities and heavy hydrocarbons, and then condensed into liquid by cooling it to approximately –163° Celsius. Producing LNG is a long and complicated process, but the LNG has approximately 600 times less volume than natural gas at standard temperature and pressure, making the storage and transport considerable more
cost efficient. This is a great benefit since most of the gas has to be shipped over long
distances, notably to the United States.

This thesis will describe the LSD designed to be in the Snøhvit Central Control Room
(CCR) is intended for the sole purpose of supporting CCR operators. Normally there are 3
operators present in the control room respectively dealing with: sub sea, process and utility
operations. A fourth loading operator present when loading is taking place (Statoil document).
The operators’ main task is to monitor the plant status and make sure that there are no threats
to plant safety. The LSD should tell the operator where relevant information can be found on
the visual display unit (VDU), so that the operator can carry out the necessary effort on the
operator workstation (OW). It is important to note that the LSD is not intended to operate on;
it is a mean to improve the operators understanding of plant status and to enhance their ability
to respond to emergency condition (Statoil document).

2.1 **Background: Statoil**

The Norwegian state’s oil company; Statoil, was established by a governmental resolution in
1972. The motivation behind it was to build Norwegian competence in the oil business and
create a national oil- industry. In 2001 Statoil went from being a fully state owned company
to be a partly privatized oil and gas company. Statoil is today considered to be the largest
company in Norway, and is continuously expanding. One of their most recent projects is the
development of the technologically innovative “Snøhvit” gas field.

There are many factors that contribute to the development of new technology in the oil
industry. The first one is economy. The oil prices have reached high peaks in the last years,
due to politics and world trade. The conflicts in the Middle East and in the Arabic world along
with other global factors have resulted in considerable increase of income for the Norwegian
petroleum industry. Good economy enables to strengthen research and development and to start new and demanding projects. The Snøhvit plant is the most technical and advanced project in Norway up to this date. First of all, it is the first plant to be controlled from the mainland in Norway. Second, this plant is taking gas from the reservoirs in the Barents Sea which has a hostile and cold environment. Third, it is the first plant in Norway that produces Liquefied Natural Gas (LNG). Since there are few specialist in Statoil and in Norway with knowledge about the LNG process, know-how has been imported from foreign LNG plants, while appreciable knowledge has been developed through research.

Because of the need for highly educated people at this project, Statoil also decided to try new technologies in other areas; to put LSDs in control rooms is one example of such innovative trend in the petroleum business. LSD technology reached the market at the end of the twentieth century as the technology for blowing up images got easy and cheap. None of the plants where Statoil got information and experience about the LNG process had LSDs. Statoil and IFE had therefore little operation-experience to draw on when they considered which factors were important to put on the screen. The first large screens in the petroleum industry had the same interface as the VDU small screens. When IFE started to design LSDs in 1997 they tried to make a completely new interface. They thought that this new use of equipment was the chance to start using a new design for operator screens. Because financial resources in the oil industry are currently abundant, many plants renovate and update their control rooms. Statfjord and Ekofisk are some of the old plants that recently have ordered new LSDs from IFE.

2.2 Safety in the LNG- Production

This thesis aim is to look at how safety was considered in the design process of a control room support device. In all the interviews I asked explicitly how each of the design
team members had considered safety or vulnerability in designing the LSD which is supposed to monitor the LNG-production. Somewhat surprising, all the interviewees\footnote{See: Appendix 1.} answered that these concepts were not considered. Some of them said that they could have considered it if Statoil had wanted it, while others said that safety and vulnerability was irrelevant because the LSD was not safety-critical. When Statoil was asked whether they had considered the vulnerability factors the LSD could bring to the plant, they also replied that the LSD was not safety-critical. From the STS-field of vulnerability, I would claim that this is a case of uncoupling between the oil industry’s goal of absolute safety at all level of production, and the decision to exclude some parts of it. If the LSD is considered just a supplement for the information presentation in the CCR, without any safety relevance for the LNG production, Statoil should ask if this screen is really necessary.

I have focused on safety considerations in the development of the LSD design in this thesis, but the reason why I find this interesting is because I see this artefact as a contributor to the overall plant safety. The LSD is one subunit of a larger complex system, and if Statoil wants to fight the vulnerability in this system they have to see the subunits as integral parts of it and thereby fight the vulnerability at every level of the system. I will also argue that one has to analyse the safety in the system as a whole. In a control room where everything is supposed to have safety increasing functions I would think that an instrument that takes 16 meters of the room will have an effect on the operators working procedures. And if IFE uncouples these 16 meters from the rest of the control room procedures and instruments, surprises may arise if these instruments or procedures should suddenly couple and interfere with each other. In the next chapter I will show a case where uncoupled subunits of an organization worked well for several years as long as they did not interfere with each other, but when the situation came where the subunits had to interact, it developed into an accident where human lives were lost.
But first I will describe the process of designing a LSD, and see what kind of factors contributed to the decision making of non incorporating safety functions.

### 2.3 Background: IFE and the start of the LSD- design

IFE (denominated IFA, Institute for Atomic Energy, until 1980), was established in 1948 as a research institute for nuclear energy. After some years of expansion and the building of the two only research nuclear reactors in Norway, the uncertainties of Norway as a nuclear power supplier started to affect the economy at IFA. The parliament’s resolution in 1975 about postponing the decision about using nuclear power, made IFA decide that they had to change the institute’s character and do research on non- nuclear assignments as well. They changed their name to IFE- Institute for Energy Technology, and became a more general energy-technological institute. From the late 1970’s IFE started doing research in petroleum. They focused on assignments where they could use their expert knowledge from the institute’s nuclear activity. After some years they had a solid expertise in the petroleum field and expanded their research (Njølstad, 1999). In 1997 the Norwegian research council started a new project with IFE where they wanted IFE to use their knowledge from the Human Factor perspective in nuclear control room design and expand it to develop a simulator based man-machine laboratory\(^3\) for the oil industry. The IFE Human Factor laboratory was intended to demonstrate how interaction between technology and the user (operator) could be optimized with respect to economy and safety. This project was intended to integrate a number of activities already performed by the institute. IFE has since 1983 had an experimental control room simulating processes in nuclear plants. These capabilities were expanded, providing an

\(^3\) Experimental Operations Centre
opportunity to utilize the same methodology, software and hardware for needs in the oil industry.

The team that was assigned to start this research at IFE soon faced problems in how they could achieve the goals set by the research council. The programme was supposed to be jointly financed from sources within the oil industry and bilateral projects for individual companies, but it did not seem that the industry was interested in these Human Factor experiments. The petroleum team at IFE therefore decided that they wanted to work with petroleum operation design centres in another way than what was done in the nuclear control rooms. The team thought that the nuclear industry was too conservative and too occupied with international standards and Human Factor revision methods. Veland⁴, who was part of this project from the beginning, said that the members of the team thought that these standards and methods inhibited innovative ideas. The design team did not just want to improve existing technology; their goal was to come up with something revolutionary, which eventually resulted in a new design of LSD. This design was later described by one of the interviewees⁵ as a “paradigm shift”⁶.

2.3.1 Organizational Structure

IFE is a hierarchical organization with two main departments; Kjeller and Halden. The Snøhvit design team is a part of the Safety Man- Technology- Organization (MTO) division in Halden. The MTO is divided into four units where the Snøhvit team is working in the

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⁴ Interview: Veland, Ø. 03. 05- 06
⁵ Interview: Braseth, A. O. 12. 07- 06
⁶ The term "paradigm shift" was first used by Thomas Kuhn in his book The structure of Scientific Revolutions (1962) to describe a change in basic assumption within the ruling theory of science. The term has since been used in many different contexts (For further elaboration see Kuhn, T.S. The Structure of Scientific Revolutions, Chicago: University of Chicago Press). Bijker draws an analogy between the concept; paradigm and his term technological frame, but he does not equalize them (see: Bijker (1995) pp. 123-127)
“operation centre (driftsentralen)”\textsuperscript{7} each unit seems to be quite homogenous with little cross sectional teamwork. IFE is a knowledge-creating company where the individual knowledge is a part of their resource. These companies usually aim to increase the organization’s sum of knowledge by transferring the staff member’s individual tacit knowledge to explicit organisational knowledge. To do this one has to motivate people to communicate and make dialogues across sections with different knowledge (Nonaka, 1991, 1994). One of the interviewees in the Snøhvit team told me that even though he would like to work in an interdisciplinary work environment and learn from different points of views he admitted that:

\begin{quote}
I sometimes meet my former self when I’m in a project; it is so easy to want to work with someone who shares your opinions, instead of having to convince other people with different backgrounds.\textsuperscript{8}
\end{quote}

It is not easy to reorganize institutes. It needs hard work to adapt to the latest ideas in how to run a well organized institution. However, this does not mean that one can afford to stagnate; especially knowledge creating organizations which have to be creative thinking and innovative in order to survive, as Snook says: “an organization is never done organizing” (2000: 180). The MTO section at IFE claims to operate with the Human Factor perspective, but it may seem like many of the employees in this section seems quite unmotivated to work with this perspective, but as I will later describe they are inspired by Human Factors in the work they do, even when they claim that it has not been used.

\section*{2.4 The Human Factor approach}

“Human Factors” is a scientific discipline that uses systematic methods and knowledge about humans to consider and improve the interaction between individuals, technology and organization. Their goal is to make a working situation that contributes to a profitable, safe

\textsuperscript{7} The other units are: Computerised Operation Support System (Driftstøttesystemer), Industrial Psychology and Visual Interface Technologies (Visualiseringsteknologi).

\textsuperscript{8} Meeting: Braseth, A. O. 01.07-06
and healthy production. The Petroleum Safety Authority Norway (PSAN) sees the Human Factors discipline as an important approach to improve safety in Central Control Rooms (CCR). They argue that using Human Factors in the design and modification of the CCR may lead to more production, more stability and less shut down time (PSAN, 2003). Human Factors is an umbrella concept that covers several research areas like human performance, technology, design, human-computer interaction, situational awareness and human reliability. The discipline focuses on how people interact with products, tools, procedures and processes. Most human factor practitioners are psychologists and engineers who focus on cognitive and perceptual factors in a design.

The Human Factor approach to design is characterized by two general premises; the first is; engineers must integrate humans into machine systems by strict scientific methods. They do not believe in the reliability of trusting intuition or common sense. The second premise is; design decisions can not be made without experimenting with trial and errors. These premises make the design process quite extensive. Because most of the engineers in the world use intuition and common sense it is hard for the Human Factor developers to keep up with the changes in technological innovations. This problem makes it hard for the Human Factor engineers to reach their goal of substituting scientific methods for guesswork.

IFE started doing Human Factor research to reduce the likelihood of human error in order to make safer and more efficient work environments in complex process systems like nuclear plants, oil/gas plants and transport systems. In IFE- Halden they have, after years of control room safety experiments, decided to focus at the increased use of screen based information presentation. They do experiments to make better situational awareness and more reliable monitors. Their goal is to give better overview and reduce the errors. As we will see later this is very similar to what the Snøhvit design team aims at in their design, even though they claim
to be more occupied with usability than human factor\textsuperscript{9}. The Snøhvit LSD design team seems to have a rather sceptical attitude towards Human Factors. In one of my interviews, the designers claimed that:

The human factor perspective is taking place outside of the design process. They make theories about how a design process should be and revise the design after it is done, human factor theories do not help very much at actually creating something\textsuperscript{10}. The IFE petroleum team claims that they are better at new-thinking, making flexible ideas and taking care of the user than the people always following standards and revision methods\textsuperscript{11}.

Toft, Howard and Jorgensen (2003) see this in another way, they say that:

Consideration of ‘human factors’ in engineering design will reduce the likelihood of human error, resulting in a safer, more efficient work environment for all stakeholders. The synergy of practicing the two disciplines of engineering and Human Factors, through an innovative teaching model, such as the one currently being developed, will ensure that graduates from both disciplines will become leaders in their professional practice.

They see that these different disciplines have different views, but that the best way of making safe and innovative design is to combine the better of the two disciplines. If this is true, one could argue that there are some organizational problems at IFE. They have all this knowledge in both human factor and creative engineering, but still they make homogenous project teams in each of the disciplines instead of making multi-disciplinary teams that could learn from each other within the organization. We will see that even though the Snøhvit design team claims that they have some sort of conflicting ideas opposed to the human factor perspective, they use many of their key principals, like considering cognition and perception. The main difference is that the Human Factor believes that engineers must solve the problems of designing and integrating humans into machine systems by scientific methods, while the Snøhvit LSD designers think this is unnecessary and believe they can make a more innovative

\textsuperscript{9} Interview: Veland, Ø. 03. 05- 06
\textsuperscript{10} Interview: Kristiansen, P. 12. 05- 06
\textsuperscript{11} Interview: Veland Ø. 03. 05- 06
design by using graphical design principles and common sense. We will also see that there are some basic differences in the importance of consistence of interface and making working procedures.

One problem with the scientific method of human factors is the dividing of technological systems into subunits. In an experiment the researchers have to test every variable separate to find the result of the relevant interaction of two variables in order to exclude external interference. By dividing the artefact or the system into subunits in the design they increase the risk of making a system where the subunits are not coupled together. There are benefits and drawbacks with most methods used in science, that is probably why the LSD design team tries to avoid the Human Factor approach while they at the same time are persistent with much of its framework.

2.5 Designing the Large Screen Display at IFE

In 1997, when IFE got support from the Research Council in Norway to establish a simulator-based man-machine laboratory for the oil industry, the team assigned to work with it tried to work out a plan for how they could achieve the Research Councils goal. After some months they found that there was little interest from the oil industry in buying Human Factor-experiments, so the team started an idea workshop where they came up with a plan to use graphical design to make a new screen design for the CCR: a large screen display (LSD). The LSD was at that time a quite new and trendy control room device, and it was therefore a big marked to sell it to because it is easy to implement as an extra support in existing control rooms. To sell the new LSD, IFE went to different workshops and conferences for the petroleum sector and promoted their “revolutionary” design. At one of these workshops IFE got in contact with the man in charge of production in Statoil’s new project at the Snøhvit field. Statoil was convinced that this was the best LSD design in the marked and ordered a
design that Snøhvit- production would pay an amount worth of two thousand working hours. This “small” amount of working hours are based on the normal assumption that the design process is just about making a product by drawing down some ideas, when it in fact is a demanding and time consuming process where one, especially in this case, has to learn and understand a complex system. IFE started the pre-project in January 2005. The Snøhvit design team consisted of six people, the members did different parts of the design and the team leader made sure that all parts were coherent with each other. After showing an innovative design that was acceptable for Statoil, they got another two-million-contract to make the display. The finished result was delivered to ABB for implementation in January 2006.

2.5.1 What to include in the design?

The German company Linde, was the designer of the Snøhvit LNG-process system; they delivered all the information about the processes involved in the LNG production to IFE. One problem was that the information given was insufficient. IFE tried to get information from Linde about the key-parameters in the LNG process; the most important processes and what needed most visual attention. But at the time IFE got in the Snøhvit project Linde was almost done with the project and they had very little time to help IFE. IFE tried to get some more information from Statoil, but even though they tried to help they had the same problem; little time and little resources to help other subcontractors. This meant that IFE had to decide what to include in the design on the basis of expertise from one of the team members that had long experience as a consultant for the PSAN, common sense and of course the experience they all had from previous assignments and knowledge in the gas process. This gave IFE freedom to make what they thought was the best solution and to be creative and make new concepts, even though they had to consider some agreements made with Statoil.
Statoil had some key principles when they ordered the LSD from IFE. One was that the LSD was to be an integral part of the Human Computer Interface. This meant that it should work in conjunction with the displays at the Operator Workstation (OW), so that the information presented at the LSD were consistent with the information presented at the OW displays. Even though they wanted consistency, both IFE and Statoil wanted the LSD pictures to complement rather than to copy the VDU at the OW.

Statoil wanted the user access and control over displays to be designed in such a way that it ensured that other user’s information needs were not compromised, they wanted the text to be uniformly presented for all text objects and to ensure that the operators were able to read the information regarding plant areas they were responsible for in the immediate field of view. This information was given to IFE from the process designers, Linde\textsuperscript{12}. Safety critical information\textsuperscript{13} presented via the LSD and OW should be given to the operator by reducing their shift of eye- or body movements between the screens. They had to make sure that the LSD was free from distortion of any kind that could interfere with readability (Statoil document). Clearly, there were many Human Factors demands from Statoil.

Even though some of the philosophy wishes from Statoil were considered, there is a problem with the consistency between the graphic elements in the LSD and the VDU’s. Symbols, set up, colours and numeric information are different in these interfaces. This means that there are actually two different sets of information systems the operators will have to learn. One of the most important differences is the reading strategy. Where operators usually look at the numeric data in VDUs as normal quantitative numbers, they are presented as trends and graphs based on deviation from highest and lowest safety value in the LSD (see figure 1). The aim is to economize the cognitive resources and to get a simple overview of the balance in the LNG process. If the plant is in a normal state you can just have a quick glance

\textsuperscript{12} Interview: Veland, Ø. 03. 05.06
\textsuperscript{13} It is safety critical information on both the VDU and the LSD, but because it is only possible to operate on the VDU they do not see that the LSD has a safety critical function.
to see if the trends are in line, if some of the bar graphs are high, one can easily see it as a skewed line\textsuperscript{14}.

Some of the members of the design team meant that the coherence between the large- and small-screen was not that important as long as the design was consistent within the screen\textsuperscript{15}. Others see the difficulties and vulnerabilities in having to learn two systems, when the goal was to reduce the mental processing\textsuperscript{16}.

A problem all the Snøhvit LSD designers recognized with this design, was the size Statoil has set for it; 16 x 1.5 meter. Usually when you design a screen, you make the design and then fit it in to a size calculated from the needs; the aim is usually to get it as concentrated as possible. If you are given a large sized screen and are assigned to fill it out, it is easy to start putting all sorts of things on it, and it won’t be a data support for the operators, but a jungle of confusing

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{figure2.png}
\caption{Numerical data in Visual display unit}
\end{figure}

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{figure2.png}
\caption{Trends in the Large screen display}
\end{figure}

\textsuperscript{14} Interview: Weyer, U 10.05.06
\textsuperscript{15} Interview: Eikås, M. 10.05.06
\textsuperscript{16} Interview: Veland, Ø. 03. 05- 06
information. IFE Snøhvit team had to stay focused on this problem to avoid going into the trap thinking that everything is important when there is room for it. It is clearly a controversy between the different actors: Statoil, Linde and IFE in the appointment of demands and information. Statoil wanted a 16 meters long screen, Linde did not give the necessary information about key processes IFE needed to develop a design with only the most important information, thus making IFE decide what components to integrate. There are little interaction between the actors, thus very little room for discussing the best solution.

One reason to put in a LSD in the Snøhvit control room, mentioned by some of the people at IFE, was that this screen could work like a “show off” to other contractors and actors in the oil industry\(^1\). This can explain why Statoil wanted a 16 meter long screen, which can seem to deviate from the LSD’s aim to give the operators a whole and integrated summery of the plant status. These 16 meters can in some situations make it more confusing because it is too big to focus on the overall picture. It is important for Statoil that the Snøhvit project looks good, because they are in a process where they try to convince actors involved in the new Stockman project in Russia that they have good knowledge and experience in producing LNG in the Barents Sea. The Stockman project is a huge and prestigious LNG project where many competitioners from the European petroleum market are trying to be engaged. For Statoil the contract can mean a Norwegian- Russian gas cooperation in the Barents Sea. The assertion of a “show off” function in the LSD is build on the belief of the design team and is not made public by Statoil, but I can maintain that the oil industry has to use clever marked strategies to expand in the competitive marked, and it is an important economic factor to remember when it comes to the development of new technology.

\(^1\) Interview: Weyer, U. 10.05.06 and Seim, L. Å. 11.05. 06
2.5.2 How to make a good design?

2.5.2.1 Change Blindness:
IFE tries to make the LSD dull in normal situations. The dull screen concept is a contrast to previous LSDs and VDUs, and the main idea is to minimize the visual noise in the picture to get higher information content. This is quite similar to what Durlach (2004) calls ‘change blindness’ (pp.1). Change Blindness refers to the failure to detect what should be an obvious visual change. These failures can have big consequences when the design and use of the system intends to monitor and control complex and tightly coupled processes. Monitoring the control systems usually involve visual searches over multiple displays, like the five VDU screens each of the operators have to monitor at Snøhvit. Research literature on Change Blindness shows that it is under circumstances like search between displays, decision making and communication where changes in display are most likely to go unnoticed. This situation is not necessary affected by stress, fatigue or work overload, it is usually a sign of bad visual design. One factor that can help avoiding change blindness is to discriminate. This is what IFE tries to do in making the normal display easy to read and without many glimmary colours for normal function because this may draw the attention away from a more critical situation. If critical situations occur the colours will change and become stronger and more intensive in order to catch the operators attention (Braseth, Welch and Veland, 2005 & 2006).

If an artefact like the LSD is supposed to increase safety in a complex system like the LNG process, knowledge of visual change detection processes should be taken into account in the design of visual user- interface systems and the training given to the operators. IFE has been good at taking care of the design tools in such a way that changes in display information can be easily retrieved without adding workload to the operator.
2.5.2.2 Key-Hole effect

The need for a new approach to petroleum display design is in particular based on shortcomings in today’s designs related to the key-hole effect, where the VDU display format only reveals a fraction of the whole process. Operators are struggling to get the whole view of the process; this will probably be even harder in the future when there will be larger control rooms where operators must operate several processes in parallel. This can mean more mental processing by the operators and decreased performance and safety. This problem has been known for a while, and many companies have tried to solve it by modernizing their control rooms with new and high-technological LSDs and introducing a large amount of small screens. The problem is that these approaches often fail because of the poor quality of the information presented and conservative thinking by presenting the information by the same old principles (Braseth, et. al. 2005/2006).

One of IFE’s main goals is to reduce the problems related to the key-hole effect by reducing the total number of process control displays. The total number of displays can today often exceed 300 in ordinary process control system. Because the operator only uses 2-4 VDU’s actively, he or she only sees a fraction of the total process at one given time. Reducing the number of images leads to more information on each VDU. This may sound odd, because too much information on one screen can lead to confusion because there are too much to focus on. IFE argues that they can make cluttered displays look information rich by improving the design. The goal is not just to present as much data as possible in each display, but to reduce the images by only presenting information rich data and reducing static information not contributing to the information content. The purpose of the information rich display is to condensate prevailing information in process displays in such a way that each display format contains more relevant information for the user (Braseth, et al.:2006). IFE’s approach to give more information is to bring forward a new process-control-design based on principles used by the graphic designer Edward Tufte. These principles are also founded in
many areas of design such as maps, statistics and others (Tufte, 1990, 2001). The designers at IFE claimed that this approach is better and more mature than the process control displays on the marked today.

2.5.2.3 Alarm System
Statoil declares in their philosophy for LSD that the operators shall be able to interact with the alarm system via the LSD (Statoil document). However they do not define how this interaction should occur. IFE does not think of the LSD as an alarm system. The operators are not able to operate on the big screens and should therefore have the alarm system at the small screens. In stead of making a confusing and complex image of each alarm at the Snøhvit plant, IFE has designed a number of alarms reflecting areas of different alarms [group alarms]. If an alarm goes off the operator must use the small screens to see which specific alarm is set off, but reducing their search by showing in what area to look. In each part of the process system there are huge numbers of alarms, and because this is a tightly coupled system, one alarm will soon make a number of alarms go off because one error soon affects another part of the system. If all these alarms should go off at the LSD it would make a very confusing image for the operators to respond to. It would not serve the goal that LSD is supposed to give a simple overview picture of the LNG process.

2.6 The Purpose of the Large Screen Display

To analyse safety consideration in designing LSDs one should also make the purpose of this operator support clear. How can this artefact increase the overall safety at the Snøhvit plant? One of the functions of this screen is to resolve problems that are often encountered with small screens at the OW display systems. One of the difficulties on these screens is to obtain

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18 Interview: Veland, Ø. (03.05. 06). Eikås, M. (10. 05. 06). Weyer, U. (10. 05. 06).
and maintain the overall plant status. As mentioned, the information presented at each VDU is only a small part of the process, and it is only available to individual operators. To get a clear picture of plant status from small screens may often involve navigation through computer space and to integrate information from several VDU pictures. This may often lead to difficulties and time delay in accessing necessary information. Because different operators have different screens and images, the operators have no visual clue about what actions other operators are taking. This restriction in information means that operators have to describe to each other verbally what is happening in their responsibility area if they need to get an overall image of the plant (Braseth, et. al., 2005, 2006).

To solve these problems the LSD aims to provide a whole and integrated picture of plant status across systems and areas. The condition of the plant is in constant change and its rate of change should be visible to the operators. It is important that this information is presented via the LSD both in normal and upset conditions, this way it will be possible to see the change from the small details of an event to see the overall effect on the whole plant. One of the LSD’s tasks is to support team coordination by providing awareness of other operator’s action. This will in turn support the communication and collaboration when operators are to diagnose the plant status and give a common overview. In abnormal situation this can direct the operators to gain additional information that can help them in decision making about what actions to take. The new LSD symbols are also designed to give the operator an indication of an unwanted deviation from the process set-point prior to alarm state; traditional process graphics do not support this type of early warning.

All these attributes aim for better monitoring of the Snøhvit plant. With better monitoring it is easier to detect errors and with better overview of the total process it can mean that it will be possible to detect even system errors with multiple interactive errors. It seems that it is a holistic mentality behind the LSD design. The designers are thinking about
the system in its entirety, and considering the importance of seeing how different sub-processes affect each other. One can clearly see how the Human Factors approach has influenced many of the design decisions. What separates the LSD team from this approach is the scientific method of making a system design and their attachment to industrial standards. Even though the purpose of the LSD is to unite the system, I will now show how the designers decision not to follow standards, regulations and Human Factors approach have made the LSD in risk of being uncoupled from other system components, which in turn uncouples the LSD from the system as a unity of interacting components.
3.0 Uncoupling in the design process

In the field of STS, there are researchers that believe in the importance of seeing technological systems as interacting physical and non-physical components, and these systems are bounded by the limits of control exercised by artefactual and human operators (Hughes, 1987: 54). In this chapter I will describe how some system components are seen separated from the system when they are designed and constructed. To integrate these components to the system one can follow standard industrial procedures, but if they do not exist or do not fit then communication between the designers and makers of the system is crucial if one wants to make sure that the component is coupled to all the related components a critical situation can require it to interact with. To elucidate the importance of interaction between the components and subprocesses in a system I will use some of Perrow’s concepts from his analysis of “normal accidents” in large technological systems, to point at the vulnerability that will rise if the system is not integrated correctly. For further analysis I will use Snooks description of interaction and coupling between subunits in an organization and present his theory of ‘practical drift’.

3.1 Normal Accident Theory

In the book “Normal Accidents” (1984/1999) Charles Perrow analyses a large number of accidents in fields like the nuclear power industry, space programs and aircrafts. He argues that the conventional approach to increase safety by building more warning systems and safeguards will eventually fail because the system is too complex to make errors ineluctable. In his analysis of accidents he introduces two dimensions of risk; complex versus linear interaction and tight versus loose coupling. I will show how Perrow looks at the interaction of
different actors and use the dimension of coupling to describe how uncoupling between actors demolish the system.

In Perrow's dimension of interaction he argues that interaction is a characteristic of our social and political world as well as our technological and industrial world (Perrow, 1999:72). To distinguish between different system-interactions Perrow focuses on the complexity of the components that interact. Most systems he argues are designed to have linear interaction. In linear interaction “production is carried out through a series or sequence of steps laid out in a line” (Perrow, 1999:72). In complex interaction, on the other hand, the units or subsystem serve multiple functions and they are connected to several other components. In case of a failure in one of the components in the system the source of the failure can manifest itself in ways that makes it difficult to locate and handle, increasing the risk of a disaster. If I was to place the LNG production within this dimension, I would say that many of the sub processes at times can be located more towards the complex interaction than the linear. Even if linear interactions are what the designers of a system wants to accomplish, and the complex interactions are generally not intended in the design, the designers recognize the possibility for many unintended interactions that make the system more complex.

Perrow uses the concept of coupling to classify systems according to the strength of connection between their internal components. With tightly coupled elements there are no buffers between the units. If something happens to one item, it will directly affect what happens to another item (Perrow, 1999:90). Conversely, loosely coupled systems tend to have more ambiguous or flexible performance standards. Here it is possible with system processing delays, the order of sequences can be delayed and slack in resources is possible. I will argue that some of the processes in the LNG production are tightly coupled, the systems here are time-dependent and can not wait on stand by, the products must move through continuously. The specific sequences in the system are invariant and the process allows only one way to
reach the production goal. It is important to stress that a system is not either complex or linear, nor that it is either loosely or tightly coupled. Every system holds subsystems with characteristics of both loosely and tightly coupled subsystems and complex and linear interaction.

Perrow has many interesting views on how interaction and coupling affects the safety in systems like the LNG-production. One drawback with the theory is that his arguments are too static. STS scholars (Snook, 2000, LaPorte & Consolini, 1991) have pointed out that Perrow's view is similar to a technological deterministic one. He sees accidents as a causal effect of properties in the technological system and underestimates the influence of social and organizational factors. Perrow underplays the dynamic aspect of a system and the fact that organizations can change over time. LaPorte and Consolini (1991) have pointed out that many of the complex systems in today's society that according to Perrow's normal accident theory would have failed are actually working very reliable. Perrow has thus provided us with important conceptual tools for evaluating risk and vulnerability in complex systems. I will now go on to use Scott A. Snook’s more dynamic theory of practical drift to further analyse Perrow's concepts and see how uncoupling of subunits can affect safety.

3.2 Integrating the organisation

“The whole determines the parts as well as the parts determine the whole” (Folett in Homans, 1950:8)

In Snook’s book “Friendly Fire” (2000), he makes a thorough analysis of an incident in 1994, when two US Air Force fighter planes accidentally shot down two US Army helicopters over Northern Iraq. The air traffic and communication with aircrafts in the area was monitored by an Airborne Warning and Control System (AWACS), but this support system could not
prevent the shoot down. There was no technological malfunction to be found in the accident investigation and human errors could not explain how this tragedy could happen. Hence, the causes had to be located in the social and organizational construction of the military operation. Snook examined the subgroups in the US military and found that the formal procedures and rules had drifted to adapt to the local demands. Different missions and years of autonomous operations created great gaps between the units. They had created different orientations towards goals, time and interpersonal relationship. According to Snook, they failed partly because the integration process of subunits is an ongoing process, while rules, procedures and orders are static tools that do not work well with changing requirements.

In every dynamic and complex process there are integrated individuals, groups and organizational factors which can not only be considered one by one, but have to be considered in their relation to one another. Often when an organization is designed, the designer will try to make rules and regulations that can help to control this interaction and thereby help running the organization as safe as possible, but at the same time procedures, protocols etc. underdetermine the employees workspace and flexibility. These procedures are rarely able to cover all situations that may arise. Snook (2000) argues that situational demands over time may lead to a change in the operational environment of the organization, resulting in increasingly obsolete rules and procedures. In these situations, local practices within a subunit can lead to the development of practical action. Snook defines practical action as “behaviour that is locally efficient, acquired through practice, anchored in the logic of the task, and legitimised through unremarkable repetition” (2000: 182). Practical Action is the driving force behind the theory of practical drift, which Snook describes as a “slow steady uncoupling of practice from written procedure”. The ‘practical action’ is a process which happens inside the subunit, while the ‘practical drift’ happens between subunits. To
understand this theory I will use Snook’s matrix (2000: 186) to show how four different process levels can develop through time.

3.2.1 Theory of Practical Drift

![Figure 3: Snook, 2000, p. 186](image)

In the matrix in figure 1, Snook captures three dimensions: situational coupling, logics of action and time. The vertical axis represents two states that can describe the interdependence of the process; loosely or tightly coupled situation. As we can see these are the same concepts as Perrow uses in his analysis of normal accidents. However, there is a difference in how Snook and Perrow use the term coupling. Unlike Perrow, Snook focuses on the dynamic nature of coupling. The interdependence of units changes over time as the organization has to
handle different situations. A loosely coupled situation can be handled by a low number of subunits, they won’t need much interaction. In a tightly coupled situation, there will be need for tight coordination between many subunits. It is in the transition between a loosely- and tightly coupled situational context that practical drift could lead to serious consequences. Here the coordination effort between the coupled subunits suddenly gets obvious. The uncoupling that can happen between the local adaptation to procedure and the formal standards can in the transition between loose and tight coupling obstruct the different subunits in the communication, thereby creating a confusing and ambiguous situation, which may lead to a disaster like the one described by Snook. The horizontal axis “logics of action”, describes how people shift norms or scripts according to context. Snook argues that:

Organizational members shift back and forth between rule- and task- based logics of action depending on the context and these shifts have a predictable impact in the smooth functioning of the organization (2000: 188).

The third dimension in this matrix is the cyclic time dimension. This is presented as a circle of arrows in the middle of the diagram and suggests a circular motion between the four quadrants.

The quadrants in the matrix represent different states of the process, which are determined by the interaction of situational coupling and logic of action. Quadrant 1 is the system as designed on the drawing board. These are the rules and procedures prescribed by the designer. Usually these rules will be designed with a situation in mind that requires a high degree of coupling. Quadrant 2 is the organization when it works according to the rules designed in quadrant one. When people find out that the rules designed are not the most efficient in the most usual loosely coupled situation they move to quadrant 3, where rule based actions change to task- based logics of action. People in the organization first feel obligated to follow the rules about the general operation and the interaction between subunits but as they become familiar with the operational context and they only experience loosely
coupled situations, the designed rules may seem like an over-controlling and unreasonable burden. Most organizations and industries experience constraints in time and resources, and in many cases rules can make the task at hand irresolvable. Snook argues that, “when the rules don’t match, pragmatic individuals adjust their behaviour accordingly; they act in ways that better align with their perception of current demands” (pp.193).

Snook uses these concepts to describe why the U.S Air force accidentally shot down two U.S Army Black Hawk Helicopters in Iraq. He focuses on the uncoupling between various organizational subunits through the emergence of local routines and standards for good work and interaction during operation. I am looking at a design and technological development of a system that is not operational yet. I will therefore draw the theory a bit further and describe how uncoupling between organizations, artefacts in control rooms and practical action in the design phase can make the design vulnerable.

If you plan for an artefact, a process or a working practise you should try to foresee the most challenging situation this design-component can possible handle and all the other components the unit possible can interact with (Snook, 2000: 190). In IFE’s design people would guess that the designers planned for the LSD to be tightly coupled with the rest of the CCR equipment and the processes in the plant, and that the designers planned for certain logical rules and procedures in how to use the LSD. We can see in the matrix that the “design state is defined by a rule-based logic of action and a tightly coupled situation” (Snook 2000:190). This is not the case with IFE’s LSD design. In their design the team has made a decision not to consider regulations, safety or working procedures. This means that it is hard to predict what is going to happen when the LSD is coupled with the rest of LNG production system where the rest of the subunits probably have been designed with these issues in mind.
3.3 Applying drift to the design process

In order to apply Snook’s theory of practical drift to IFE’s LSD design team, we need to see under which conditions this drift can develop. Snook is talking about uncoupling between organization subunits during operation, while I will describe a system which is not in operation yet. I will therefore draw Snook’s theory of practical drift further and describe why and how the IFE Halden organization uncoupled safety in the design process. The theory of practical drift is based on deviation of some global rules, so I will start by explaining the regulations in the Norwegian oil-industry.

3.3.1 Regulations

The development of oil-business in Norway started in the 1960’s. The government who has the prime ownership of the natural resources in Norway soon recognized that for the sake of the citizens, environment and future generations, the state should play an active role in the development of laws, practise and contracting for the exploitation of these resources. The Norwegian state has the legitimate authority to grant concessions to the oil companies. The concessions given do not mean that the companies are free to do what they want. The licenses come with conditions, and to make sure that these conditions are met they have to keep long distance control through a set of rules and regulations. These regulations are functional in the way that they only set a goal and leave the specifics on how to achieve them to the contractor. The Norwegian Petroleum Act is the largest set of laws; these are made by the government and parliament (Wackers, 2006). A relevant example is the regulation relating to design and outfitting of facilities in the petroleum activities, which in section § 20 about Man-Machine interface and information presentation says;

Screen based equipment and other technical equipment for monitoring, controlling and running machinery, plants or production processes, shall be designed in such way
that the danger of mistakes that may be significant to safety is reduced. [...] The information presented shall be correct and easily understandable. In the event of incidents, deviation or failures in systems of significance of safety, alarms that stand out clearly from other information shall be given. The alarms shall be given in such a way that they can be perceived and acted on in the period of time required for safe operation of equipment, plants and processes\textsuperscript{19}.

As we can see, the regulations from the state only set goals for the different concessions holders in the oil field. Most companies use industrial standards like the NORSOK- standard and the ISO- standard to set the details for how theses regulations can be achieved technically. These standards help representing the industry’s collective experience and make standards for best practise (Wackers, 2006).

There are different state institutions that control the different rules and regulations. The Petroleum Safety Authority monitors the oil companies so that they follow the rules and regulations. They have also developed some more specific regulations and revision methods to meet some criteria in construction; these are usually based on Human Factor principles. The Research Council, that first financed IFE’s simulator- based man-machine research for the oil industry, wanted IFE to do Human Factor studies and they wanted them to use standards and regulations (Forskningsrådet). As we have seen, IFE has drifted from both of these approaches, we will now look at what kind of factors made the IFE team deviate from the external demands.

\subsection*{3.3.2 Drift at IFE}

When the research council gave IFE the project of developing an experimental operation centre for the oil industry, it was based on IFE’s knowledge in complex and tightly coupled

\textsuperscript{19} Petroleum Safety Authority Norway (PSAN), Norwegian Pollution Control Authority (SFT) and Norwegian Social and Health Directorate (NSHD). 03.09.2001. http://www.ptil.no/regelverk/r2002/frame_e.htm
procedures in the nuclear industry. The project was supposed to use their knowledge in Human Factors to make experiments with control room screens on demand from the petroleum industry, these expectations together with the expectations from PSAN to follow standards and regulations is representing quadrant 1 in Snook’s matrix. Quadrate 2 in the matrix is represented by the period in which IFE got the concession for the project and started to apply the formal demands. In this period, however, there were some organizational problems in the sector where the engineers and physiologist worked with Human Factors at IFE. This lead to severe problems of cooperation for the two disciplines, and finally they split into two different sectors. Based on assumptions by one in the LSD design team\(^\text{20}\), this multidisciplinary problem together with the lack of demand for Human Factor experiments from the petroleum industry can have resulted in a change of course in the project. The situation is starting to change because the formal demands do not fit the situational demands, and this situation represents the move towards quadrate 3. What occurred at IFE was a steady uncoupling of local practice and the formal demands. The team, now consisting of engineers only, decided to make a completely new design for the screens based on graphical design principles instead of Human Factor principles and they made it a goal to make a more innovative design, thereby excluding the PSAN- standards.

To help designers that make devices to increase safety in the oil/gas business PSAN has created standards and regulations to reduce designer’s errors. These regulations remind the designers to foresee the challenging situations and to make proper risk analysis. In the LSD design these standards and regulations were deliberately not followed because they felt that these were too strict in the framework and inhibiting creative ideas. To use Snook’s concepts one can see these regulations and the Human Factor approach as the rule based

\(^{20}\) Meeting, Braseth, A. O. 01.07.06
logics and the Snøhvit-design team’s graphical design and common sense as the task-based logic.

Figure 4. IFE's design process applied to Snook’s matrix.

When we use Snook’s matrix, we can see that most of the process I have witnessed is in quadrant 3. Quadrant 1 is represented by the global regulations, standards and use of human factor principles required in the project description from the research council and Statoil. I can not predict the shift from quadrant 3 to quadrant 4 when the situation changes from loosely coupled to tightly coupled. I can however mention one context where a critical situation may originate; when the LSD is implemented to the whole system at Snøhvit, and all the components will be put together to a system in operation. This situation will probably uncover if any sub processes are uncoupled from the system as whole.
There are many factors that influence organizations to drift from formal demands. Some of my interviewees²¹ claimed that “the standards and regulations in screen design are so old and tight that they will never lead to any new and innovative results”. Constant demand of local efficiency can dictate the path of the drift. Institutions like IFE need economic results and want new technologies to be invented. Over time, the drift can become institutionally accepted, and is implicitly reinforced. The shift from quadrant 2 to 3 is affected by external demands such as interests from the industry. Social factors have also contributed, e.g. how the team’s desire to make an innovative design and the conflict in the MTO- department where the design team got separated form the other Human Factors researchers. As long as the situation does not require a high degree of integration between subunits, drift from the originally formal demand can continue to creep along unnoticed and unchecked. When no accidents happen leading the design to be checked upon, it will be harder to demonstrate the benefits of standardizations over the more dynamic local adaptation. After some time there will be a total uncoupling between the formal regulated demand and the finished result.

Formal and informal structures are often driven by the competing logics of efficiency and sentiments, and this may result in contrary goals (Snook 2000: 196). The management at IFE knows that the LSD designers have developed a practical action, and drifted away from the method of Human Factors they originally wanted. Their concern is that it is selling and they are proud to have such projects as the acknowledged Snøhvit project. The practical action is institutionally accepted.

‘Practical drift’ and ‘practical action’ have much in common with what Vaughan calls ‘normalization of deviance’. In her ethnographical work on why NASA made the fateful decision to launch the Challenger, she describes how engineers and managers collectively struggle to define acceptable risk by making the deviances from standards centrally

²¹ Interview: Veland, Ø. 03. 05. 06, Braseth, A. O. 12.07.06, Kristiansen, P. 12.05. 06.
acceptable (Vaughan, 1996). The IFE design team did not normalize the deviance between what was expected from the research council and their organization, they just collectively agreed that the method they was supposed to use did not fit their wish of making something more innovative. Both Snook and Vaughan describes “practical drift” and ‘normalization of deviance, as a more subtle process.

The local adaptation to procedures can be very efficient in loosely coupled situations, where the different subunits do not interact, but the LNG-system where the LSD is going to be integrated is unlikely to remain loosely forever. In a critical situation at the control room the operators have to be totally sure that all the support devices are working properly. There is no redundancy system to back the LSD up in case of malfunction. The designers and Statoil claim that the LSD is not safety critical because it is not where one operates, but if this screen is helping in all those areas described in chapter two, the operators may have integrated the monitor to their working procedure, and since it dominates 16 meters of the room one can easily imagine that it will have some effect on the safety if it turned black or showed wrong data. In a circumstance like this one can see where the local adaptation passes over to quadrant 4 in Snook’s matrix; failed. These failures are what Perrow would have called “normal” not only because it was the property of the system, but also because it is what Snook calls “normal people behaving in normal ways in normal organizations” (Snook, 2000:202).

The drift at IFE is based on their reluctance to use strict scientific human factor methods and innovation restrictive standards and regulations, but another condition that also increases the likelihood of practical drift is the tendency to over-design and over-control. When we face lack of control in hazardous systems we tend to try controlling some more by making more severe rules. Even though these are well intended efforts, it may occasionally produce just the opposite effect. What is the solution if more rules and tighter control do not increase safety? I believe people have to forget the urge to eliminate all the vulnerabilities, to
aim that high is unrealistic and probably counterproductive. Rasmussen (1994 & 1997) argues that one should try to control some of the local adaptation instead by identifying safe performance by analysing work procedures, I will describe how IFE has considered working procedures in a later section. Efforts for improvement must be focused on the control of performance in interaction with the safety system. As we will see in the next sections designers of system units can not overestimate the importance of communication between actors working within the development of technology and the actors using the technology. In this section I have described how the practical action at IFE has drifted from the rule based standards in the industry in order to make a new design. New projects should be valued even though they deviate from formal procedures and standards, on the condition that all actors are informed and that the other actors contribute in making adaptations to fit the new innovative artefact. In every system the designer should make sure that interacting components fit in both loosely and tightly coupled situations. Finally by choosing not to use industrial standards they also drifted from actors making other components which are supposed to interact with the LSD.

### 3.4 Actors in the development of an LNG- production

Practical drift shapes and is shaped by factors that cut across all traditional levels of analysis such as individual, group, organizational and environmental factors. If you study one single of these factors you may miss the drift. “Practical drift is a holistic mechanism that only makes sense when travelling across traditional analytic boundaries” (Snook, 2000:223). There are several factors contributing to practical drift in a design process. At IFE we can see that when they started their design they drifted away from the Human Factor perspective originally wanted from the research council, they drifted away from the human factor
revision-method wanted by the PSAN, and when all the members told me that they had not considered safety- or vulnerability factors in the design, they drifted from the Oil Department and PSAN whose goals are zero-tolerance in safety issues.

Complex collective tasks, such as making a LSD that is going to monitor the whole process of extracting gas from the reservoir at the ocean bottom, to the loading of the finished product at ships, requires high degrees of both differentiation and integration of relevant actors. They have to differentiate it to make it surveyable and manageable, and integrate it to make the system complete. Snook says: “Whatever you divide, you have to put back together again; the more divided, the more effort required to rejoin” (2000:143). He is mainly talking about one organization divided into subunits. I want to use his theory to discuss how Statoil and its subcontractors can unify the development of an artefact and a complex system in the design process; first the making of the LSD has to be considered as a separate process done by IFE. Secondly, the LSD as a system component has to be integrated to the enormous and complex LNG process where also other actors have participated with their components. To implement all the right functions to the LNG-process, there has to be cooperation between completely different organizations who have contributed with their special expertise to make their specific product completely realized in the system.

3.4.1 The actors in the development of the LSD

When a new product or design makes its way to the market there are many actors involved in the process. The relevant actors have to come to agreement as there is diversity of interests between the actors. In the process of designing the Snøhvit LSD, the most prominent actors are: a) Statoil, the principal for the Snøhvit development project and the proprietor of the LSD, b) Linde, the designers of the LNG production process and the plant itself, c) IFE, the designers of the LSD, and d) ABB, who is implementing the LSD design to the 16 meter long
screen and with the system. In order to make this control room support device work at its best, and to increase the safety by making the screen integrated to the gas production process, it is necessary that all the actors cooperate and contribute in the design process. At least, this is the ideal development in a design process. Because there are different actors working at different levels of the process, there is a good chance that some of the processes are uncoupled in their interaction. IFE got into the Snøhvit project in 2005. At this stage of the process, most of the decisions were already made and the designers of the LNG process, Linde, were mostly done with their job. Even so, IFE experienced problems in receiving all the relevant information they needed about the key processes in the LNG production. Linde, who had delivered what they had been paid to do, had at that time transferred their resources and people to other projects. This is an indicator on how difficult it can for many subcontractors to contribute in making something that another company has the contract to do. It is not hard to understand that it is bad for business to spend a lot of time and resources in a project you do not get paid for. The same goes for the cooperation between IFE and ABB. IFE has to make sure that they give all information ABB requires if the design is going to be implemented the way it is designed to be. I am left with the impression that this cooperation has worked to a higher degree than the one between IFE and Linde. IFE went to a Factory Acceptance Test in June to see how the design was implemented to a test screen, and the team seamed very pleased with the result. In order to increase communication and cooperation between the subcontractors Statoil should make it part of the contract to put the companies under obligation to deliver all the relevant information to relevant subcontractors. Statoil, the LNG system operator should want to make sure that all the subunits in their process are integrated to each other, and that they are coupled together in the process. The uncoupling between actors leads to uncoupling in the process, which in turn is decreasing safety on the plant. The operator should especially make sure that the control room devices are coupled to the process they are supposed to
monitor. If people are going to trust the technology in safety-critical situations, it is crucial that the technological devices are monitoring what they are supposed to monitor.

3.4.2 Uncoupling Actors

Cooperation and communication is important if different actors in a development process are going to succeed with their product. A typical example of bad communication is when the customers are unable to communicate their requirements for the new product, and the developers have the same problem in communicating how the product they are designing will end up. The risk will be that the product won’t get used the way it is intended to, which is a fundamental risk to the safety of that product. If nothing else is told, the designer will inscribe their ideas and assumptions about the potential use and users into the artefact (Rosness, 2003).

In Rossnes’ (2003) evaluation of the railway accident at Åsta in Norway [2000], he writes about uncoupled decision making. Here the decision process contributed to a vulnerable state at the railway line. He argues that this was not due to bad procedures in decision making, but an adaptation to conflicting demands from the environment. He uses the ‘drift’ concept to describe how complex organisations may drift into a vulnerable state when facing conflicting demands. In complex systems there may be several activities taking place parallel. The different actors may have incomplete or inaccurate knowledge about the state of the system and its activities. There are also chances that the parallel activities can interact in unforeseen manners. This can lead to a vulnerable state where the actions of one actor may interfere with the boundary of safe performance for another actor. The risk when different actors do not share all their information is that all the actors will strive for local optimization, based on their incomplete knowledge about the system (Rossnes, 2003). The importance of thinking about components or subprocesses in its totality can not be overestimated. When subcontractors are used, it is the operator’s responsibility to make sure that the subcontractors
are explicit about their aims and methods during the whole design, and that these are in accordance with the rest of the contractors and the system in its entirety.

Industries develop standards for what kind of measures, materials, symbols etc. they should use in order to make the coordination between different contractors easier. The different actors in the industry follow and rely on these standards, the engineer responsible for one artefact will have to rely on the standards in his own artefact and that the artefacts that are interacting with it are following the same standards. In making and using standards it will be easier for the different actors in the industry to cooperate without using a lot of resources in making decisions on small details. We can see that the drift the LSD design team made from using standards may have larger consequences than first recognized; it may also affect the actors who firmly believe that all their collaborating organizations are following the formal design procedures. On the other hand, these standards are not necessary optimal and should not restrict designers from doing innovative solutions in order to fit the standards. If the designers are explicit about their artefact and cooperate with all the relevant actors they can still make new solutions where the artefact is coupled with all the related components in the system.

3.5 Lack of working procedures

In the design of the Snøhvit LSD designers had very limited operation knowledge to draw on. First of all the designers are theoretical planners who have never worked in a control room. They tried to draw some information from the operators who normally are the experts, but in this case none of the operators had ever worked in a similar control room. That was the second problem; this control room is the first to be onshore in Norway. And further this plant is the first with an LNG process in Norway. Some experience was sought in the rest of the world where LNG plants and onshore control rooms have been running for a longer period.
The difficulty with drawing knowledge from these plants are that the climate and ground conditions are totally different in the Barents sea where Snøhvit is, and most importantly none of these plants have a LSD. This control room support equipment is such a new trend in the petroleum industry that it is rare in all kinds of oil or gas processes. Not only did IFE lack any concrete experience with this kind of plant and control room, they also had to do the design before the plant was ready, unable to draw any information from the field. As a result of the lack of information the design team did not write any concrete and explicit procedures for the working process with the LSD. Some working practises are implicitly designed into the LSD; they have made the colours and signs easy to focus on over a longer time period, so that in normal situations the operators can mainly focus on the LSD. The screen is made static so that the operator knows exactly where to find the image and information he or she needs. And the units on the screen are situated according to the gas process and the operator responsible for that area is placed in front of it. As we can see these are all Human Factors characteristics which aim to decrease the operators cognitive processing, they are not working procedures. What IFE hopes for is that the operator’s performance will adapt to the LSD and optimize over time. This process looks very similar to Snook’s description of practical action, and as we can see from his case this is not a working procedure that can be recommended. Most work situations are normal and it is easy to build a routine and procedure where deviances are absent and there are only the regular couplings between the system components. To make the CCR run optimal and the LNG show to advantage one should make work procedures that makes sure that every coupling and system unit are taken into consideration and that all the information are correctly understood.

When IFE started to design the LSD, the people delegated to be in the design team made some explicit purposes for their design. They wanted the key-hole effect reduced by giving the operators a monitor that present the whole LNG-process. They wanted to enhance
communication between operators which also gives more information on the entirety of the process and helps in decision making. The alarms are only presented as group alarms to decrease the overload of information. However, the problem is that the operators working in the Snøhvit CCR are experienced workers with well established work procedures which do not include the LSD. Usually people are very reluctant to create new working procedures especially if they have to figure out how to use a new technology themselves. If there are no pressure from colleagues or management and no reinforcement to use the LSD, there is a chance that the LSD will not affect the operators to any great extent. But if the LSD come with procedures that integrates the procedures the operators are familiar with it might be easier to teach them the correct way to interact with the LSD. If the LSD does not get used, it is just an unnecessary artefact, but if it in some way affects the action in the CCR in an erroneous way, it may cause a vulnerable situation.

In control rooms there may be a culture where pride in their own responsibility sometimes prohibits the operators to ask for help in decision making and reading data. If the operators have an overview of the whole process, it can be easier for the operators to detect errors in other operator’s responsibility area, which in turn can decrease human error.

### 3.5.1 Inconsistency between the Visual Display Unit and the Large Screen Display

One major reason to make working procedures is the fact that the information the operator are going to rely on in order to run the plant safely is presented at two displays with different interfaces and different functions. The LSD at Snøhvit is supposed to show the majority of the key-processes at the plant, it is made to support the VDU in giving operators information about the plant status. It is not supposed to be used in crisis situations because it can not be operated on directly. One of the LSD’s main functions is to monitor the system in order to
detect abnormalities or errors in the process, to fix the problem the operator is supposed to go over to use the VDU. This means that the operators have to go from one screen with its interface and symbols and over to a different screen where he or she has to find the right picture and see the problem or the projected data on a completely different interface. This inconsistency between the two screens does not fit with either Human Factors or common sense.

Some of the designers also expressed concerns about the inconsistency between the different screens. The designers claim to have uncoupled the two different CCR monitors in order to complete the operator’s information needs, but one can only imagine what the consequences might be if this uncoupling confuses the operators enough to make them make a wrong decision. According to Kletz (2001), our aim should always be safety by design, but often we do not have any reasonable practicable or economic way of improving the design, and we have to rely on improvement elsewhere. This is one of the problems with the petroleum control rooms. IFE believes the best solution to the inconsistency is to make a new design for the VDU. The problem is that it would be very work- and cost-demanding to get the process automation suppliers to dispose new solutions. Because it is difficult to make a new design for the VDU, they have to make up for the deficiency by supplementing it with the LSD. The inconsistencies between the two monitors are also inconsistent with the purpose of the LSD. This monitor was created in order to decrease the operator’s workload and making it easier to detect deviations, but instead the LSD deviate from the screens the operators have long tradition working with, and it may increase their workload by making them lean on two different information sets.
3.5.2 Procedures in complex systems

In the airport-, army- and nuclear industry it is normal that the operators have thick manuals on how to handle equipment and manage different situations. In making these manuals the designer really has to picture the worst case scenarios. My interviewees\textsuperscript{22} claimed that the petroleum industry is much more flexible than these industries and operators have experienced that in some cases\textsuperscript{23} it is better not to follow the procedures in order to increase safety. Snook (2000) claims that if you have a lot of burdensome rules there is a greater risk that you will make local adaptation to the rules in normal situations, and because of this it is easier to make mistakes during critical moments.

In Law’s (2003) analysis on failing systems he argues that a procedure intended to increase safety can lead to catastrophe (p.13). This is a recognized phenomenon in the safety literature (Perrow, 1999, Rasmussen, 1994, 1997). One can discuss whether this lack of procedure is improving safety or if it may lead to a local action that actually makes the LSD screen decrease the safety in the CCR. In a way one can argue that without any formal procedures, one avoids local adaptations. On the other hand, if you do not have any working procedures to follow then the only thing you do have is local adaptation. I can agree that strict rules may give negative consequences, but a new monitor screen that dominates 16 meters of the control room, I claim needs some working procedures in order to deserve such a prominent position. IFE should not expect an intuitive understanding of how to position to the images represented at the LSD.

The main function of the control room is to run the LNG production safely, so in order to assure safety it is crucial that the operators understand the data representing the production. If the operators are to interact with a new artefact and interface I believe they would like to

\textsuperscript{22} See Appendix

\textsuperscript{23} See Wackers, G and Coeckelbergh, M (Forthcoming). Imaginability, Distributed Responsibility and Vulnerability: Imaginative Coping with Technological Systems- The case of Snorre A.
know how. The working practise can be the link between operator and artefact which tells them how to relate. The fact that the operators only deal with representations of a system, means that the working practise is the translation of symbols into meaning. Safety is in many cases today connected with technological instrumental monitoring. We do no longer trust humans, after all, we have for several years now been indoctrinated with the fact that 80 % of all disasters are caused by human errors (Rasmussen, 1997, 1994, Vincente, 2003, Reason, 1997). To check plant status we trust that sensors in different areas of the plant give an alarm to tell the operators if something is wrong in a certain area. When the operator has localized the area, they have different procedures in how to tackle the problem. If a petroleum control room operator sees changes in the pressure in the tube leading oil to a platform, this can typically be due to the forming of hydrates in the tube, blocking the oil from floating through. To fix this problem the operator has to make a decision to push some buttons in order to insert some methanol, increase the temperature or decrease the pressure, so that the hydrate gets dissolved. The point is that in order to fix the problem, the operator has to see a deviance on the monitor, give it a meaning and make a decision on how to interact with the technology; for any of the screens in the CCR to have any meaning the designer has to couple them to the operator. The screens are just a representation of a system that exists many miles away from the CCR. If the data represented at the screen has an interface based on graphic trends, or just numbers that gives information on e.g. pressure, is irrelevant if nobody knows how to translate the data into a comprehensive meaning possible to act upon. On the other side, if the operators did not have any form of collective data representing the system, it would be hard to have an overview on the plant at all. A technological system has inputs and outputs. These can often be seen as two sides of the same coin. Systems consist of subsystems that are linked by internal inputs and outputs, or what engineers call interface (Hughes, 1987). My point is that in order to maintain control of the plant status and the safety operators are totally
dependent on working procedures that can help them handle the technology they are supposed to monitor and operate on. The outputs from the operators are related to the input, if the input is understood wrong then this would negatively affect the output. In this CCR where two monitors are giving input in different ways it is necessary that the operators knows how to relate to the different displays, especially if there should be deviances in the data. When dealing with a critical situation operators can not take the time to make procedures for how to handle it. Instead off hoping that the operators will develop a practical action which may be incorrect in tightly coupled situations, designers should make the working procedures flexible so that the operators relate differently to the LSD in loosely and tightly coupled situations.

Rasmussen (1994) talks about human- system interaction and the problem of adapting them to normal successful conditions, He argues that the fundamental design problem is to accept adaptation that is too tight to fit during normal conditions and that is flexible enough to widen the tolerance band when required.

What I have tried to show in chapter three is that when an organization deviates from the formal standards in the development of a system unit, this does not necessary affect that specific unit or the organization in question. When making a system unit one are making a part of a holistic entity, thereby affecting the system as a unit. When developing a system one can not only consider the factors one by one, but also their relation to one another. To show this, I have used Snook’s theory of practical drift to show how different subunits can hurt the system in its entirety if the interaction between them is uncoupled. However, Snook’s theory also seems to assume that things would be less risky if standards and regulations are followed. Clearly, standards and regulations are not always the best answers; they are made to be unequivocal and are thereby too static to be applied in all situations (Lundestad, 2003). If formal standards were to be followed without question there would hardly be any innovation or development of new solutions at all. Snook’s theory holds an underlying assumption that
practical drift is something negative, but as we have seen in the development of the LSD, task-based actions may lead to new designs and new technologies. Apparently there are some safety decreasing aspects by deviating from regulations specially made to assure safety, however these can be worth the risk if it in the end appears that this design increases safety by giving the operators an overall view of the LNG production.
4. 0 Conclusion

4.1 Summary

In order to gain understanding of the issues related to the research question: How the design process uncoupled the LSD from the liquefied natural gas production system, and how this affects the safety in the system? I began this investigation by presenting how the large screen display designed and manufactured for the central control room at Snøhvit petroleum field was developed. IFE’s LSD is a new control room monitor display which is designed to supplement the visual display units which originally was the only information display in the CCR. The design team’s goal was to make a display that could show the LNG production as a whole system because the VDUs only show images of small parts of the system on each screen. The research council started to fund IFEs research in interface design for the petroleum business in 1997. This was based on the assumption that IFE would use Human Factors approach to do experiments in bilateral projects for the oil industry. After the IFE team realized that the oil business would not invest in these projects they separated from the research council’s approach and started designing the LSD based on an approach which did not consider Human Factors, state regulations, industrial standards or safety. In 2006 when the LSD design team was finished designing the LSD for Statoil’s new and grand project “Snøhvit”, the team members called the design a “paradigm shift” because of the innovative design they had made.

For the analysis of the design process and how it affects safety at the Snøhvit plant, I set out to investigate whether Perrow’s normal accident theory could be applied to this mean of research. His concepts of complexity and coupling were found to be directly relevant to the LNG systems and important tools in describing and analysing the LSDs interaction with the whole system. However, scholars within the field of high reliability theory are convinced that
Perrow’s theory is too static, and argue that one has to imply social and organizational factors when analysing safety. Acknowledging the importunate notion of accidents in complex systems I went on to the analysis of Snook who expand Perrow’s concepts in his theory of *practical drift* where he formulates the concept *practical action*: a locally efficient reaction to formal demands, procedures, standards and/ or regulations seen as redundant in normal situations. This adaptation means that the subunit within an organization or system may drift from the common set of standards and procedures governing operations where interaction with other subunits may occur. I use Snook’s theory of ‘drift’ and his concept ‘uncoupling’ to describe how the LNG system is vulnerable based on two notions: One, because IFE wanted a new and innovative design for the LSD they did not follow regulations, Human Factors or standards, in this way they drifted from the formal requirements from the research council, Statoil and PSAN. Two, the drift from these requirements may have entailed a drift from the LNG system and its components because interaction between the sub- system- contractors often relies on the assumption that other contractors have followed these formal demands. I have tried to open the Black box of the LSD to see what factors have affected the uncoupling between actors, components and procedures, I will describe these in the review of my analysis.

### 4.2 Coupling the analysis

By employing the interdisciplinary theories of STS in this analysis I have seen how the technology has been shaped by social factors. By examining the designers’ understanding of system and technology and their perceptions of the risks involved, I have been able to gain insights in the ways IFE’s practical action has uncoupled the LSD from the system. I believe one of the reasons for this uncoupling is that IFE and Statoil view the LSD as non safety-critical. I believe this view in turn makes the LSD decrease the safety in the CCR because it
undermines the affect a control room component can have in the CCR interface and as a part of the system. Giving a component this status means giving the designers the freedom to perform practical action.

Statoil has to use a lot of subcontractors in their building of a LNG production plant. The system is divided into subtasks which companies with special expertise are engaged to solve. In these companies there are different actors and different situational demands which contribute to form the result of the subtask. This means that in most companies there is some deviation between the project goals set by the operator of the system, and the subcontractor’s actual result. In complex systems which consist of many components made by different subcontractors these deviances can affect each other in completely unexpected manners when they interact. Because these components do not necessary interact in normal situations, these deviances from the system designers goal may work for long periods without being discovered.

The LSD team’s drift from industry standards and the oil industry’s recognized method of human factor to the locally adapted design method is not necessary a safety critical action. People working with rules and regulations often hold the conviction that compliance with regulation makes the operation at an oil/gas plant more reliable, but rules are static and not suited in every situation. In a dynamic industry like the oil/gas industry, the technology is always changing leading to new organization- structure and work practise. If regulations are so tight and strict that they inhibit innovative solutions it may be better to choose the new solution. I emphasise that this has to be done in an explicit manner where all the relevant actors are able to share contributions and departures. Communication and cooperation is essential if the components made by different subcontractors are going to interact correctly.

Thomas Hughes includes humans as components in his definition of technological systems, and because all components can affect the system it is important that the component
acts in a predictable way. In order to influence human action the system designers and the
designers of the interactive components should make working procedures to reduce the
possibility of uncertainty in decision making. Because neither people nor situations are static
it is important to make the procedures flexible and adaptive within the boundaries of safe
actions. In this case where the designers of the LSD did not make any working procedures
there is a risk that the local adaptation to the monitor can lead to vulnerable situations where
ambiguous information may lead to confusion about the plant status. This is especially
relevant in this case where the operators have to coordinate information represented at two
different information displays; there may raise situations where it can be a question of what
information they are going to trust. Such an ambiguous situation can not be afforded in a
control room where every process at the plant is monitored for errors which have to trigger
quick decision making.

4.3 Implications

Safety is not an attribute of the LSD component; it has to be considered together with the rest
of the components of the LNG production system. What I want to suggest is that some new
requirements should be made for the designers in order to improve system safety at petroleum
plants.

PSAN who to controls that oil companies follow regulations and insure safety should
probably revise regulations to allow for innovation. A high-tech industry like the petroleum
industry where the market changes radically from day to day can not afford making rules and
regulations that inhibit the development of new technology. Technology is in constant
development and there is always strive for more automation and efficiency. With such new
technologies there will follow new vulnerabilities, but we will never be and have never been
in a state of complete invulnerability. We can not and should not fight technological
innovation in the name of safety. In this thesis I have discussed the implication for safety by designing a large screen display for the control room at the “Snøhvit“ petroleum field. As we have seen the study of the design process has revealed that the LSD as a subcomponent at some points has been uncoupled from the LNG production system as an entirety. Snook’s theory on practical drift has been important in this analysis since it identifies the concepts of practical action and the drift away from established rules that it can entail. As we have seen these concepts which originate from an organizational approach can fruitfully be applied to technological systems where system- units interact.

The aim for this study was not only to show how this uncoupling happened in the design of a LSD, but to illustrate how easy it is for a system or an organization to uncouple some of its subunits. Usually a system can work for a long period without anyone noticing that some of the subunits do not interact. This can happen because normal situations do not necessary require as tightly coupled units as a critical situation. What is special with this case is that the LSD’s function is supposed to monitor deviances in the LNG production for safety reasons. If the LSD is not coupled to an error process this won’t be noticed, and the fault may continue to influence other related processes. Because most systems and industries can not afford accidents to happen I would suggest that responsibility for these kinds of system errors be taken by two actors. First, the designer of the subunit, in this case that would be IFE. This subcontractor has the responsibility to follow the project description given by the operator/proprietor. However, as I just described there may be difficulties in following such formal manuals. I will therefore suggest that interaction can not be totally dependent on regulations or standards for the interaction between subunits to work. New ideas that conflict with rule based action should be supported because it could lead to an innovation. But then it is important that this happens with clarity, so that the operator or eventual other related
subcontractors know if there are any subunits which in the most tightly coupled situation would not fit the design.

Secondly, it is the operator’s responsibility to make sure that all subcontractors cooperate and communicate. Ultimately it is their system that will fail if subunits do not interact. It is also their responsibility to make sure that the subcontractors get enough resources to go through with the cooperation with the other relevant subcontractors. Different subcontractors have different assignments and hold different parts of the system or process, the main operators have to make sure that the parts are coherent when put together.

Most of the research on drift has focused on accidents and disasters, usually of the devastating kind, such as nuclear accidents and friendly fire incidents. Another approach is to study organizations or systems in the primary process and see how the members experience the task based versus the rule based action. The LSD design process has only been studied to the point where the design is done, ABB has implemented the design to the screen, but the screen has never been used by the operators. If this was a more extensive study it would be interesting to study how the LSD will work when it is implemented and in operation at the Snøhvit control room, to see the potential effect the LSD has on the system. How the operators relate to it, their impression and if they will notice the uncoupling I have discussed in this thesis. In the use of Snook’s theory I have described the process of practical drift up to the level in quadrate four, where he describes the failure that occurs as a result of interaction between subunits that have drifted from the rule based procedures. This level of the practical drift theory is not applicable in my case, first of all the interaction between subunits in the LNG production have not occurred yet, and secondly it is not certain that any failures based on the uncoupling of the LSD will ever occur. When seeing how easy it is to uncouple elements in a technological system, one can assume that it is quite normal, but still there are not that many accidents in these systems due to such uncoupling.
Theories from the STS field, with their emphasis on studying both social and technical factors, should prove invaluable in gaining understanding of how we can build technological systems and its components in a way that takes uncoupling, practical drift and safety into account. With new awareness system designers at every level can use their skills and innovative ideas to improve a system as long as they put enough emphasise on cooperation, communication and clarity to interacting contractors and users.
### Appendix A: List of interviewees

**IFE- Snøhvit Large Screen Display designers**

<table>
<thead>
<tr>
<th>Name</th>
<th>Profession</th>
<th>Date of interview</th>
</tr>
</thead>
<tbody>
<tr>
<td>Øystein Veland</td>
<td><strong>Project Leader</strong> Engineer Cybernetics</td>
<td>03. 05- 06</td>
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<tr>
<td>Alf Ove Braseth</td>
<td>Engineer</td>
<td>12. 07- 06</td>
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<td>and meetings:</td>
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<td>01.07- 06</td>
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<td></td>
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<td>14. 07- 06</td>
</tr>
<tr>
<td>Unni Weyer</td>
<td>Engineer science and mathematics, computer</td>
<td>10. 05- 06</td>
</tr>
<tr>
<td>Lars Åge Seim</td>
<td>Technical Engineer</td>
<td>11. 05- 06</td>
</tr>
<tr>
<td>Per Kristiansen</td>
<td>Computer Engineer</td>
<td>12. 05- 06</td>
</tr>
<tr>
<td>Malvin Eikås</td>
<td>Engineer Cybernetics</td>
<td>10. 05- 06</td>
</tr>
</tbody>
</table>

**Statoil:** Mail exchange with Knut Vinje Galaasen, Senior Engineer Automation. Snøhvit Operation.
List of figures

- Figure 1. Control room with large screen display, Melkøya and the Snøhvit field.
  Illustration by IFE p. 12

- Figure 2. Visual display Unit information and Large Screen Display information.
  Illustration by IFE. p. 24

- Figure 3. Snook’s matrix of practical drift. Revised from Snook (2000:186) p. 35

- Figure 4. Practical drift at IFE. Revised from Snook (2000:186) p. 41
References:


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Norwegian Petroleum Directorate: http://www.ptil.no/NR/rdonlyres/03F68C8E-5095-4D46-BCEE-5DECBE8BCCBF/0/HFAM30min.pdf


ROS - Risiko- og sårbarhetsforskning; Helse, miljø og sikkerhet- definisjoner. Norsk


Statoil document. Large Screen Display Philosophy for CCR. Confidential document.


