Offshore Blow-out Accidents

- *An Analysis of Causes of Vulnerability Exposing Technological Systems to Accidents*

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Preface

This thesis is about understanding causes of vulnerabilities leading to specific type of accidents on offshore oil and gas installations. Blow-out accidents have disastrous potential and exemplify accidents in advanced technological systems. The thesis aims to reveal dysfunctional mechanisms occurring within high reliability systems whether in organization or socio –technical interaction. Technological systems form a central place in technological development and as such this thesis is placed in the technology and society group part of the STS- field, though describing technological risks and accidents at group, organizational and industrial sector level.
The contents are description on developments in offshore technological design, theories on how organisational vulnerabilities occur, empirical analysis on three major blow-out accidents, empirical analysis on one normal project for reference, sosio-technological historic description on development in Norwegian offshore industry and final analysis

Keywords
Blow-out, Offshore, Vulnerabilities, Accident causes, Technological development, Social construction of technology, Bravo – accident, West Vanguard, Snorre A, Ormen Lange

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The 14 interviewees I owe big thanks for the time they spent talking to me a novice in the offshore industry. I would also thank employees of Shell Well Services and Seadrill for the practical help I received around the interviews. I was met with a very positive attitude by all I asked to interview or explain tings
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DNV/research & innovation supported me with 8240 Nkr to cover travel expenses during the interviews. I could also use their facilities free.

Though I have received helpful advice during the project I am solely responsible for the content of this thesis

Content

1. Introduction

1.1 Blow out accidents - Dramatic Accidents in

"Sunday the 6 of October 1985 at 20 30 an uncontrolled blowout occurred on the semi-submersible drilling rig West Vanguard during exploration drilling on block 6407/6 on the Haltenbanken. A so called shallow gas blowout occurred during a routine drilling operation before sufficient progress was achieved to install a blowout safety valve.

The gas diverter system of the rig did not withstand the forces of the blowing gas with it's contained sand an solid particles and the gas flowed out onto the platform and were ignited. Explosion and fire caused grave damages. Of the 80 persons onboard 79 were saved. The material damage to the rig runs into hundred s of millions Norwegian Kroner. …

(NOU 16/86 West Vanguard report 1986:7-- authors translation)

Blow out accidents can be dramatic as illustrated above. These accidents are taking place on offshore oil& gas platforms, the technological systems, which should be of very high reliability. Accidents where ultra costly modern technology fails to perform safely and lives are lost or put at risk and damages run up in hundreds of millions, what is a actually causing them ?

1.2 Modern technology dysfunctions, accidents and vulnerability

Describing side effects of technology in our contemporary society from quite different approaches the authors Ulrich Beck (1992) and Charles Perrow (1999) both find common ground in unintended negative effects of modern technological development. In his book *Risk Society* (*Risikogesellschaft* in its original language) Ulrich Beck (1992) attributes the *general risks* to humanity as consequences of the development of modernity reflecting back at us, the humans and our human society. Beck describes the mechanisms and effects at the general level of society, but a central underlying notion is that technology develops into something so advanced and complex that humans and human society has problems understanding the consequences of development and controlling the effects of technology in society. In this thesis will not focus so much on this general level of society, but I will bring it back into the discussion in the final chapter.

Before we leave the theory of Ulrich Beck I will just point out that energy and energy in the form of oil and gas are at the core of development of modernity. Assuming its central position as one of a few technologies central to the development of modernity, oil and gas technology it is reasonable to expect it to should show some of the core attributes Ulrich Beck describes in his book *Risk Society*.

If we drop down in level of analysis and look at specific technologies and technological systems Charles Perrow also writes about negative side effects of technology. According to Perrow's book *Normal Accidents* (1999) all technologies has inherent weaknesses causing accidents. Accidents will then become a normal consequence of the choice to apply a given technology. All technologies are accident prone, the degree dependent on the two central dimensions Perrow calls *complexity* and *coupling*.

Perrow describes *complexity* is the opposite to *linearity* in the functions of a given system (ibid 77-78). When there are conditions of linearity the outcome effects of an abnormal incident/accident on the rest of the systems is foreseeable. In conditions of complexity we find the opposite, the outcome effects of an abnormal incident/accident on the rest of the systems is not fully foreseeable. Abnormal incident/accident s can cause surprising secondary effects for the operators or those who designed the system.

Coupling determines the possibility of recovering from a mistake or error. Loose coupling means that an incident/accident causing failure of a sub-system will be isolated to that sub-system and not spread to the rest of the system. Physical distance or internal boundaries will prevent ripple effects.
If coupling is tight an incident/accident in one sub-system, what Perrow calls *component failure accidents* (ibid:70), can not be contained and negative effects are determined to lead to lead to new *component failure accident(s)* in other sub-system(s) in proximity or in contact with the sub-system that initially failed. This will continue in one way or another through the system and lead to major systemic accidents. In open or de-coupled systems the elements are not so close in relation and the system will give the systems operators a possibility to contain the error without the error starting a chain effect running through or across the technological system.

With Perrow we now se a shift from general description of negative effects to description of negative effects specified to certain technologies and the technologies inherent system attributes. We can also se a shift from general negative effects of technology, to negative effects of technology in the form of accidents.

Is this technological determinant approach reasonable? Do system accidents come out as output of a linear function of dependent only on the chosen technology and its inherent technical and social structure? What about the quality of social - technical interaction? Do social actions within the organization manning the technological system cause differences? What about the effect of surroundings on a given technological system? Do we find effects in accident risk not determined solely by technological structure, but differences between the technological systems within a given technology?

Research objects and research question

I have selected the offshore oil and gas industry with its contained, compact and quite complex technological systems of offshore oil/gas drilling and production rigs/platforms as suitable examples of technological systems to study.

I will focus the thesis on blow-out accidents as a type of accidents that are both systemic in character and with potential to be catastrophic to the entire technological system and to a degree damaging to the surroundings.

The contexts of the accidents will form a central part of my analysis and I have limited my thesis to look at major blow-out accidents on the Norwegian Continental shelf (Norwegian sector) of the North Sea and Norwegian Sea

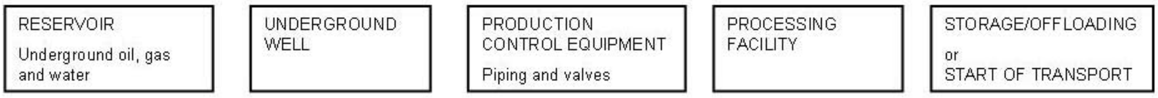
I want to find out how weaknesses in the organization and techno-social interaction of operations within a technological system cause exposure to accidents and how outside conditions affect the technological system and expose it to risk for accident

Blow-out accidents and why blow-out accidents are good examples of accidents in modern technological systems

A blow-out accident is a common name for uncontrolled release of hydrocarbons (gas, gas condensate and oil) from an oil/gas production line. The main components of such a production line are:

- the reservoir of oil/gas (and water) contained within rock formations deep underground,
- the drilled well running deep under ground into the reservoir,
- the production control equipment in the form of pipes and valves connected to the well/reservoir,
- the processing facilities separating water and dividing oil/gas into useful substances and finally
- storage and loading facilities or connection to transport pipes for the separated oil and gas.

When oil and gas are produced off the shore, the technical facilities for production, production control and supportive facilities are usually but not always contained within a rig/platform.



By definition *a blow-out accident* is an uncontrolled loss of oil and/or gas under pressure that happens from the reservoir and/or the production line *before* the oil and gas enters the processing facilities for separation of water and division into its useful components of crude oil and gas. An uncontrolled loss after the oil/gas/water has entered the process facilities is called a *process leak* and is by definition *not* a blow out accident.

The oil/gas industry is by common designation divided into two major segments, the *upstream* and *downstream* segments. Upstream are the segment where crude oil and gas, whether dry or liquefied, are extracted from the ground and processed and made ready for transport. The downstream segment is where the crude oil are refined and distributed to users or where the gas is transported to end users. And for the sake of order, I focus solely on the upstream part, loss of containment during downstream operations are not within the scope of this thesis.

From a techno – social perspective offshore oil/gas platforms as technological systems are interesting and relevant to study for a set of reasons.
The conditions of (relatively) deep sea call for few isolated systems in the form of platforms/rigs where technical artefacts for several critical functions are placed in a spatially small system, so we get to study technological system within clear physical boundaries. Offshore rigs/platforms are also by a systemic description quite complex and tightly coupled according to Perrow's (1999) criteria. In Perrow's classification on level of accident, a blow-out will rank as a component failure accident, but due to the tight coupling onboard most offshore platforms, chances are high that a blow-out accident can develop into *a system accident*, damaging or destroying the whole system.

These offshore rigs/platforms are also functionally centred round the production line running from the oil and/or gas reservoir. Deep down in the reservoir we find the untamed forces of nature in the form of high pressure oil and/or gas containing waste amounts of energy. The offshore platform/rig forms a technological system that is tying together nature's forces with human utilization by the use of human engineering knowledge. This gives this type of technological systems a relevant position in the human–technology – knowledge perspective. As mentioned earlier oil and gas production are central in fuelling the modern technologies of modern society. This places the study objects in a relevant position in relation to discussions on effects of technological development in modern society.

Blow outs as accidents are very interesting as *accident-type* for a number of reasons:

- the potential forces of destruction are present within this bounded technical system and not coming from the outside like for instance a ship colliding into an oil/gas rig/ platform.
- blow-outs unlike the other types of accidents with disastrous potential happen at the boundary between natural objects and technical artefacts and human ability to sense and interpret nature are relevant to understanding consequences of actions and thereby relevant for safe operations
- the accident form has potential for destroying the whole facility

- this type of accident is dangerous to those Perrow define as first, second and fourth party participants[1] (Perrow:1999: 67-68)
- environmental consequences to the surrounding sea can be substantial

Blow-out accidents do not show up in the statistics as the largest danger during offshore oil and gas operations on the Norwegian Continental Shelf (NCS). During the 41 years of offshore oil/gas operations on the NCS, blow outs have not been a major “killer”. Only one person has been killed in a major blow-out accident during this period[2], compared to two digit numbers of deaths in accidents stratified in the categories of heavy lifts/dropped objects or diving accidents. The clearly largest cause of deaths is the sc. Alexander Kielland accident of 1980 when 123 persons died following a breakdown in structure and capsizing of a floating rig.

Still the potential of a major disastrous accident is evident. There are three major problems with blow-outs that can cause grave dangers. The first is that the gas or vapours from leaking oil can ignite and burn/explode. Such explosions can cause major destruction to platforms/rigs and lead to loss of substantial number of lives. The other major danger is that major streams of leaking gas can erode the sea-bed under those types of platforms standing on

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[1] - First party victims are those who carry out the work in direct relation to the accident,
- second party those who participate within the system and benefits from it , but do not have direct influence on the work being carried out,
- third party are victims who does not participate within the system and benefit from its operation, but just happen to receive the worst consequences of the actions , and fourth party victims are future generations that in a negative way become affected by consequences of an accident

[2] During the West Vanguard accident which we will look into below

the sea-floor and cause them to tilt over. The third problem with potential for disaster is that major gas leaks into the water can cause a floating rig/ship to get stability problems and cause the rig/ship to capsize or sink.
Only ship collisions, structural breakdowns and explosions in onboard process facilities rank equal to blow-outs as accident with potential disastrous destructive consequences to a rig/platform.

As there are generally a substantial degree of similarity in offshore oil/gas operations over the world these illustrations acts as examples of the severity of blow-out accidents.

The first example, selected from the World Offshore Accident Database (WOAD) run by the Norwegian safety consultant company Veritas, can illustrate the severity of blow-out accidents:

> *“During well completion operations the platform suffered a blowout and fire….some 45 people were evacuated from the platform…The platforms self contained drilling rig “Sundowner XV” was totally destroyed in the fire and will not be repaired” On jan 27th (three days after the initial blow-out, authors comment) the fire was still out of control. After 4 days the well was still blowing….The well was capped 12th of February* (19 days after the initial blow-out, authors comment) *(WOAD ref: Eugene Island 3 80/A-1 1996 -05-24/002)*

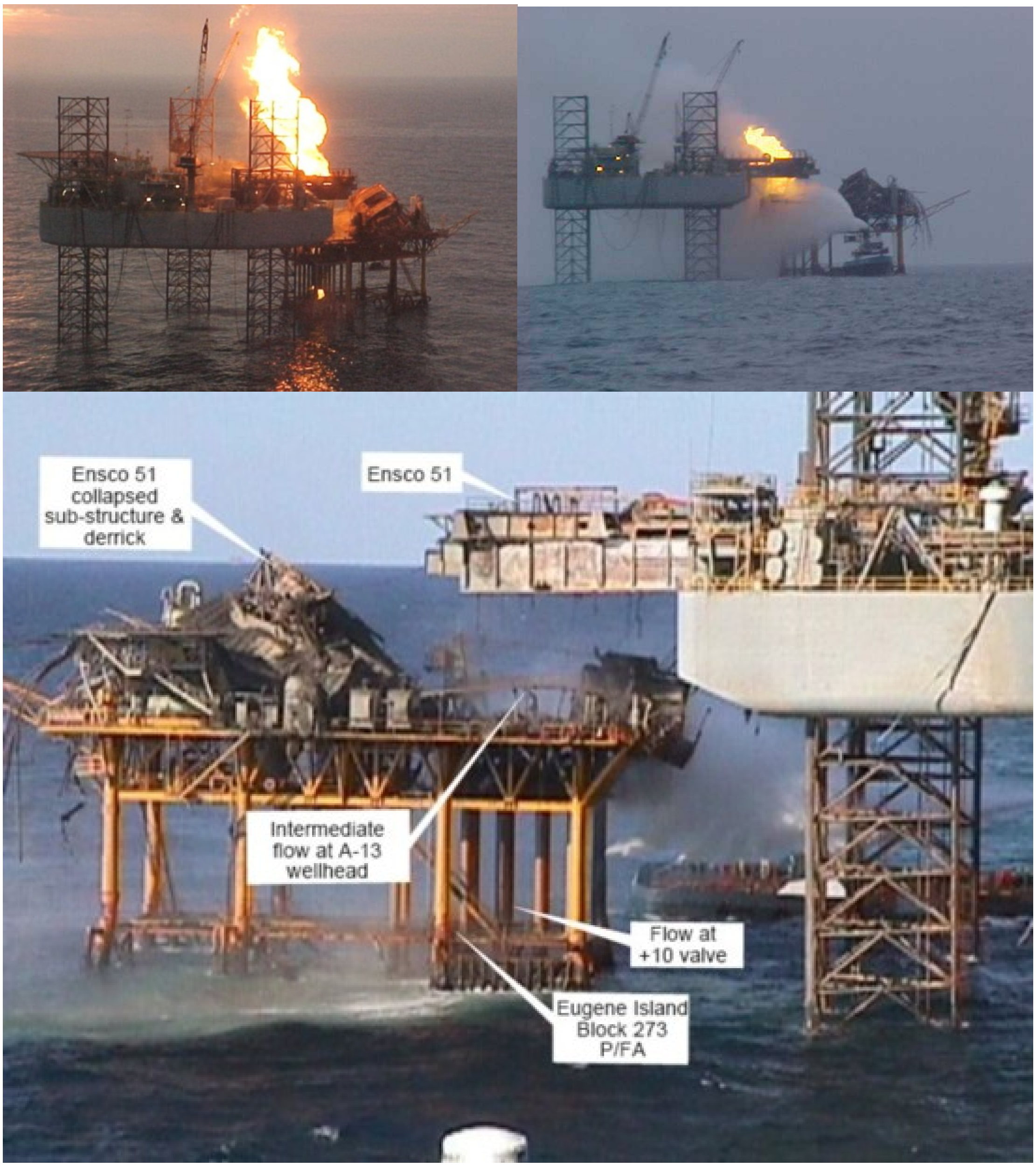

Fig 1,2,3 Below are three pictures of the platforms during and after the accident, Sundowner XV laying wrecked across the smallest of the two platforms, Eugene Island

Another example:

The third of June 1979 the crew of Sedco 135Fwere drilling the IXTOC I well for PEMEX, the state-owned Mexican petroleum company off the coast of Mexico. During operation the crew nad tig suffered a blowout. Attempts to shut inn the well failed. Oil and gas flowed to surface where it later ignited and engulfed the Sedco 135F in flames. The rig collapsed onto the wellhead littering the seabed with large pieces of debris

The well initially flowed 30 000 barrels (approx 4,7 million liters- authors comment) of oil a day gradually sinking to 10 000 barrels (1,6 million liters - authors comment) a day. In spite off over 500 aerial missions to spray the oil slick with dissolvent, the oil slick measured at the largest 180 by 80 km. Large areas of the southern US coastline were contaminated.

The well was capped 23 of march 1980, 9 months after the initial blow out, after drilling of two relief wells. This is the accident with the biggest single spill known, estimated to a release of 3.5 million barrels (556 million liters - authors comment) of oil. (Versatel-1)

Fig 4 (Upper left) the Sedco 135F rig that sunk after explosive fires,
Fig 5&6 (Upper right and lower centre) The Sedco 135F /IXTOC blow out. Pictures showing oil/gas flow with fire and clearly visible oil slick. The other platforms are drilling relief wells. The Sedco 135F platform is at the time of the pictures sunk © Both Versatel

A third example illustrating how floating rigs of the type frequently used on the NCS can be affected. This accident also illustrates how quickly a blow-out can develop into a grave accident.

On the 22 September 1988 the crew of Ocean Odyssey drilling in the UK sector for the oil company ARCO lost control of the well resulting in a blow out. The blow-out caused gas to leak out and explode. During dramatic circumstances with explosions raging the 67 man crew hastily abandoned ship with eight persons having to jump overboard from the rig. One crew went missing onboard the platform during evacuation and were killed in the fire/explosion(s). The rig was severely damaged, spent a long time in the yard an was later rebuilt for other purposes (Versatel-2)

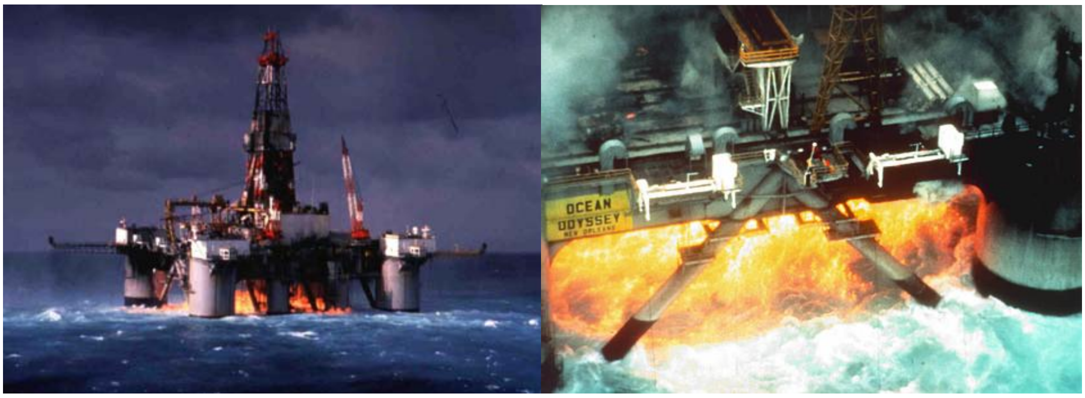

Fig 7, 8 Ocean Odyssey blow-out and fire © Canadian wellsite © japt

The fourth example illustrates the dangers posed of loss of buoyancy and/or stability due to gas in the sea. On the 27th of August 1981 during drilling operations on the in the South China-sea the crew of the drill ship Petromar V hit a shallow gas pocket. The resulting blow-out with gas in sea caused the drill ship to lose stability and capsize. (Versatel-3)

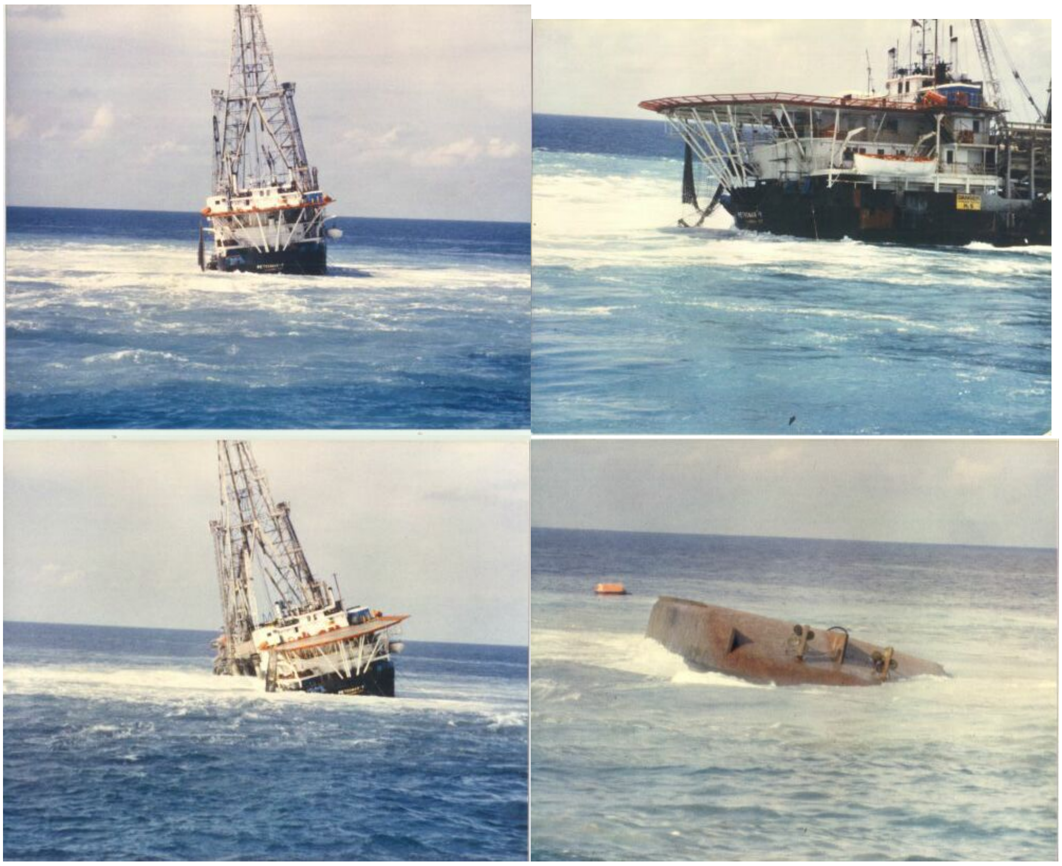

Fig 9-12 Blow-out and capsizing of Petromar V drill ship © Research and training Centre – Australia

Low average risk

Statistically spoken blow-out accidents are rare. The combined figures derived from offshore oil/gas operations in the Norwegian sector (NCS), UK sector and the US sector of the Golf of Mexico (GOM) which forms the most reliable statistical data available, places the risk of blow-out accidents per year in production per oil/gas well at an average rate of 0.000047 (Holand:2006:74). The risk of blow-out per drilled and completed production well is 0,00327 [3] and for drilling an exploration well is 0,00516 (ibid 73-74).

The probability of ignition of oil/gas that are leaking out during a blow-out is on average 0.136 per blow-out (ibid:22)

Looking at these numbers and knowing that many blow-out releases of oil and/or gas are so small that most people will conceive them as “leaks” the statistical risk of a *major* blow out accident is so small that for most of us it is hard to conceive.

As example:

One of the largest types of offshore platforms can have as many wells as approximately 60.

Calculated, the *average risk* of experiencing a blow-out in a given operational year if we exclude the drilling of wells are 60 x 0,000047 = 0,00282 per operating year. Or described another way 1/0,00282 =354,6 which means one blow out in every 354,6 years on *average*.

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[3] For drilling a development (production) well Holand places the average risk of blow-out to **0.00250.** In addition comes a risk component of completion calculated to **0.00077. Completion is necessary** for all production wells. The value of the added risk components then become 0,00327 for drilled and completed development (production) wells.

Knowing that it is on average only 0.136 chance of ignition, the accident risk of a blow- out with fire and explosion for a rig with 60 wells and no drilling activity is 0,00282 x 0,136 = 0,000384 per operating year or on average, one major accident with fire and explosion in 2607,4 operating years.

Taking these numbers into consideration and *remembering that these are average figures* with *limited value* to an individual case, offshore oil/gas platforms must in relation to blow-out accidents still be considered as high reliability systems. Remembering the potential severity of blow-out accidents illustrated above, we talk about systems of high-reliability, but with disastrous potential.

Vulnerability

During 41 years of offshore operation on the NCS there have only been three *major* blow-out accidents[4], a very small number of accidents/incidents. When looking in detail, as an investigation committee or board of inquiry does, offshore oil/gas platforms/rigs are large and complex systems with a multitude of technical and human input variables.

Looking at the multitude of detailed input variables and considering the low probability of this type of accidents, finding reason to generalize based on exactly how a given blow-out accident started will be difficult. The answer can be and most likely will be that there is a specific and almost unique combination of technical malfunctions and/or certain set of specific human actions that triggered the particular blow-out accident.

-[4]the Bravo accident of 22nd April 1977,
- the West Vanguard accident of 6th October 1985 and
- the Snorre A blow-out incident 28th November 2004
We will return to these accidents in section 1.3 and chapter 4

We can expect these technical malfunctions and/or human actions are closely related to that particular technical system and if we try to transfer the set of causes to another blow out accident in another technical system, we will not be able to find the exact same variables. The set up of the technological system or organization is too specific to the case. Our ability to generalise on causes, even with our specific strata of accidents will be poor.

Instead of acting like a second investigating committee and just re-trace the findings in identifying the detailed causes or combination of causes leading to accidents I will base my approach on the article *"An Approach to Vulnerability Analysis of Complex Industrial Systems"* by Setfan Einarsson and Marvin Rausand (1998)

The central notion in the article is to *look for vulnerabilities exposing the system instead of looking directly for causes*.

> *"The vulnerability concept is used to characterize a systems lack of robustness or resilience with respect to various threats, both within and outside the boundaries of the system" (ibid:535).*

Notice her that Einarsson and Rausand also talks about looking for both *internal and external input variables*. Einarsson and Rausand does not explicitly state if the internal or external input variables shall be on the same or differing societal level(s). Interpreting from their figure (ibid: 537) I understand external factors to be of both similar and higher societal levels (for instances *Market* or *Society* but also *Infrastructure)*.

Further on the relation between vulnerability and risk: *"Vulnerability may be considered as the "opposite" of robustness and resilience, in the same way as risk is the "opposite" of safety" (ibid 536).*

So far I have described the reasons for *why* I want to study blow-out accidents in offshore oil and gas production systems, illustrated the danger *potential* of blow-out accidents and outlined the reasons for *focusing on vulnerabilities* to accidents rather than direct causes.

Now I will turn to how I intend to study these accidents.

1.3 Methods

I intend to carry out a multiple cross case study of the social and socio-technical causes of vulnerabilities exposing technological systems of offshore oil and gas operations on the NCS to blow-out accidents. I will do this by looking at a set of internal causes for social disruptions, and external conditions surrounding the technological systems as well as interactions between relevant elements across the boundary of the technological systems. I will focus on the time immediately before or running up to the accident.

The findings in the three cases, I will compare them to a normal situation in an offshore development project where there has been no blow-out accident.

Finally I will try to analyse how the findings describe conditions of vulnerability in offshore oil/gas technological systems. I will also to a limited degree generalise into how these vulnerabilities in technological systems can be understood and how the associated risks fit into a larger picture of risk to the individual.

Chapter two is an introduction to technological designs of platforms/rigs in use on the NCS and introduction to wells and drilling techniques.

The reason for this chapter is fourfold

- It gives a background to understanding the technical aspects of the blow-out accidents
- It shows system structures that are relevant to understand the problem of complexity and coupling and the potential for disastrous consequences of blow-outs.
- It illustrates the rapid technological development and diversity of oil/ gas drilling and production facilities. This is relevant for understanding both the crews' situation in operating the technical items onboard and the control authorities' challenges in keeping up with development.
- Relevant for as background when discussion the social influences on development on technological (technical and organizational) structures

In chapter three I will describe a set of five social theories relevant for understanding disruptions of the social organization exposing for vulnerabilities leading to accidents. These theories form basis for the analysis in the two following chapters.

The fourth chapter is an analysis of the investigation reports/analysis from the three major blow-out accidents that has happened in the offshore oil/gas operations on the NCS. The three accidents are;

- the Bravo accident of 22nd April 1977,
- the West Vanguard accident of 6th October 1985 and
- the Snorre A blow-out incident 28th November 2004

I will analyse the findings from the accident/incident reports based on the five social theories described in chapter three. I will also check for indications of complexity based on the theory of Perrow (se section 1.2). For the purpose of later analysis I will also look for indications on effect of safety authorities control in the time leading up to the incident/accident.

In chapter five I will analyse conditions in a normal offshore development project by the same theoretical basis as I use in chapter four. The reason for this is to form a basis of normal operations.

In the last section of chapter five I will discuss across the three accident cases from chapter four and the case of normal operation in chapter five.

The purpose is twofold; to identify if there are inside causes of vulnerability running across time and the three accidents and secondly to identify if there are conditions not related to accidents, but inherent vulnerabilities in the industry as a whole.

If there are clear differences between operating conditions leading up to accidents and normal operation then I can explain the causes of vulnerability. Are there similar organizational conditions across accidents and normal successful operations, this will serve as a strong indicator that there are general inherent structural causes for vulnerability in the industry.

The sixth chapter will open with an introduction to theoretical foundations for understanding the influence of context on accident vulnerability.
In the second section I will look for the broader techno-social history of the Norwegian offshore oil/gas industry. That conditions set out by the social surroundings affect the technological system will be a central basis for further discussion.

Chapter seven is divided in three sections
The first section is where I intend analyse the findings from chapter four (accidents) and compare with the techno-historical context in the time leading up to the accidents. I will try to identify effects indirectly causing conditions of vulnerability across external - internal boundary of the technological systems

In the second section of the seventh chapter I will look at all the accident cases and see if there are general key features in the techno-social interrelationship running along the different cases. If I find indications that the operation conditions that lead to accidents are existent across accident cases and normal operating conditions this is an indication that there are indirect causes of weaknesses across time in the general system of the Norwegian offshore industry (considering that I have chosen relevant theoretical background for my analysis).

In section three I will reintroduce the general basic notions from Beck's *Risk Society* and discuss how my findings are relevant for understanding risk distribution in society.

1.4 Definition of key terms

Technological system: A system consisting of both physical artefacts and organized humans. The system can contain and have boundaries to natural objects. The technological system can set premises for human technical interactions within the system. A technological system is constituted around a (set of) purpose(s) and a (specific set of) technology which is a part of defining the system.

(NOTE: This definition takes up the social, technical and knowledge integration from Hughes founding article on large technological systems (Hughes 1993) . But by avoiding the "large" I want to utilize the social, technical and knowledge aspects of Hughes description while I simultaneously want to limit the physical size and find natural self-explaining boundaries for a given technological system

Technical (structure): Man made physical structure that forms the physical man made part of a technical system. The outer physical limits of the technical structure will play a considerable, but not definite role in defining the boundary for the technological system.

Technical design: Deliberate design, selection of physical components and the ordering of the component's internal relations within a given technical system. Technical design does not include social organizations, but can affect the structure of the organization manning the technological system. Technical design is dependent on available knowledge and production techniques. Technical design will most likely be affected by demands and selection mechanisms in the social surroundings through all phases of the technical designs life cycle.

Organization: The social organization of the group of people manning a given technological system. Organization spans both formal and informal organization.

(Social) surroundings: The social conditions surrounding the technological system. In some cases this can include how the surrounding social elements perceive the natural surroundings of a given technological system.

2 The technical – Offshore Platform Designs and Well Technique

The role of looking at technical designs in this thesis

In this chapter there is a general introduction and then a focus on the development in technical design of rigs/platforms and on drilling technique. All three parts are relevant as background reference when reading chapter four on the experienced blow-out accidents. Technical development and design choices in the areas of rigs/platforms and wells are also directly relevant to the notions of complexity and coupling as described by Perrow (1999) and as such the potential for accidents and the potential extent of damages in case of an accident.

Looking at technical design development also serves a tertiary purpose. This chapter serves as reference for discussion of the large scale socio-technical development discussed in chapter six. The development of technical structures reflects back on the social circumstances the design was developed under and functions as indicators of development in social structures, relevant for the final discussion in chapter seven.

I suggest that this chapter (chapter two) is keep at hand and used for comparison when reading section 6.2

2.1 The Major Components in the Offshore oil/gas Production Line

Schematically spoken the offshore production line of oil and or gas consists of four elements, oil/gas deposit, well, well control line/equipment and processing with storage/offloading facilities.

An underground reservoir is where gas and water and often also oil are trapped in porous layers of permeable rock under more solid layers of dense rock. These layers can be from some hundred meters to several thousand metres below the sea bed. Usually the layers containing oil/gas have thickness in the range of some tenths of meters up to some hundred meters. A deposit is usually much larger in horizontal than vertical direction. The geological structure can be complex with several pockets and dividing layers within a reservoir.

Contrary to common beliefs the deposits do not only contain gas or oil, oil, gas and water are lying in separate layers in the deposits. Due to the differences in specific gravity the gas is always on top and water on the bottom. Not all deposits contain oil, on the NCS it is quite normal with deposits with only gas and water. In all reservoirs the gas on top provides a high pressure.

Oil is always mixed with gas and water (and often some sand) when it is produced.

Gas is also a mix of dry (gaseous) gas and liquefied gas. Some water, gas bonded with water and sand usually is present in the production stream.

The well, is a drilled hole of varying diameter in the rock formation. The upper section is widest and then the well becomes slightly narrower in a few steps toward the reservoir. Inside the well, the drillers lower a steel pipe called *casing* and cement the outside of this casing to the surrounding rock. A common dimension of casing is 9 5/8 inch (approx 24,5 cm).

Inside the well piping for containing the production flow of oil/gas called *tubing* is run. The volume outside the tubing is called the annulus. Both the volume inside the tubing and the annulus is closely monitored for pressure to keep control of the production and for safety. There can be different valves in the tubing regulating the well stream. One type of well is the Down hole safety valve (DHSV) which is a valve that can act as a safety valve to close the well.

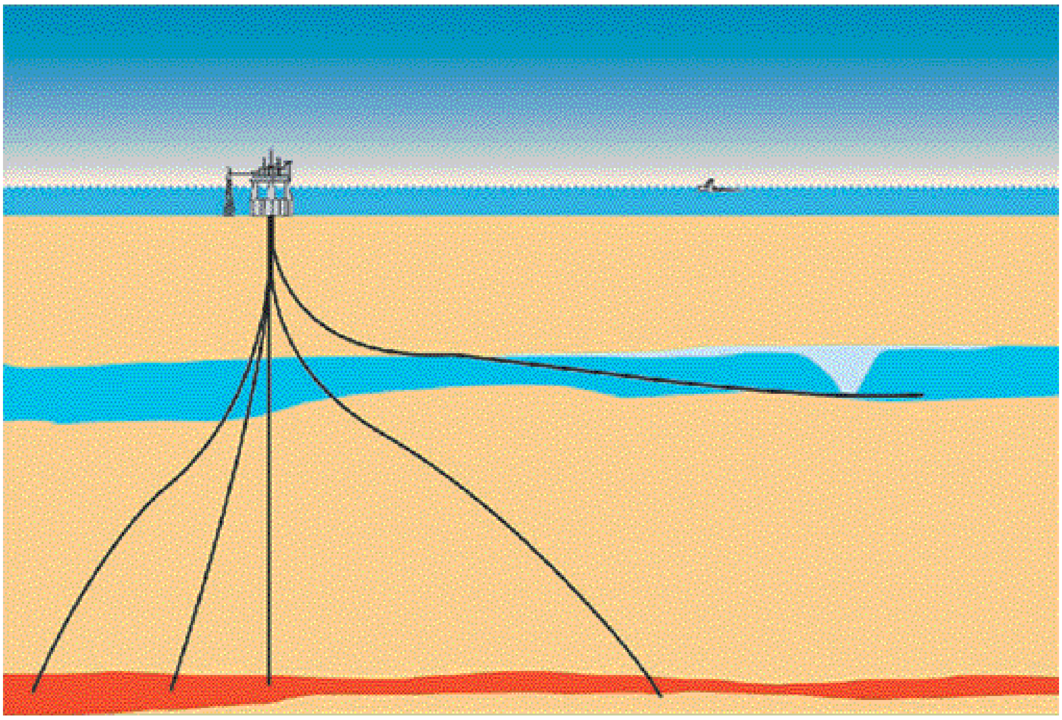

Fig 13 This illustration gives a fair picture of the dimensions of the large oil/gas platform (approx 200m high), the sea and the oli/gas deposits (on this illustration of the thicker type). The dimensions of the wellbore of the oil/gas wells are of course grossly exaggerated

By the top end of the well we find the wellhead. At the wellhead we find a set of strongly dimensioned control valves called the *x-mas tree*. The x-mas tree can either be placed on the deck of a platform with a marine riser with the tubing inside running down to the sea floor (the traditional type of structure) or there can be a sub-sea x-mas tree on a frame attached to the well at the sea floor (the newer sub-sea type). This type of sub-sea x-mas tree is run by remote control and the wellstream run through piping to the processing unit at the platform. Sub-sea wellhead units can be placed directly below a platform or at some distance out to the side of the platform in separate sub-sea modules.

From the wellhead the production stream goes through piping to the processing plant. Here sand, water gas and oil are separated. Except for the first years of operation on the NCS, it has been common to pump the water and/or some of the gas back into the reservoir through what is called an injection well to keep up the pressure inside the reservoir.
The separated crude oil is usually stored in onboard tanks or pumped directly over to a ship for transport to refining.
In later years gas is separated into dry gas and liquefied gas and transported through one of the sub-sea pipelines into the large gas transport system running through several pipes to onshore facilities in Norway, Germany, Belgium, France and the UK

2.2 On the Drilling and Maintenance of Wells

Drilling

There are in principle two types of drilling; *Exploration*[5] *drilling* to verify the existence, size or quality of a field and *development drilling* to develop wells for production or establish extra wells into a deposit already in production. The

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[5] Ther are two sub divisions to Exploration called Wildcating (finding/ verifying the existence of a field and appraisal which is to verify the extent of already confirmed field

general principles for drilling and completion are the same for both types. Exploration drilling is done with moveable drill rigs/ship (se next section) without processing equipment.
Development drilling can be done from a stationary platform with capacity for both production and drilling. To drill a development well for a platform without drilling capacity or a sub-sea well unit (se next section) requires a separate drilling rig/ship.

Basic to all the drilling is a rotary movement provided by the rotary drive on the drill deck (old type) or a top drive in the derrick (tower over the drill deck) (new type). A drillstring consisting of sections of steel pipe running down from the drive and into the well, the drillstring is power rotated. In the down-hole end there is a drill bit. Sections of pipe can be added to the drillstring as one drill deeper. Below the rig/platform and down to the seabed well head runs a tube outside the drillstring called a riser. During drilling the riser connects to the top of the well so the well practically ends on the drilldeck of the rig/platform.
Initially a large diameter top-hole is drilled downwards from the seabed. When the top-hole (upper part of the well which can run for a several hundred meters) is finished a and the first casing segment is cemented in place, a Blow Out Preventer (BOP) can be installed. The BOP is a huge set of valves that can shut in the well even under high pressure. Most but not all BOPs have shear rams which can by hydraulic power cut of the drillstring and lock in the well.

The BOP can be placed on top of the well on the deck of the rig/ platform (old style) or be placed at the well head on the sea floor and be remotely operated. (new style)

For the rest of the operation the drillstring and casing/ tubing to be installed will run through the BOP.

For the sequences of drilling where there is no BOP or in case of complete failure, some types of rigs are equipped with a diverter system that can send gas directly to the side of the platform.

To hold back eventual pockets of gas or the gas/oil in the reservoir hit during the drilling, the drill operators are dependent on the *mud*. Mud is fluid pumped into the drill hole to give weight and pressure to hold back gas or liquids under pressure down in the drill-hole. The specific gravity and hence the weight of the mud can be altered by changing the composition. To cool the drill bit, remove crushed rock substance and vent out minor amounts of gas mud is circulated through the well during drilling operations

With the upper part of the well completed and the BOP in place the drilling continues and can reach large depths. There are techniques to control the direction of drilling precisely. The vertical angle and direction in azimuth can be precisely adjusted with a positional accuracy of less than 1 meter during drilling.

To keep the pressurised oil/gas under secure control there is an industry standard to always keep two barriers to secure against blowouts during the main phase of the drilling. The normal way to do this is to rely on the weight and pressure of the mud combined with leak proof casing to form the first barrier, the second barrier is the BOP.

Other solutions can be a Down Hole Safety Valve (DHSV) that can come in some different shapes and is locked to the sides of the well acting as one barrier.

Fig 14 On the drill deck, two operators checking a large bore drill bit © Hydro

Completion

When the well is drilled a completion phase takes place. During the completion phase the well is cleaned out and all the underground equipment like different screens, packers (sealing off parts of the well), internal tubing and different types of valves are installed inside the well. Completion is usually carried out by the same type of rig/platform as the one used for drilling. In the final stages of completion the well is opened to the reservoir by puncturing some designated areas of the casing. Then the well is tested for pressure integrity of the whole system and the wellflow is checked before the well is ready for production.

Workovers (Maintenance)

Workovers are the industry’s own word for major down-hole maintenance in a well. Maintenance to down-hole equipment is done much in the same way as drilling. Mud is pumped inn to “*kill*” the well (balance the pressure). The top-side safety valves are removed and equipment can be run down the well in order to change, clean up or remove what’s necessary. After the down-hole operation is finished the well head is closed and mud is pumped out, the well is cleaned up, tested for integrity and production is opened much the same way as after drilling.

Wireline equipment is different specialized tools run on a wire inside the well that can be used either during major workovers when the well is killed or by a special technique when the well is in production.

2.3 Development of Rig/Platform Designs on the NCS

Background

When offshore activity started with exploration drilling on the NCS in 1966 the techniques and technology were imported from US oil companies operation the Golf of Mexico. There the first independent platforms off the coast had been developed through the two previous decades.

The technical solution to producing oil/gas off the shore was to put the drilling equipment, control valves & piping and the associated processing equipment on a platform raised above the sea. Add control room, workshops, living quarters & galley, cranes to load/offload equipment, helicopter deck and fire-fighting equipment and the almost self contained oil/gas platform is complete.

The first of a long series of major oil/gas platforms on the Norwegian Continental Shelf (NCS), the platforms on the Ekofisk field, were installed in the early 1970s. They were installed at approx 70 meters depth on the southern part of the NCS. Already during the introduction of oil/gas production on the NCS in the early 1970s the offshore equipment and procedures brought in from the GOM had to be modified. Soon Norwegian and UK companies started to produce own designs. First own designs in floating rigs followed by the specially developed Condeep concept (se below). From being an initial importer of technical items originally developed for use in the GOM, the Norwegian offshore industries gradually developed new technical designs. Influential in the development of new designs were also the gradual movement of the industry into deeper waters further north in the North Sea.

The eight distinct types of design[6] of offshore rigs/platforms in use on the NCS

Below, the description and illustrations of the different designs are listed in the order they appeared on the NCS.

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[6] of FMC technologies introduced me to this way of describing design steps in design of platform/rig structures during a conversation in October 2006

The first is the semi-submersible floating drill rig

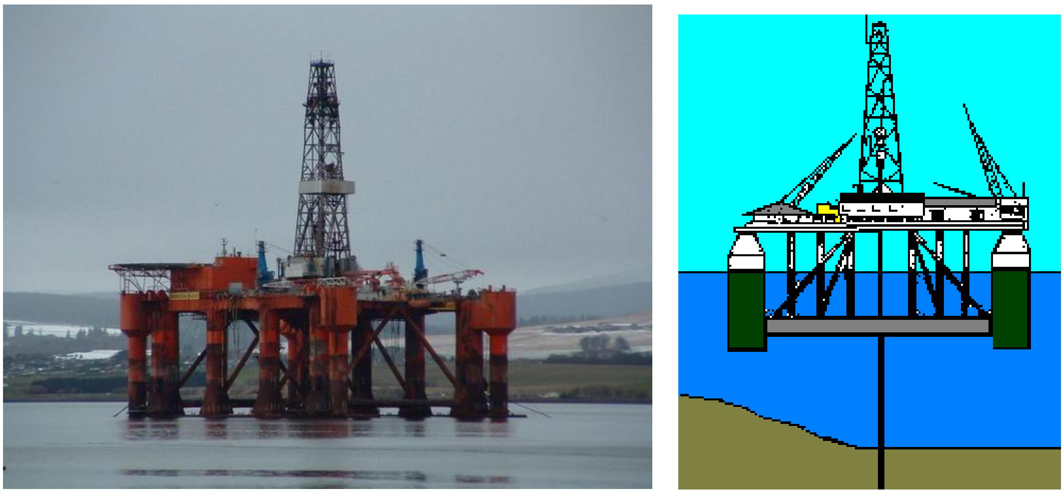

Fig 15& 16 Floating semi-submersible drill rig © Transocean © Statoil

This type of rig is floating and moveable by its own engines. There are no processing/production facilities onboard, except equipment control valves (x-mas three) and BOP to shut in a well. It is used both for drilling wells and for maintenance operations (workovers). When positioned at the drill site, the rig is anchored by 12 to 16 anchors and lowered in the sea for stability during the drilling operation.

This technical design was imported from the US with the introduction of offshore exploration drilling on NCS in 1966. This general design is today common on all major offshore oil/gas provinces

A version that by appearance looks different, but in principle of the overall design and tasks is similar is the drill ship.

Drill ships and on some occasion later models of rigs have dynamic positioning (DP) equipment for operations in waters to deep for anchoring. DP is a control system utilizing a type of precision positioning system coupled to a set of motors and propellers. This DP-system can in spite of wind, waves and currents hold the rig/vessel in a position with sufficient precision to carry out drilling.

Fig 17 West Navigator drillship **© Seadrill**

The second is the steel jacket platform[7]

Fig 18 &19 Ekofisk steel jacket platform from the 1970s **©unknown, ©Dagens Næringsliv,**

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[7] On an international basis an additional technical solution can be added after the steel jacketed platform; the "Jack Up" rig. It's a floating rig with (usually) three long steel framework legs that can be lowered to the sea bottom. With the legs placed on the seabed the rig is jacked up into position and used fort drilling and/or production. Due to its limited capacity for larger water depths, this technical solution has hardly been used on the NCS.

Fig 20 Ekofisk steel jacket platform © **unknown** **Fig 21 Oseberg Sør, a 1990s Steel platform** © **Hydro**

This type of rig/platform consists of a steel structure, placed permanently on the seafloor. This type of technical design was imported from use in the Gulf of Mexico at the start of offshore oil/gas operations on the NCS. The Ekofisk field, Norway’s first field to enter production was designed with this type of platform. Steel jacket platforms is used for production and has processing facilities onboard, and some of the larger platforms are also equipped with drilling equipment for drilling and servicing production wells. Much of the equipment is quite universal in the sense of possession of the production competence and access to material and production facilities. This type of rig/platform is used in the southern shallower parts of the NCS.

The third is the (large) integrated Condeep platform

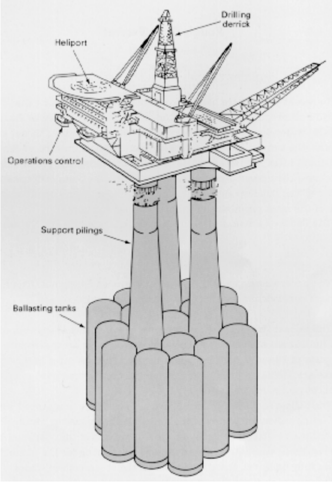

Fig 22& 23 Condeep GBS platform ©Statoil Gullfaks Condeep GBS platform ©statoil

Concrete Deepwater Gravity Base Structure (Condeep). Consist of large platform on top of large concrete structure with legs and seabed storage tanks. On top of the concrete structure, a large steel deck with drilling equipment, processing plant and all supportive structures. The platforms have capacity for simultaneous production, drilling and storage of oil. Riser structure and drillstring runs inside two of the concrete legs. According to Seiersted (1992) condeep were developed during the 1970s because it fitted the needs of several Norwegian actors. Condeep formed the technological core of the sc. "*Norwegian model*". Almost exclusively used for the large oil/gas fields of medium water depths on the NCS. In later years sub-sea equipment has often been attached to these large structures.

The fourth is the separate sub sea production system

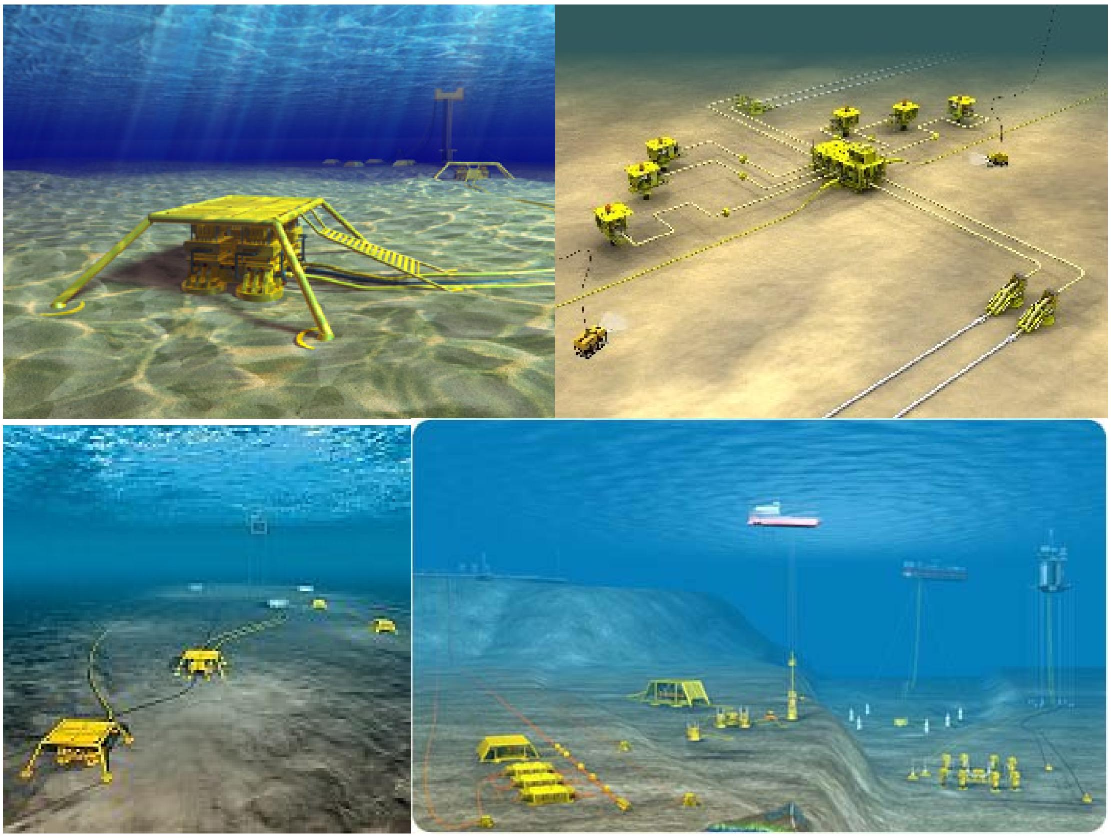

Fig24, 25 , 26 & 27 Sub-sea production equipment ***©FMC Technologies (all four)***

Fig 28 Sub sea production systems ©Statoil

Sub sea equipment is control modules installed on top of the wells and is remotely operated from a nearby platform. Oil and gas are transported to this nearby platform through smaller pipelines. Sub sea systems have been developed gradually so as of today underwater separation of water and sand from the wellstream is possible. Water and sometimes gas is often pumped back to the reservoir through a sc. injection well to keep up the pressure in the reservoir. Drilling of wells, installation of equipment and well workovers are done with floating drill rigs/ships and with the aid of remotely operated sub sea vehicles (ROVs). Sub sea installation can be connected for production to all the different types of platforms as long as the rig/platform/ship is permanently in position. Sub sea equipment has been installed down to 3000 meters water depth in foreign waters.

The fifth is the Tension Leg Platform (TLP)

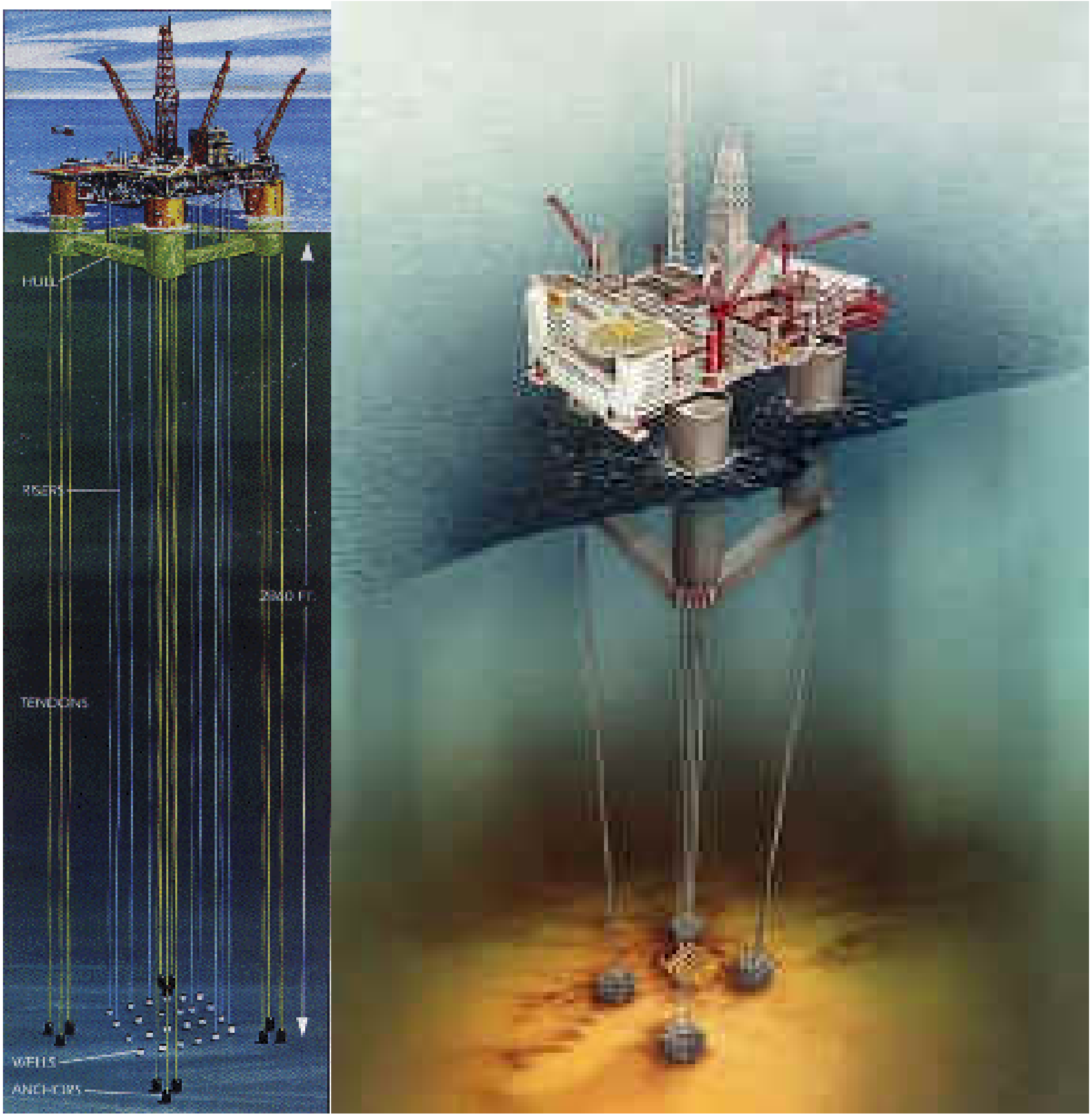

Fig 29 & 30 Floating TLP rig © HRC-Corp © Virgina Tech

Fig 31Troll B concrete TLP **© Hydro**

Fig 32 Steel TLP **© Offshore technology**

A Tension Leg Platform is a floating concrete or steel structure tied to the seafloor with tension legs ie. steel struts extending all the way down to a set of suction anchors embedded in the sea floor. The platform is lowered in the sea so the updraft causes tension on the anchoring struts in order to increase stability. Fully integrated platforms with production, processing and drilling facilities exist as well as smaller production or production & processing platforms without drilling equipment. Early models had the sub-sea wells on a frame directly below the platform (between the suction anchors). Newer models have on sub-sea wellheads on templates that can be positioned at quite a distance out to the side of the platform with smaller seabed pipelines and/or flexible pipes run up to the platform.

The sixth is divided processing between land and platform

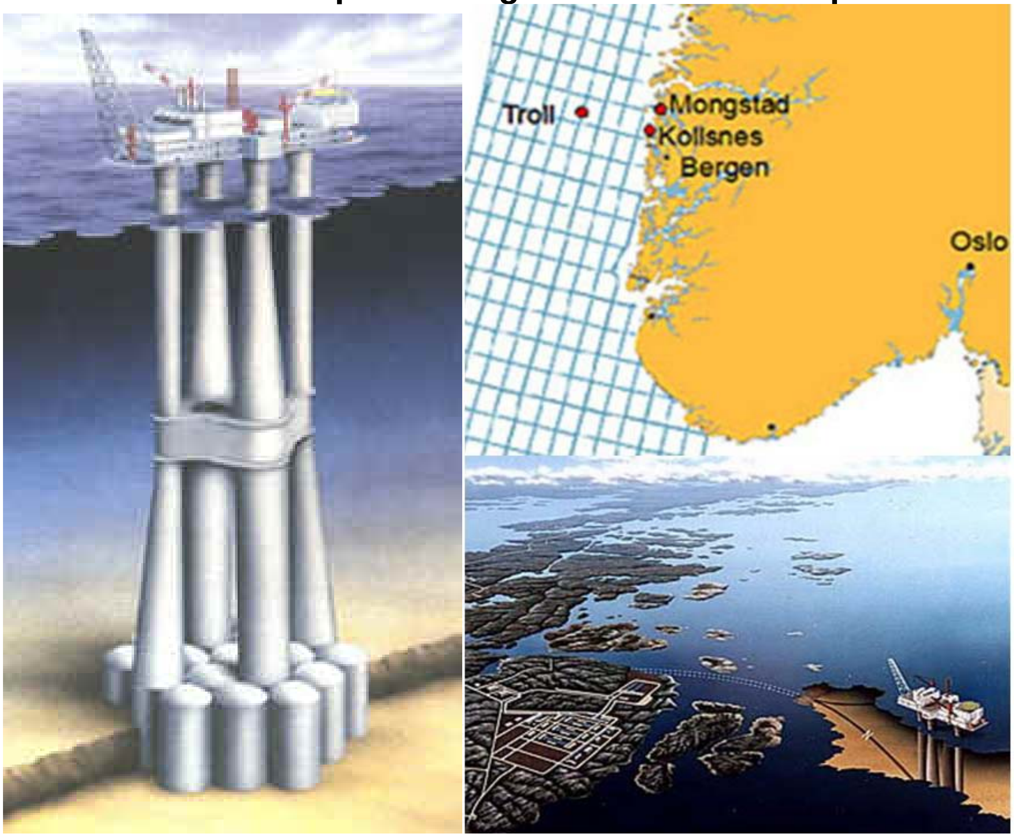

Fig 33 & 34 Troll A platform with limited gas processing equipment © Statoil
Map and sketch shoving distance to land processing plant at Kollsnes © Norsk Oljemuseum

Fig 35 Gas processing plant at Kollsnes © PSA

This design is based on the Condeep platforms structure, but is characterised by separation/movement to the shore of the processing equipment and the use of multiphase[8] pipelines mixing dry and liquefied natural gas from the well

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[8] Multiphase means that both dry gas and liquefied natural gas is transported in the same pipeline. It sounds easy, but in reality it has proved to be technically challenging because the unprocessed gas contains water and other contaminations that forms ice plugs and blocks the pipeline. The solution has been to mix the gas with glycol and/or methanol during the

site to the onshore processing plant, still with platform based production control and drilling. The platform retains the seabed storage tanks from the Condeep design. The system of Troll A platform & Troll Gas production unit at Kollsnes is the only example of this technical structure on the NCS. The platform was built as the last of the series of Condeep platforms and was commissioned in 1995. This unit is also the tallest of the concrete base and leg systems ever built.

The seventh is the FPSO ship combined with the sub sea production equipment

Fig 36 & 37 The Norne FPSO system © Statoil© Statoil

The Floating Processing Storage and Offloading ship (FPSO) is in principle similar to a floating production platform with the exception of the hull. The FPSO ship has the production and processing equipment and all support functions for production. Some FPSO ships also have drilling equipment and hence the capacity to drill production wells. In the FPSO ship there are possibilities to store and offload oil. Gas is normally transported through a pipeline after onboard processing. The hull structure with equipment with the exception of the processing equipment closely resembles a normal ship and

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transport phase. These substances have to be removed and recycled at the processing plant on shore.

the technology for producing the hull is widely available. The types of FPSO ships used on the NCS are dependent on sub sea modules at the sea floor well heads.

The eight is the platformless oil/gas field.

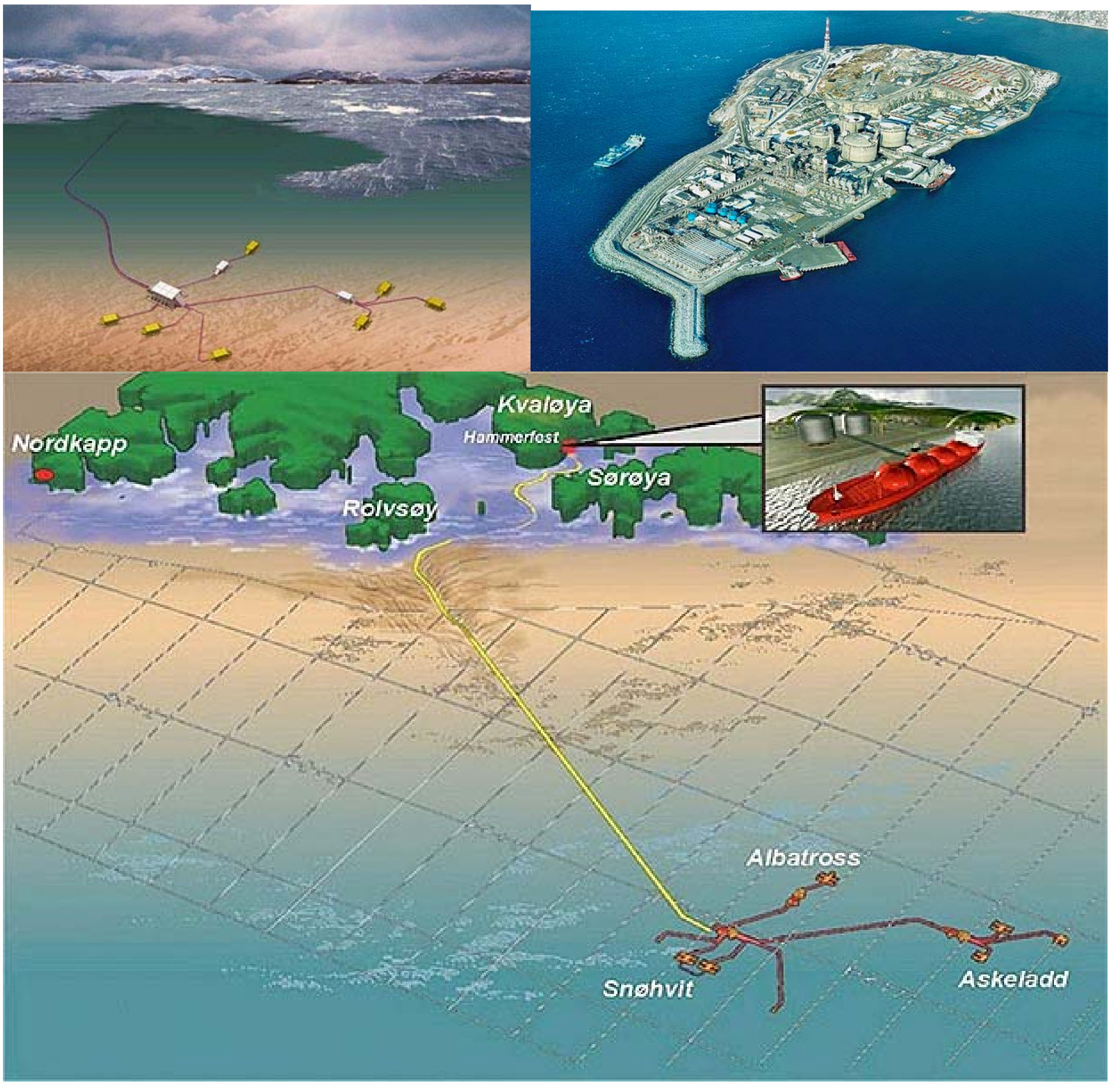

Fig 38 , 39 & 40 The Snøvit platformless gas field currently under construction outside Hammerfest with the controlling, processing and loading facility at Melkøya © Statoil

This design is characterized with sub sea production including sub-sea removal of water and sand from the wellstream. The sub sea production and initial processing equipment must be combined with long multiphase pipelines and onshore processing of gas or gas & oil. The production control facilities are also placed on land, and the operation of the sub sea equipment is done by remote control. Drilling of wells, installation of equipment and well workovers are done with floating drill rigs/ships and with the aid of remotely operated sub sea vehicles (ROVs). The two only fields with this design structure, Snøhvit and Ormen Lange are currently in the later stage of construction and are becoming operational during the autumn of 2008.

2.4 Development of Advanced Drilling Techniques

In 1989 Hydro drilled an experimental well with a horizontal tail end from the drill ship Petrojarl (Lie 2005:81). This was world first “horizontal” well drilled from a floating platform and represents the entry into what we can call advanced drilling on the NCS. The utilization of injection wells where gas or water was injected on sides of the deposits to push the oil/gas in the direction of the production wells was also important.

Advanced drilling combined with new geological understanding and improved management of oil/ gas deposits grossly increased the recovery rate of oil from many fields on the NCS.

During the 1990s this development in drilling and well technologies continued and during the late 1990s the first sidetracked wells on the NCS appeared. To sidetrack means that the drillers drill an additional well out from the walls of the original well. Over a few years this developed into three, four, five and six tracked wells.

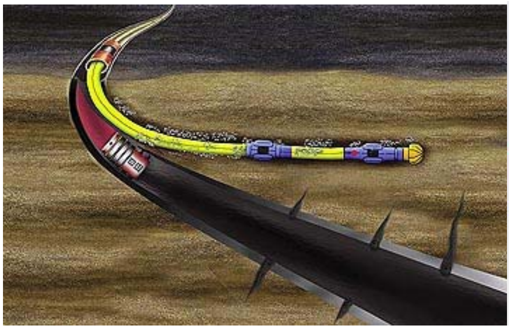

Fig 41 Drilling of sidetrack from a wellbore © Statoil

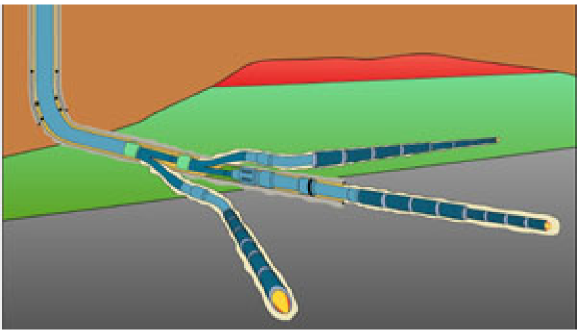

Fig 42 Three tracked well © Hydro

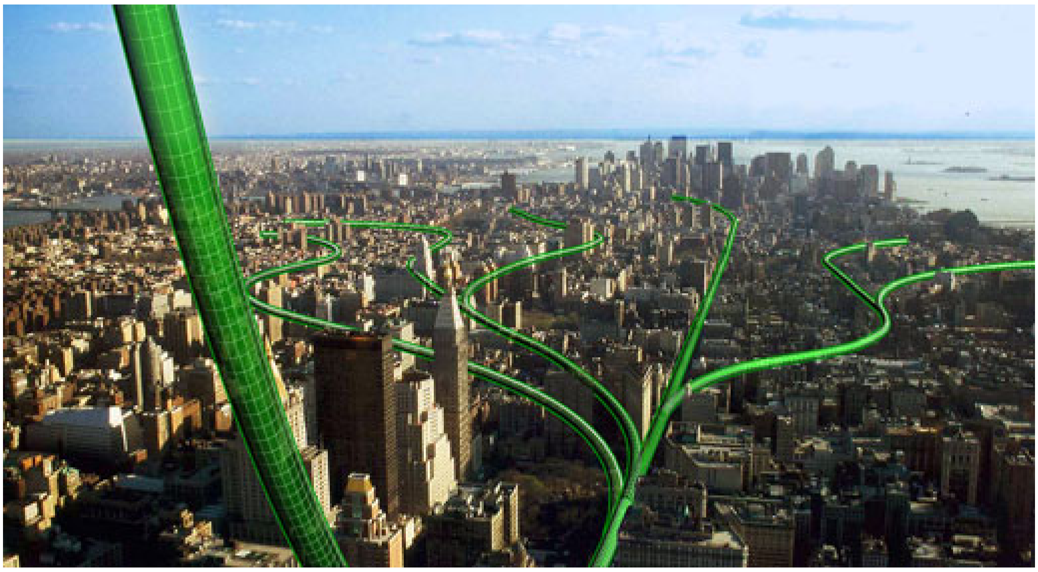

Fig 43 Hydro's artist impression of a six track well superimposed over Manhattan, New York to illustrate the sheer size/reach of wells when utilizing advanced drilling technology **© Hydro**

The new and longer well tracks also lead to more complex down-hole structures. Wells could penetrate more than one oil/gas layer demanding down hole valves or plugs between the layers. A wellbore could pass through long stretches of loose formations demanding long sections of specialized sand screens. Or a wellbore could zig-zag horizontally for a considerable distance through the oil layer of deposit just meters below the gas layer or above the water layer.

Not so visible and not so celebrated as platform developments, this new combined enhanced drilling techniques and more advanced utilization of oil/gas deposits represented the silent technological revolution of the 1990s.

As an example; the Troll West field was during the first Troll development plan initially assessed to be unsuited for oil production due to its complicated geological structure. The field was re-assessed several times, developed and by 2003 it was largest field in terms of produced quantities of oil on the NCS (Lie:72).

2.5 Safety Consequences of the Development of These Technical Designs

The early designs, semi-submersible floating drill rig and the steel jacket platform were imported to the NCS. The designs were imported from a different surrounding setting both social and physical in the GOM. The TLP design was also imported. There is a chance that weakness in the structural design these platforms could be exposed with the changing conditions. Condeep, and much of the sub- sea equipment and the divided processing and platformless designs were on the other hand tailor made designs developed especially for the NCS. Here weakness can on the other hand lie in the limited numbers of unit and limited operational experience. Troll A is the only system in the world of this specific design and as such is a prototype.

The use of larger sized platforms integrating more functions like drilling and production on the same platform add to complexity of the technological system. In general offshore platforms are by Perrow’s (1999) demands quite tightly coupled systems. Some of the platforms are tighter coupled than others. The integrated Condeep systems adds many wells to a platform where there are also drilling activity. On occasion drillstrings pass just meters away from the wellhead of a substantial number of operational production wells. Some of the early TLP platforms hover in the water directly above a large number of operational production wells.

The large integrated platforms with a large number of wells combined with advanced drilling technology increases the spatial reach and complexity of one integrated technological system dramatically. (Close you eyes and imagine you are straight above the 20 or so production wellheads. Then think of the picture above of the well superimposed over Manhattan, multiply the picture by 20 and imagine the wells running out from the platform in all directions around the full circle – both the size and the complexity is gross).

An interesting international example for comparison;
On the 1st of May 1991 the crew of the rig *Pelican* operating outside Trinidad and Tobago drilled into one of the rigs own wells at 4583ft (1389m) below the surface. The plan was to bypass the well by a mere 10 ft (3 m) at this depth. Later re-calculation showed that at a depth of 1000ft (300m) the two wellbores were only 2 ft (0,6m) apart. The consequence was a gas blow-out that lasted for 16 days before it was stopped (WOAD ref Pelican 1993-11-24/002)

Development of independent sub –sea modules has had positive effects in relation to safety. The distance between the sub-sea templates on the well/wells and the platform can be increased. In relation to blow-out accidents this loosens up the tight coupling between the well and the rest of equipment one usually finds on an integrated platform. This lessens the chance of a blow- out accident developing into disastrous scenario.

The new drilling and field management technology lead to a substantial revision of the values of many of the oil/gas fields on the NCS leading to new assessments of the lifespan of a number of production facilities. This had a double sided effect as it meant platforms would on some occasion bee kept in service longer leading to old equipment in use. On the other side it meant better margins for investment in modernization or major overhauls of platforms.

Rapid development of new major design structures meant that on average there has been 5-6 years in between the introduction of a totally new design concept. During the early-mid 90s three different designs, TLP-platforms, divided processing, and FPSO's, were introduced almost in parallel. Knowing that the lifespan of a given rig/platform can typically be 30 years or more we see many different designs in parallel use. Though a few platforms have been decommissioned none of these designs has yet been abandoned and we see a *diversified set of designs in use on the NCS today*.

Well service specialist travelling from platform to platform doing smaller specific task like certain types of wireline services had to work in shifting systems. Challenges are also posed to operators and operating companies' knowledge of systems

This rapid diversification has had several consequences.

It has been hard for safety authorities to keep up in developing the more detailed provisions of safety regulations suited to the particular systems design structure.

3. Theories on Social Causes of Organizational Breakdowns Leading to Errors

Reasons for Selecting These Theories

This group of theories are selected because they help in understanding how groups of humans in an organization whether formal or informal end up in a situation where one or more individuals have a higher than normal chance of acting erroneously.

In other words the theories are relevant for understanding how the *human organization* and individuals acting within it becomes *vulnerabl*e to doing errors and especially errors at critical moments in relation to operating in the technological system.

In the next chapter (Chapter four) I intend to analyse accident reports based on this set of theories. My purpose is to analyse the inner workings of the organization manning/operating the technological systems where the three accidents happened. I also intend to use the theories as basis for analysing one offshore organization under normal conditions where there is no accident (Section 5.1/5.2).

In selecting the theories I have prioritized using theories explaining how errors occur or how humans in organization become vulnerable to making erroneous actions.

For the reasons of clarity and usefulness I have avoided to theories on *managing risk.* These type of theories often explain causes of vulnerability but the integrated part of the theory on how to control, mange or avoid accident risks will blur the image and I risk loosing clarity in the analysis.

3.1 Karl E. Weick on making sense of it all

In his article *“The collapse of sensemaking in organizations: the Mann Gulch disaster”* (1993) Karl E.Weick, analyses how a group of elite smokejumpers (parachute fire-fighters organized for fighting forest fires) were overcome by a raging forest fire in the Mann Gulch in Montana in 1949. While conditions changed rapidly and developed into difficult and dangerous scenario, the social organization of the fire-fighting unit smouldered away: The unit stopped to work as group and when ordered to act in an unconventional way, to drop their tools and move out of dangers way in order to save their own lives, only a few of the fire-fighters obeyed the orders. The sad end of the story was that 13 out of the 16 smokejumpers died.

Analysing the events, Weick describes how an individuals understanding of the dangers in the surrounding environment is tied to social position. The individuals understanding and attribution to the social structure is dependant on the *sense* the individual can make *of the social groups accepted understanding of the situation*. When individual have problems making sense of the accepted common perception in a group, the individual will be prone to exit the social group and act independently on an own track. This will lead to breakdown of the social order/structure of the group.

There is also a reciprocal effect, as long as the individual wants to be a part of the social group the individual sticks to the perceptions of the situation. To raise a deviating perception on how observations are connected and make sense, *challenges the existent social order* within the group. This can in situation where the groups social organization is strongly connected to specific way of making sense of the situation mean to exit the social group

Relevant for further analysis we see two effects;

- a given participant will have problems making sense of danger signals lying outside the common understanding within the group the individual adhere to, and
- when sensing the signals of danger and seeing an erroneous sensemaking of a situation within the group, forwarding the perception of danger calls for challenging the social positions of members of the surrounding social group. A likely outcome is controversies or conflicting views on the interpretation or importance of danger signals in the period leading up to an accident

In connection to assessing problems related to sensemaking it is interesting to look at complexity or more precisely perceived complexity.
When technological systems are perceived to be complex by the individual, the struggle of making sense of a large set of “values” from a large set of “perceptions” *with unclear or complex interactions* can *add problems* to the individual’s ability to make sense of a given situation.

Speaking out of starting point of the technical side of technological systems, sensors and instruments bringing forward a set of values/readings demand a type of assembly and interpretation against knowledge before the information makes sense for action among humans.

3.2 Deborah Anchona and Chee Leong Chong on *entrainment problems*

Their 1992 article “Entrainment: cycles and synergy in organizational Behaviour” describes how the term entrainment developed from biology, where

> *“entrainment refers to the process whereby an endogenous biological or behavioural rhythm is modified in its phase and periodicity by powerful exogenous influences”(ibid:5)*.

Anchona and Chong state a slight modification from the biological understanding of entrainment when applying the entrainment term on organizations, the direction of influence can be bi-directional both from the internal to the external or the external to internal (ibid7).

Describing entrainment in organizations, they further state that entrainment can be conscious, subconscious and instinctive. They also divide entrainment into three types*, tempo*, *synchronic* and *harmonic*.

Their central notion is that entrainment is found where different parts of an organization, inside and outside groups or individuals start to work in synchronized fashion weather it is in tempo, synchronized cycles or mutually harmonic actions.

For participants in a complex technological system a certain level of entrainment is usually critical for a systematic operation of the technological system. The problem of *disharmonic entrainment* arises in two ways

- when different parts of the organization come out of harmonic, temporal or cyclic entrainment because one of the organizational elements enforces/or coerces another organizational element to act in tempo that is not suited to the tasks at hand, or
- individuals are overachieveous, whether conscious or unconscious, in achieving entrainment with other organizational elements when this

goes against the necessary time to carry out the tasks at hand in a good manner

As there is not likely that higher level management leading the organizations within a technological system wish for unsafe operations, this theory must be viewed in a sense that there are influences inside and outside the technological system of conflictual character to safe temporal, cyclic or harmonic entrainment of operations.

In my analysis of organizations involved in accidents it is relevant to see if there has been signs of non- harmonical temporal or sequential adjustments between different elements of the social system or socio-technical system prior to the blowout accident;

- work cycles that were obviously out of synchronization,
- to long or to short time to carry out work operations safely
- enforced temporal standards on work processes that are contested by involved groups/ or conflicting view on how long time should be used
- enforced *and* contested views how specific work operations should be sequenced for proper/safe operation
- individual persons taking on them to many tasks/working in to high tempo in order to impress or compensate for temporal problems in other parts of the organization

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3.3 *Trickle-down effects* according to Diane Vaughan

Diane Vaughan has based her research on the organizational causes on the disastrous accident with the space-shuttle Challenger in 1986. She has developed the theory of The Trickle Down effect described in her 1997 article

“The Trickle-Down Effect: Policy Decisions, Risky Work, and the Challenger Tragedy”

She describes how opposing views on the organizations role and attached priorities from actors with influence outside the organization affects groups within the organization. Conflicting views, frames or understandings of the organization or operations role lead to alterations in priorities, related procedures and decisions within the organization. In some cases such alterations to the priorities, related procedures and decisions can lead to actions that jeopardize safety.

Vaughans example from her article is how an altered frame for the space shuttle program from an “experiment program” where time were clearly subordinate to necessary checks and experiments to ensure safe operation to “production [of regular space launches] program” where the uphold of a programme of scheduled launches into space where dominating. Before the 1986 launch of the high tech and complex space shuttle *Challenger*, the safety of operating the shuttles solid rocket boosters attached to the large hydrogen/oxygen fuel tank were in question. The rocket boosters were known to have a potentially dangerous weakness in the seals at the joint between the four sections of the rocket boosters. Exposure to low temperatures could cause the seal to give in and cause a leak of flaming hot gases out of the rocket booster toward the large flammable hydrogen/oxygen fuel tank.

On the day of the fatal decision to launch the space shuttle in temperature conditions that was soon to be proved it was not suited to operate under, the key question became put in *the frame* of *producing regular launches*.
The question was turned into keeping the scheduled time for launch *unless* the engineers from the company that produced the solid rocket boosters could come up with decisive proof that it was unsafe to launch under this conditions. In other words we talk about *upholding a production schedule* instead of framing it as a question *if all conditions were ready* for launching the experiment vehicle into space. It would have been reasonable to expect a frame of experimental program to rule the decision considered the experimental character of the design/materials and limited operational experience with the space shuttle. Had a framing of an experimental programme been upheld, the question should have been more in the line are the conditions suitable for launch, and the burden of proof would have been to prove that all conditions were safe for the space shuttle to be launched.

In analysing in relation to accidents I will look for:

- has there been alteration of the frame the participants of the technological system view the technical system under.
- are there conflicting views on how to frame the technological system, its operation or key operational elements (like for instance overall risk level) between different groups working within the technological system

3.4 Scott Snook on *Practical Drift*

In the concluding chapter on his much apprised book *“Friendly Fire – the accidental shootdown of US Black Hawks over Northern Iraq ”* (2000) Scott Snook introduce the term *Practical Drift*. The book is a detailed three level analysis of the conditions leading up to US Air Force’s accidental shoot-down of two US Army helicopters over a No-Fly zone over Northern Iraq in 1994. Snook describes *how*, by the incremental adaptation of small practical deviations, the large, high tech and well trained US military airspace control and operations system ends up with making the disastrous decision of opening fire to its own helicopters. By analysing the conditions and background of the minor deviations done in the operating procedures he describes the underlying reasons for how the whole system failed and ended up with shooting down and killing 26 of their own members.

Snook’s approach is quite close to Diane Vaughan’s *Trickle-Down* theory, but where Vaughan describes conflicting framing and the influences on leaders and critical decisions at the top of the organization, Snook looks more to the minor errors and small changes/deviations done to operational procedures done in good intentions by lower ranking members of the organization. Snook also look at how alternations to the original organization plan done with the intention of reinforcing the knowledge an competence in reality creates unclear conditions and confusion about responsibility at a critical moment.

While Snook primarily writes about social organization, his writing is not free of techno-social value. He describes a story unfolding in a high tech environment and one central notion is how the airspace control and operations organization and the helicopter pilots for a long time accepted missing radio communication when they did have the necessary means to establish direct communication (tough of a lower quality than usual). How this underutilization of the technical means settles in the organization is one quite important part of his study. Another is how to fighter jet squadrons with different equipment (different type of fighter planes) and background from different roles *interpret their* then *identical tasks differently*. The differentiation in interpretation leads to differentiation in in-theatre training creating a critical gap in key abilities with dire consequences at a critical point in time.

Analysing in relation to accidents I will look for;

- deviation from written/ established/ recognized operation procedures, The deviations can be in the technical to human interface or in human to human interaction.
- shifting perceptions on key tasks in units/pats of the organization that should have seemingly similar tasks. As an example major differences between a night and a day shift in how they operate one important piece of machinery

3.5 Anthony Giddens' *Trust at Distance*

I have picked a notion from a theoretical description, not developed for the organizational level but at general societal level. This notion, from theory put forward by Anthony Giddens in his book *"Consequence of Modernity"* (1991) become relevant because operation of offshore oil/gas platforms are closely associated with spatially distributed work. Giddens describe how *trust at* *distance* became a key element in developing modern systems of communication, transport and trade.

Because drilling and workover programs on offshore rig/platforms are run according to detailed plans developed specifically for the particular rig/platforms operation by a land based engineering/planning organization, the element of *trust at distance* is important.

The land based planning/operation group is so closely associated with operation of the technological system that though I described how offshore platforms was clearly defined by physical boundaries I am willing to include such planning groups as part of the technological system when I do my analysis.

Since Giddens in “Consequences of Modernity” does not give a qualitatively or conditional description on when trust at distance is good for efficient operation of modern systems, I will have to look for whether trust at distance supported safe operation or caused vulnerabilities

In analysis in relation to accidents I will look for:

- to what degree do we see elements of trust at distance between spatially distributed elements of this organization
- to what degree do trust at distance support safe operation or create vulnerabilities

With these theoretical tools laid down and with a set of derived questions relevant to analysing accidents I will now proceed to the next chapter to analyse the three accident cases.

4. The Major Blow-out Accidents on the Norwegian Continental Shelf - An Analysis

Method

I have analysed five reports in the three major blow-out accidents on the NCS in regard to the theories described in chapter three with the addition of Charles Perrow ‘s notion on complexity (Se section 1.2). I have also included an element on Social Construction Of Technology (SCOT) relevant for later analysis in chapter six:

The five reports analysed are;

NOU 47/1977 Bravo rapporten on the 1977 Bravo accident,

NOU 16/86 West Vanguard rapporten on the 1985 West Vanguard accident,

And three reports on the 2004 Snorre A incident;

Brattbak, M., Østvold, L-Ø., Zwaag, C. v.d., Hiim, H. (2005) *Gransking av gassutblåsning på Snorre A, brønn 34/7-P31 A 28.11*

Schiefloe, P.M., Mauseth Vikland, K. (2005) *Årsaksanalyse etter Snorre A hendelsen28.11.2004.*

Ger Wackers (2006) *Vulnerability and robustness in a complex technological system*: *Loss of control and recovery in the 2004 Snorre A gas blow-out*

I have put the findings from the analysis into a scheme; *Attachment D* to this report. I recommend the reader to use the attachment for detailed reference.

4.1 The Bravo Blow-out Accident (1977)

> *“On the 22 of April 1977 an oil and gas blowout occurred in well B-14 on the Bravo production platform in the Ekofisk field…A workover is an operation performed on a producing well. It is generally a complex operation that may*

> *involve serious risks. In the case of well B-14 the workover involved pulling approximately 10000 feet of production tubing from the well. For this type of workover, before the tubing is pulled the valves on the production deck the so called christmas tree, have to be removed and a special arrangement of safety valves, denoted blowout preventer(BOP), has to be installed. From the time when the christmas tree has been removed until the BOP has been installed the well is open and provisional means of assuring that it will not flow must be used. Before the Christmas tree is removed the well is killed with mud, which is a fluid of sufficiently high density to generate enough pressure at the formation depth to prevent oil and gas from coming out of the reservoir. In addition a mechanical safety device is installed in the production tubing, to prevent flow from the well. The blowout occurred during installation of the BOP. Before the Christmas tree was removed, a down hole safety valve (DHSV) had been installed as a mechanical safety device at a depth of approximately 500 feet [50 m - authors remark] under the rig floor, corresponding approximately to 110 feet [33m - authors remark] below se-floor. After the blowout was stopped this valve was found practically undamaged on one of the decks of the platform. It had been blown out of the tubing. The immediate cause of the blowout was that the DHSV had not been properly locked into the seating nipple in the tubing, at the time of installation during the night between April 21st and 22nd thereby failing to prevent flow of fluids when the well became unstable during the morning of April 22nd. In spite of this the accident was not unavoidable. Two warnings of abnormal conditions were received during the day of the 22ndAppropriate actions were not taken. The first warning came before noon when mud was observed flowing out of the control line coming from the DHSV. The second came when the Christmas tree had been removed, at approximately 16:30, when mud also came up through the tubing. Each of these warnings should have resulted in the immediate ceasing of the work and closing of the well.*
> *(Bravo report1977 – English summary:7)*

The Blowout lasted for 8 days, leaking an estimated 157500bbl (22500tons) of crude oil. The well was closed in by a US specialist crew with no lives lost. (Bravo report 1977:9)

Fig 45 Ekofisk Bravo platform blowout of oi l- to the left a supply vessel spraying water to avoid ignition of the oil *© Norsk Olje museum*

Fig 46 The wellhead on the Bravo platform after recovery
© Norsk Olje museum

Fig47 Oil blowing out through the derrick of the Ekofisk Bravo platform
© Norsk Olje museum

The Ekofisk 2/4 Bravo is an integrated jacket steel platform with production, processing and drilling capacity. It was one of the first platforms installed, and at the time of the accident the about two years old. A number of key personnel like for instance the drilling supervisor were foreign nationals. At the time of the accident 1200 wells had been drilled in the entire North Sea region. There were five known blow-outs, non in the Norwegian sector and the workover were allegedly the ninth workover on a production well on the NCS. The investigation committee also states that it have been difficult to get information about other incidents/ accidents on other regions, operating companies were reluctant to disclose information (NOU 47/1977 Bravo rapporten:21).

The investigating committee also ran into a problem; at the time of the accident no operating guidelines/rules for drilling operations existed. There was only a valid rule set for floating installations. As the drilling and workover operations are very similar on these particular types of platforms it does not play a major role in relation to the accident and its outcome, but it serves as an interesting indication on the Norwegian Petroleum Directorate/Department of Industry’s capacity at the time.

Examining the accident investigation report (NOU 47/1977 Bravo rapporten) and comparing with the theories on causes of organization vulnerabilities/breakdowns from chapter 3 there are numerous indications of problems in the days and hours leading up to the accident. Most distinct and numerous are the indications of difficulties in *sensemaking* including controversies on how to interpret signals of dangers. There are also distinct sets of indications of disharmonic entrainment and practical drift in the form of deviation from SOP.

I do also find some indications on the fuction of the distributed onshore-planning – offshore execution system functioned. There are some indications on the effect of *trust at distance* and whether to much or to little trust at distance were a contributing factor.

I do not find that there are sufficient indications of cross pressure or conflictual framing to support a hypothesis on a *Trickle-Down* effect. I will therefore leave this question open with a notion that the lack of clear indications can be related to the scope of the accident report and how it was written.

Turning back to the question of *trust at distance*, the distributed system of onshore planning and offshore execution is briefly described (ibid 28, 50). The lack of redundancy and weak information transfer is criticised in the report (ibid:42, 50). It is clear that a more thorough check of the workover plan by competent personnel could have reveals weakness in the plan in relation to the installation of Down Hole Safety Valve. The DHSV was installed after the well was filled with mud. It later was later revealed that the first type of DHSV the wireline operators tried to install was not suited to be installed in mud. Also the lack of proper testing procedure of the DHSVs function before the X-mas three on top of the wellhead was disassembled might have been discovered by a proper cross check of the workover plan.

The investigating committee’s assessment might bee a bit to brief in this matter to draw a very clear and distinct conclusion of information transfer and reliance on distant management. In it self itself the lack of investigation of the planning process is an interesting notion on the understanding, competence and systemic oversight of the investigators.

Looking at whether we can see indications of problems in *sensemaking* among persons operating the system we find many indications.
The wireline operators' experienced problem in sensing if the safety critical Down Hole Safety Valve was correctly set deep down in the well. Their only tool was to use wire pull on the wire running down into the well (ibid:31, 39-40)

Also the drilling crew including drill-chief and drilling operator had problems of understanding why mud were slowly coming out of the well in the hours leading up to the accident

> *"Drill chief tells that he found no reason to inform his superiors, as he was not sure there were floating more out of the production tubing than through the control line, and he viewed it possible that the cause could be the same. The commission finds his reasoning wrong and can hardly understand how an experienced drill chief could not recognized this clear warning of a blowout" (ibid:43 - Authors translation)*

Challenging one owns perceptions when facing complex technical systems, insufficient information and lacking oversight;

> *"Drilling engineer were guilty of ...errors. In the choice between temperature caused expansion and instability in the well as an explanation for the increased pressure, he choose the least dangerous alternative, hence the temperature expansion" (ibid:42 – authors translation)*

Other persons working on the drilling deck also had problems of sensing the danger of mud slowly coming out of the wellhead (ibid:31 & 42)

Minor controversies could also be observed between several op the persons involved in the operations on the drilling deck.

There was discussions over reliability of the chosen DHSV vs alternative equipment between contractor operating the wireline equipment and acting drilling superintendent (ibid:29). Knowing that it later showed up that the DHSV was not meant to be installed in a well with mud, there might be that the operator of the wireline equipment sensed something weren't right.

One of the other specialist contractors tells the commission he contacted the drilling supervisor perceiving something was wrong with the pressure balance in the well.

> *"Drilling supervisor choose to accept drilling engineers explanation and decided to carry on with his work without seeking advice with his superiors" (ibid:42 authors translation)*

Still with these minor objections there is no description of anyone seriously challenging the drill chief or drilling supervisors' interpretation that the observed abnormalities were just related to minor, not important deviations, and not indications of dangers in the form of an approaching blow-out. This point has not passed unnoticed by the commission investigating the accident. On the Drill chief;

> *"It is surprising that none of his subordinates, including the shift supervisors, put forward objections against continuing the work when mud came up through the production tubing" (ibid:43 - authors translation)*

Elements of *disharmonic entrainment* can be observed. Contractors working with the wireline equipment had to try seven times before they got the DHSV in what they assumed was a set position, this lead to two work periods of 20 and 30 hours respectively. (ibid 28 & 42) The contractors operating the specialist equipment were organized in a single shift. They where supposed do shorter work sequences operating their specialist equipment. When the wireline operators ran into the problem of setting the DHSV and had to try no less than seven times this lead to very long work periods.

Drilling supervisor slept for one hour during a 36 hour period just before the accident. He then went to sleep while the well showed abnormal tendencies with mud slowly coming out of the well.(ibid:43)

It is worth noting that the drilling crew is organized so that drilling supervisor is working single shift while he supervises a two shifts, day and night shifts of drilling crews.

When looking at the question of *practical drift* we must compare the findings against three key sets of rules canonical for any workover or drilling operation.

- branch standards and general official safety rules/standards. The standard of always keeping two tested barriers can act as example
- the second is the company and/or rig/platform specific operating procedures
- the third is the drilling or workover programme

In the investigation report I find several indications of deviations from this set of operating rules. There were deviations from the plan when installing the DHSV (ibid:29-30). When the wellhead x-mas tree was disassembled, the Blow Out Preventer (BOP) was not assembled and tested, but was in two parts. The crew assembling the BOP ran into problems because they did not know the particular type of BOP (ibid:34,38,43). The normal an expected procedure would be to have the BOP assembled, tested and hanging ready to be lifted over the wellehead at the moment the disassembly of the x-mas tree started.

Also the mud weight was not in accordance to the mud weight specified in the workover programme. (Ibid:29 & 38).

The investigating committee also quite harshly criticises the later stages of the operation

> *"A pre- planned on programmed workover job, in accordance with the demands of safety regulations par 99, where now replaced with improvisations, Differing views surface among the actors on which solution should be selected , and the decision process is not assuring" (ibid:39 – authors translation)*

4.2 The West Vanguard blow-out (1985)

> *"Sunday the 6 of October 1985 at 20 30 an uncontrolled blowout occurred on the semi-submersible drilling rig West Vanguard during exploration drilling on block 6407/6 on the Haltenbanken. A so called shallow gas blowout occurred during a routine drilling operation before sufficient progress was achieved to install a blowout safety valve.*
>
> *The gas diverter system of the rig did not withstand the forces of the blowing gas with it's contained sand an solid particles and the gas flowed out onto the platform and were ignited. Explosion and fire caused grave damages. Of the 80 persons onboard 79 were saved. The material damage to the rig runs into hundred s of millions Norwegian Kroner. … The drilling went along normally until the minutes before 2100 when there were drilled into a thin sand formation containing gas at a depth of 263 meters below the sea-floor. This sand formation was not proven by the pre drilling check of the [geological data of the – authors remark] drill site. This pre-drilling check had indicated a sand formation containing gas approximately 60 meters deeper, but also pointed out - among other things based on previous experience from the Haltenbanken area – that one had to expect to meet shallow gas…..Drilling personnel circulated out the gas that entered the wellbore and continued the drilling. They had a new sequence of increasing gas values and further circulation. The next increase in gas measures were the blowout. (NOU 16/86 West Vanguard report 1986:7-8- authors translation)*

At approximately 2300 the blowout had progressed fully and general evacuation alarm was sounded. During the following minutes under dramatic circumstances the crew attempted to divert the gas flow with the diverter system, releasing the riser connection at the se floor and moving the platform away from the gas plume by releasing the anchors on one side of the platform. As two explosions occurred the last personnel to evacuate experienced a dramatic evacuation and one of the crew went missing, never to be found. Two of the rigs crew climbed down one of the platforms legs, swam away from the platform and was picked up by a small craft from the stand-by vessel. After the life boats got away from the rig the personnel was quite easily picked up in calm seas by the standby vessel. A search operation for the missing crew member went on with helicopter and a number of vessels for some time without results. The well continued to blow-out with the same force for five to six days and the gradually calmed down. The rig was pulled away from the immediate area three days after the accident and towed to a repair site in the following days. (ibid 27-33)

Fig 48 West Vanguard besides the gas plume from the shallow gas blowout
©Canadian Wellsite Gallery

Fig 49 West Vanguard after the blowout – fire/explosion damage to the main deck and the list of the rig is clearly visible **©Nils Aukan/ANS agency**

Exploration drilling is considered more risky than development drilling. Shallow gas eruptions is viewed as risk associated with exploration drilling (ibid:34)

This accident was the first and so far only blow-out on the NCS where someone got killed. The rig was a new, only commissioned three years earlier and at that time of a modern type. Both the operator, Statoil and the rig operating company, Smedvig were Norwegian companies. Compared to the Bravo accident there were only a minor representation of contractors in the form of two specialist engineers The crew involved was Norwegian, with the exception of three crewmembers, the assistant drilling supervisor, a drilling engineer and a geologist in the land based organization (ibid:23-26) Though we se foreign nationals in a few key positions the majority of the crew including most of those in leading positions, were Norwegians.

The exploration operation on the Haltenbanken area had commenced one year earlier 1984 and there had been drilled 10 wells in the area before the start of this particular drilling operatio. Looking at the situation on a large scale, the operation was a part of the major movement north on the Norwegian Continental Shelf. Exploration with following production had progressed far in the southern and northern part of the North Sea. Now the third sector was in the process of being opened up for production.

Examining the *NOU 16/86 West Vanguard report* further we find that *sensemaking* is a clear problem in relation to the drilling operation. The crew had its drilling experience, company manuals of Statoil (the operator) and Smedvig (the drilling operating company) and the drilling programme with some geological data. Still considerable prpblems with making sense of whet was going on is clearly evident.

While the drilling went on at about 2100 hours, the drill made a sc. “drill break”. The drill bit suddenly lost the down-hole resistance, the drilling system suddenly revved -up and dropped down a bit. (Ibid:27). In the period after the drill break there were two periods with high readings of gas in the mud and it was also unclear if mud was lost or gained at the top of the well. (ibid:37). The investigation report describes how the drilling crew had problems with assembling the different data from instrument readings and how there were problems with interpreting the gas measure readings in the mud returning from the well (ibid:46,59).

The commission concluded that the drill break was into a pocket of underground sand 507 meters down in the well and that gas at first slowly seeped into the well and formed a set of bubbles slowly rising to the surface (against the pressure resistance of the mud). This caused the first reading of gas in the mud, then the process repeated itself a second time, this time with higher concentration at the surface and at the third time, about two hours after the initial *drillbreak*, the gas had gathered sufficient pressure and momentum to push mud out and up through the wellhead and the blow-out started for full. (rf - ibid 49-52)

As a part of the conclusions of the investigation report;

> *“The drill crew have in this instance not seen and/or understood danger signals which with sufficient time could called their attention on what were developing" (ibid:72 – authors translation)*

The commission also calls for future improvement

> *"Presentation of drill data should be made better"*
> *(ibid:73 – authors translation)*

There is only one report of controversy in interpreting the signals (ibid:67). The continued use of sg. 1.08 mud (light mud) was neither challenged. It seemed to be a quiet consensus among the drilling crew on using light mud in fear of cracking up the geological structures around the well (a real potential problem that can cause uncontrolled loss of mud into the formations around the well with the secondary effect of loss of down–hole mud pressure- author’s remark).

The above information clearly shows that the crew had problems in interpreting the situation and its approaching dangers. Considering the lack of controversy reported the most likely explanation can be found in lacking knowledge and/or lack of sufficient experience and/or lack of transferred knowledge on how the data could be interpreted and made into signals of approaching danger. The complex presentation of data (rf. - ibid:38-40,42-46) further enhanced the crews challenges in interpretation.

Looking for indications of *practical drift* there were some deviations from SOPs. Both Smedvik and Statoil manuals states that there should be a break in the drilling while circulation of the mud in the well continues (circulation break) after a *drill break.* Also there was a deviation from the described method for gas measurement in the mud returning from the well. Some persons tested with an improvised “hand test” to feel for gas content in the returning mud and did not rely on the gas measurement instruments. The commission consider this method totally unreliable (ibid:46). This way of dealing with the difficulties in understanding the gas content in the mud can have contributed to the problems of interpretation of the measures of gas in the mud in the two hours leading up to the blow-out. Still there these deviation where not the primary/major cause to the blow-out, the lacking sensing of signals danger stands out far more clearly than the deviation from SOP. Compared to the Bravo accident (above) these deviations seem less of a general trend.

The crew of West Vanguard tell the commission that they did not suffer from time pressures or were forced to work to long shifts. There was in other words no indication of *entrainment* problems *within* the crew. But there seem to be a problem in relation to the planning process, the crew received little time for

preparations (ibid:55) There were problems in transferring data on the geological conditions underground, between Statoils office for geological assessment in Bergen, Statoil's operation office in Harstad responsible for the drilling plan and the crew on the rig. (ibid:67).
Also the drilling engineer in Harstad did not look through all documentation handed over from the Bergen office due to time pressure and knowledge of potential hazards did not pass out to the crew doing the job to a sufficient degree (ibid:54-55) Improper cyclic adjustment between those elements of the organization seems to have contributed to the lack of transfer of knowledge of geological conditions on the Haltenbanken.

The problems with getting the plans ready also give an indication of the *complexity* of the land organization. As a result of previous years exploration drilling Statoils geologists in the Bergen office had knowledge from neighbouring fields on Haltenbanken, parts of the same geological structure. Still this information had to pass through the Harstad office and not all of the necessary information did reach the crew of the rig. The complex structure and sheer size of the documentation (rf ibid:55) contributed to the information not getting through. We see that the complexity and spatial distribution in the land organization contributed to a weak planning process.

There where considerable trust from the West Vanguards crew toward the land organization. The continuation of drilling according to schedule when the drilling plans arrived late shows that there were no major incentives for double checking the plans for drilling. Possibly there was to *high a degree* of *trust at distance*

On the technical side there is important to note one point in the commissions' findings. The commission pays much attention to the rapid failure of the diverter system (which were supposed to lead the uncontrolled gas stream out over the side of the rig).(ibid:58,70) (Ibid appendix 1:114 -124).Three important points raised by the commission;
The commission describes experience from the use of diverter systems in blow-outs in the Gulf of Mexico. In 7 out of 18 cases the diverter systems functioned as intended, in 11 it failed.
"As a conclusion…in spite of the diverter system on West Vanguard being among the best in use on contemporary rigs, it had grave weaknesses…This and earlier blow-out accidents have shown the diverter system to be unsuited to fulfil the tasks attributed to the system". (ibid:58)
and further on page 70 the commission states serious objections to keeping the drilling provisions demand for diversions system combined with marine riser as the sole approved solution in the phase before the well is secured by a Blow Out Presenter. (Drilling without marine riser would cause the gas to blow-out to the sea at the seafloor instead of blowing–out on the deck of the rig). I will return to this point for further discussion in chapter 6.

One significant development can be seen when looking in between the lines of the commissions report. Compared with the report after the Bravo accident eight years earlier, this report spans much wider. There are discussion on the relation between land and offshore organization. Both have quite lengthy attachments with technical research on key components, but the 1986 WestVanguard is filled with recommendation for a larger number of improvements and there are recommendation of further research, among other things on buoyancy in relation to gas in sea problems, a question we will return to quite soon.

The commission in some points had a pragmatic approach;

> "When it comes to safety norms and safety standards the commission will express that in the rule sets not can pose stronger demands than what is practical, both technical and economically. Not at least exploration drilling for oil and gas do by experience bring a considerable risk for accidents. When the activity are deemed legal one has to accept this" (ibid:69 – authors translation)

4.3 The Snorre A Blow-out (2004)[9]

The third case of a major blow-out I will look into is the *Snorre A incident* on the 11th of November 2004.

Unlike the two earlier cases the three reports on the Snorre A incident are not official investigation committee reports. The first report on is the Petroleum Safety authority Norway's incident investigation (Brattbak et al 2005), the second report is made by a research bureau on behalf of the operating company (Statoil Schiefloe et al 2005) , the third is a scientific research report the STS researcher Ger Wackers (2006). I primarily used these sources to take out factual descriptions. As the Ger Wackers report is built on the two first reports I have tried to stick to the principle on relying to the primary /closest sources to the actual incident used the two first reports as sources for

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[9] I have not been able to find any pictures of this incident

the factual descriptions and relied on Wackers report for information not found in the other reports.

> “On 28 November 2004, an uncontrolled situation occurred during work in Well P-31A on the Snorre A facility (SNA). The work consisted of pulling pipes out of the well in preparation for drilling a sidetrack. During the course of the day, the situation developed into an uncontrolled gas blowout on the seabed, resulting in gas on and under the facility. Personnel who were not involved in work to remedy the situation were evacuated by helicopter to nearby facilities. The work to regain control over the well was complicated by the gas under the facility which, among other things, prevented supply vessels from approaching the facility to unload additional drilling mud. After having mixed mud from the available well fluid chemicals, this was pumped into the well on 29 November 2004, and the well was stabilized”
>
> “The PSA characterizes this incident as one of the most serious to occur on the Norwegian shelf. This is based on the potential of the incident.” (Bratbakk et al. 2005:2)

The situation developed when apart of the production tubing called a *scab liner* was pulled through the BOP. A suction effect caused gas to enter the wellbore, and from the wellbore gas found its way through a hole in the production tubing and through a damaged spot in the casing. The gas leaked outside the BOP and ended up leaking from the seafloor creating several craters close to the suction anchors and the well frame. A number of different gas alarms started to go off. This was first understood as problems with gas leaking from one of the process modules and into the cooling water, then other gas alarms went off in other places, the crew had problem finding the source of the gas. Most of the crew started evacuating by helicopter. About two hours after the first alarm, gas was observed in the sea below the platform. Situation had now become quite dramatic; below the platform substantial amounts of gas bubbled up and had entered the coolant circuits and fire deluge system. In the other end the pilot flame in the flame tower could not be shut off. The main power generators were shut down and the emergency power system did not provide enough power to operate the mud pumps needed to mix heavy mud to counter the gas in the wellbore. While the crew were lifted off by helicopter to neighbouring platforms a skeleton crew remained onboard and started to improvise an operation to pump heavy mud into the well. During the night this operation slowly succeeded and by the morning after with all the stores of mud expelled the well became stable and was closed in. (Based on Brattbakk 2005 and Wackers 2006)

Examining the reports for signs of *trust at distance* we se a shifting picture The Safety Authority Norway report describes a fragmented system of planning (Brattbakk et al:14-15). Also in the report from Schiefloe et al (2005:30-31) we find a description of major differences in offshore and land personnel's view on the technical conditions of equipment on the platform. Offshore personnel also view land personnel to know little about conditions on the platform. Simultaneously we se a high degree of reliance among the offshore personnel in the onshore managements plan for the well recovery programme. Both drilling supervisor and drill chief signed off on the drill programme rather quickly and the drilling crew did not make any objections. Neither did the drill crew call off drilling and ask for a check in spite of things being done quite hastily. I find it difficult to draw a clear conclusion, ther seem to be a high degree eof trust on one side and a lack of open and good communication on equal terms at the same time.

Looking at the problems of *sensemaking* we se that there were problems with understanding deviations from the pre-calculated gas pressure. (Brattbakk et al :15) "to the crew on the platform the problems presented themselves as a strange pattern of pressure surges in the various compartments of the well and tubing at the drill deck" (Wackers:56)

It took 2 hours and 6 minute from the first gas alarm sounded until the crew were able to confirm there was a blow-out.(Brattbakk et al :19) Initially the gas alarm sounded because gas bubbling up alongside the platform structure had entered the cooling waters of one of the processing plants. The gas alarms were attributed to a leak in this process system. The blow-out was only confirmed when crewmembers saw gas bubbling in the sea below the platform (ibid:16,19).

For the Crew to grasp that a blow-out were occurring happened first after the crew had been subject to the dangers of the gas from the blow-out for quite a while. The conception that there were two safe barriers down in the well was mentally and socially hard to break.

There is also another side to the question on *sensemaking*. In the onshore staffs planning of the well recovery workplan none of the participants raised objections after alteration in the sequence (Brattbakk et al:25)

Neither did the drilling supervisor or the drill chief raise questions, the programme were approved by all necessary instances (ibid:13).

No one were able to grasp that when the *scabliner* (extra reinforcing liner inside the production tubing where the production tubing is damaged or worn) was pulled through the BOP after the down-hole 2 7/8 inch pipe had been deliberately punctured *only one safety barrier* in the form of *mud* and *casing.* would remain. To operate with only one safety barrier would be a breach of a well recognized industry standard. Wackers (2006:54) point out that locally the decision to later sequence look smart.

Disharmonic entrainment is also visible in the form of a failed sequence of planning the well recovery workplan in the land management organization. There was neither time to use relevant documentation. There was insufficient time for planning (Schiefloe et all 2005:20,26,28) There were also insufficient time for offshore leaders to supervise because of large burden of administrative duties (ibid:40). Temporal adjustment by starting well recovery operation two days earlier than planned due to the early finishing of previous job (Brattbakk et al 2005.37) caused last safety check of the plan in land management staff to be skipped and a hasty sign off by the drilling supervisor and drill chief. *The onshore – offshore cyclic entrainment came out of synchronization* and the cycles that should have carried out became disrupted.

Looking at the recent history the higher management of the Snorre A had changed twice during the previous years. When Saga the operating company owning Snorre A after years with a of challenging economic situation was sold to Hydro and Statoil in 1998-99, the two companies agreed that Hydro should be operator for three years before handling over to Statoil. There were also some cost saving incentives in the agreement (Wackers 2006:33,35,38).

Though the people managing Snorre A had remained in the organization through these changes, they were exposed to new conditions.

Two elements of complexity and tight coupling became important, not as causes of the grave incident, but in worsening the potential outcome. The first is that the emergency shut down of power productions (gas turbines) caused insufficient power to the mud pumps to pump mud into the well in order to push back/down the blowing gas. Also there was not power to generate nitrogen to use to extinguish the small flame on the tip of the flame tower (this flame normally burns continuously so that minor pockets of gas inside the gas venting system will be burnt off and will not cause explosions). So when switching to emergency power in order not to ignite the potential gas plume with the prime turbine power generators, there was not sufficient power to stop the pilot flame or pump down mud into the blowing-well, that’s a good example on what Perrow call tight coupling

The second element is related to the platform being by its technical design structure a Tension Leg Platform (TLP) (se section 2.3/TLP-platform). This platform is designed so that it is anchored down by tension legs in each corner but at the same time floating. The problem with this design is when it is combined with a seafloor well frame with 42 wells directly below. If this platform should sink or capsize either because of loss of buoyancy due to gas in sea or because of damages from an explosion, it can potentially fall on top of its own seafloor well connections and damage them. This is why;

> *“The PSA characterizes this incident as one of the most serious to occur on the Norwegian shelf. This is based on the potential of the incident.” (Bratbakk et al. 2005:2)*

Finally before I leave the Snorre A incident, I will look at the influence of the safety authorities: Below is a quotation of parts of the the NPDs[10] press release dated *11 November 2003* after the previous safety inspections onboard Snorre A:

> *“Background for inspection*
> *The background for inspection is the general increase in the number of reported gas leaks on the NCS in the 1998 – 2002 period.…In 2003 the Snorre field is among the Statoil operated fields with the highest number of reported gas leaks…The purpose of the inspection is to assess the Snorre A organizations daily monitoring of gas leaks, including registration, internal and external reporting, identification of causes, establishment, dealings and conclusions of actions. In additions ongoing and planned actions for the preventions of gas leaks on the Snorre A are assessed…*
>
> *Results of the inspections*
> *It has been both been conducted and are planned a number of actions helping to improve focus and prevent incidents stratified as gas leaks on the Snorre A…Signals from onboard management that one always has time to work in a safe manner are clearly communicated and understood in the organization. …SNA revealed no deviations” (SNA 2003 - authors translation)*

Considering that the all the three reports (Brattbakk et al. 2005, Sciefloe et al 2005 and Wackers 2006) all agree that there were weaknesses in the platforms technical condition and in the operating procedures of the crew and land organization running back for several years, this report is remarkable. My slightly harsh conclusion is clear; NPD (later SNA), had very limited influence on the safety level in the Snorre A operations leading up to the accident. One can also wonder if SNA’s very strict reaction with describing 28

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[10] NPD was divided into NPD and SNA onth e1st of January 2004. About two months after the inspection

breaches of rules little over a year later (Brattbakk et al 2005)[11] is a recoil action to regain lost authority or even to cover up on weak controls.

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[11] This lead to Statoil later being issued a 20 mill NKR fine for breaching regulations mandatory by law

5 Normal operations and cross case analysis with the accident cases

Background for the interviews

During the last parts of July and August 2007 I interviewed 14 persons working in the offshore part - completion phase of the Ormen Lange gas field development. I will first turn to explain the Ormen Lange project as context for the interviews

5.1 The Ormen Lange project - completion phase

- Carrying out challenging work on the forefront of offshore technology

Overall picture of the Ormen Lange Project

During the spring and summer of 2007 the completion phase of the sub-sea wells was the largest activity in relation to drilling, well completion and workovers on the NCS. The Ormen Lange project is one of two projects representing the eight step in technological design on the NCS, the platformless design (se section 2.3). The Ormen Lange gas field are to be constructed with two large sub-sea well templates, sub-sea processing unit for removal of sand and water, a double 80 km long multiphase pipelines and a processing and control facilities on land in Nyhamna on the Northwest coast of Norway. Quite unique is the depth of the sub-sea well templates and the lower part of the pipeline, the dept is approximately 800 meters.

The gas field was confirmed through exploration drilling in 1997 and construction start was approved in 2004.(OED Factbook 2006:160)

Hydro is operator for the construction phase while Shell will be operator for the field when completed. Hydro are responsible for the construction of the land control and processing facilities The installation operations offshore are run with the somewhat strange organizational structure of Shell being sub-contractor for drilling and completion of wells, FMC-Technologies provides the sub-sea units and the company Seadrill are contractors for the drilling and are providing the drilling ship for completion works. A number of smaller contractors are involved. Ormen Lange are considered to be among the major field development projects within the Norwegian Oil and Gas industry. (Information provided by Hydros information office and Shell employees)

Fig 50 The onshore processing and control site in Nyhamna under construction ©Hydro/ Ormen Lange project homepage

Fig 51 Dimensions of the sub-sea well template for eight wells with control equipment ©Hydro/ Ormen Lange project homepage

Fig 52 Dimensions of the sub-sea well template for four wells with control equipment ©Hydro/ Ormen Lange project homepage

Fig 53 Artists impression of Sub sea well template containing wellhead control equipment, in the background start of 80 km double multiphase transport pipelines to land processing plant ©Hydro/ Ormen Lange project homepage

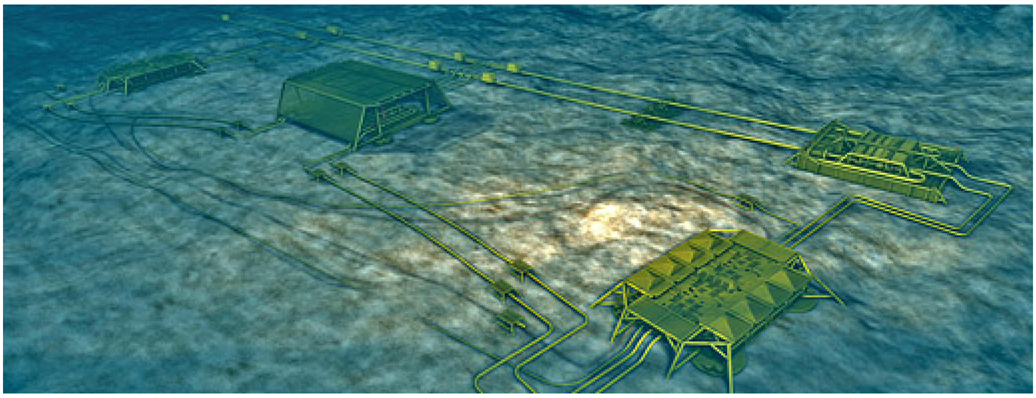


Fig 54 Artists impression Ormen Lange sub-sea installation, two well templates, right and left, sand/water separation unit centre and start of multiphase transport pipelines upper right and background ©Hydro/ Ormen Lange project homepage

The completion phase

The completion phase was only a part of the gigantic Ormen Lange project and ran in parallel to the completion work being carried out on the onshore processing plant and control systems. Prior to the completion phase the affected gas wells had been drilled and the 80 km multiphase pipelines transporting the unprocessed gas to the shore were laid.

The completion phase can briefly be explained as consisting of:

- cleaning out the wells after drilling,
- installing the piping and cementing it,
- installing the down hole-equipment (equipment below the seafloor) inside the well,
- installing the sub sea wellhead control and safety equipment,
- testing the integrity of the assembled well and control equipment for a multitude of situations
- connecting the well head to the transport piping

All is carried out from the drillship West Navigator at a water depth of about 800meters

Fig 55 (left) West Navigator drillship ©Seadrill Fig(right) Workers on drill deck of West Navigator ©Hydro/ Ormen Lange project homepage

Fig 56 Artist impression of completion work on Ormen Lange sub –sea well template
NOTE Protective shields folded to the sides and the exposed well-control assembly and blow out preventers. To the rear a Remotely Operated Vehicle (ROV) used to do the actual operations at 800m depth ©Hydro/ Ormen Lange project homepage

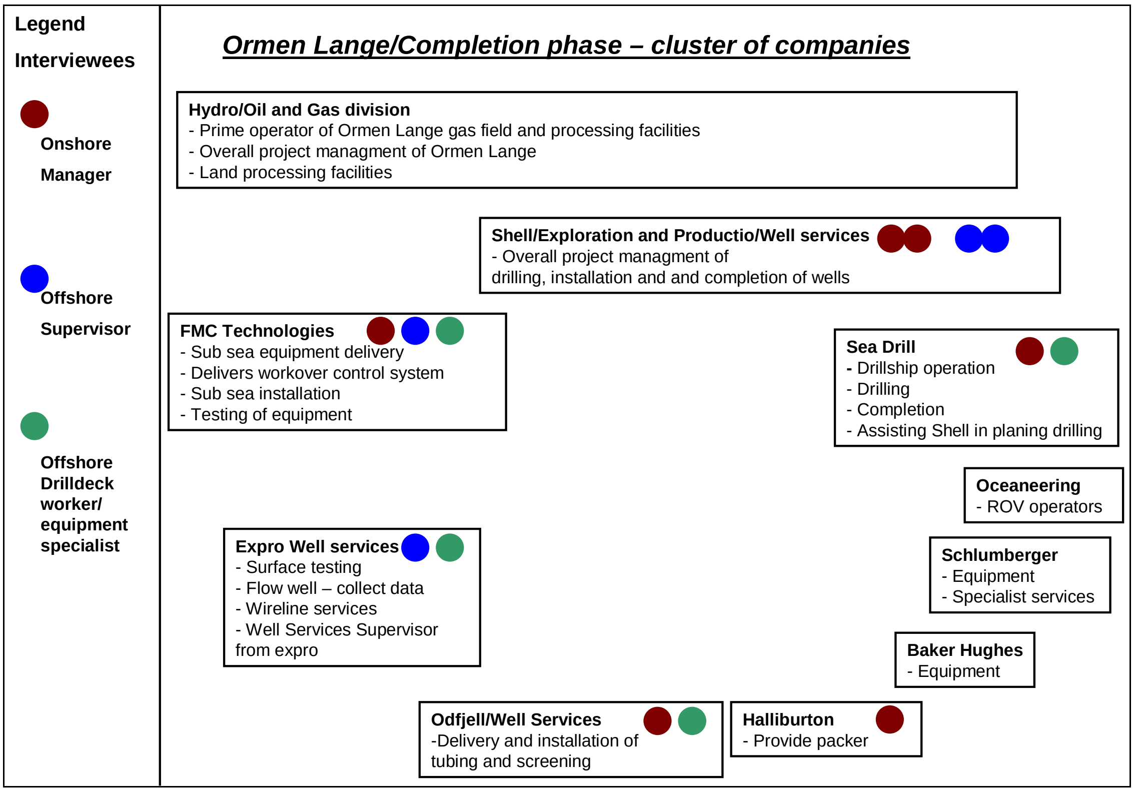
Fig 57 Artist impression of completion work on Ormen Lange sub –sea well template
NOTE Protective shields folded to the sides and the exposed well-control assembly and blow out preventers. In front a Remotely Operated Vehicle (ROV) used to do the actual operations at 800m depth ©Hydro/ Ormen Lange project homepage

5.2 The interviews and observations – Ormen Lange Well Completion operations

Methods and selection of interviewees

During the last days of July and in August 2007 I carried out 14 interviews of people working in different positions for different companies that took part in the carrying out the completion phase of well number 3 on the Ormen Lange. Most of the interviewees had been involved in the earlier completion phase of well number one and two earlier in the spring-summer or were working on the planning of the fourth well already under way.

The interviewees were employed in seven different companies working in tight relation while doing the completion work on the sub-sea wells. Selecting the interviewees I tried to get an equal a mix of "offshore" and "onshore people" and a mix of project management, planners, offshore supervisors and those who carry out the actual work on the drill-deck of the drillship.



For a detailed list of persons, companies and positions see Attachment B.
The interviews lasted between 40 and 65 min each and were carried out as semi structured interviews were I after a little introduction ran through a list of talking points with the interviewee. For the introduction and talking points see Attachment C. For the analysis se Attachment E &F

I was also at twice present in Shell Well Services daily routine teleconferences between onshore operations management and offshore supervisors. I was also present on one daily teleconference between Seadrill operations management and captain and drill supervisor onboard the drill ship West Navigator.

I analysed the interviews and observations in relation to the theories in chapter 3 through the help of the two analysis schemes Attachment E and Attachment F respectively. I recommend the reader to use these two attachments for reference.
In the main text the interviewees are held anonymous because the interview group is small and some of the interviewees choose to answer anonymously.
I have grouped the interviewees in three main groups;
Onshore management (including management at equipment suppliers/service providers (6 persons)
Offshore supervisors (4 persons)
Offshore drilling operators/equipment specialist (4 persons)

Results

The general impression is that the well completion project/Ormen Lange was run safer than most projects experienced. Also with one person disagreeing, those of the interviewees with international experience viewed the Norwegian offshore oil/gas industry in general as safer than the normal situation in the international offshore industry.

Looking at *trust at distance* first there is considerable communication onshore – offshore as well as vice versa. Details workplans are generated and transferred from onshore management to offshore. Considerable amounts of information go the other way also.

Central in the completion process are a set of workplans called Complete Well on Paper (CWOP) provided by Shell. CWOPs are drafted and run through quite extensive planning meetings with the affected sub-contractors representatives present. . Sub- contractor/equipment suppliers personnel found it generally easy to get their views included in the planning process. “Shell is very professional and thorough in the way they plan the operation” an onshore manager outside Shell expressed, comparing the Ormen Lange project with earlier experience.

The offshore personnel both supervisor and drilling operators/equipment specialists generally trusted the transferred plans. Most of the offshore personnel found it fairly easy to question the sequence or asking for the reasons behind a certain procedure in CWOP. Two of the interviewees express that they find Shells system rigid and finds it difficult to get necessary procedural change. The amount of documentation was also felt to be too voluminous and detailed. One of the interviewees attributed this to a UK-management style (Majority of the Shell management and supervisor personnel comes from the UK).

Information distribution is important in keeping trust. Workplans were generally received in reasonable time according to one interviewee working as operator offshore. After reception the workplans were reviewed by supervisors but also operators had access to the plans before they were briefed. The offshore operators except one felt it was easy to ask for explanation for the reasons for a certain sequence or details in the workplans. The plan for different work phases were reviewed in planning meetings or pre - shift (handover) meetings. Smaller coordination's and reviews of working procedures happened as toolbox – talks often.

"Generally I find this system to function well" (Offshore operator) is a good description of how most of the interviewees expressed there view on the onshore planning – offshore operation/execution system.

When observing the three daily teleconferences between onshore management - offshore Well Services Supervisor and Onshore management - Captain/drill operations leader on drilling ship, I found the tone to be open, though the discussion was quite detailed when it came to program, logistics, operational procedures for well operations or safety issues. More often than not the agreed solution to problems was initiated offshore.

In relation to *sensemaking* the interviews did not provide sufficient information on whether those working offshore had problems understanding the operation. I did not observe any indications when I observed the daily teleconferences, but this is not sufficient to draw any conclusion.

When it comes to the question of social barriers to challenge a common perception that a given operation is safe, so where there as mentioned earlier an open tone where the operators/equipment specialist explained that they could easily ask why certain details or sequences were planned as they were. On calling for stop in case of emergency these two quotations give good indications;

> "*We try to push a culture where everyone can stop the process... because we don't know the people it is difficult to know if they will say stop" (Offshore supervisor)*
> “Everybody has the ability to shut a well in if something is not going quite right” (Offshore operator)

Two other offshore operators/equipment specialists expressed the same view.

A challenge to getting a common and unified understanding of what is going on during an operation, especially in the area of safety, is the diverse procedures/systems of risk assessment. By different representatives from different companies using their company’s risk assessment methods/matrixes/systems chances of diverse opinions in case of a situation of doubt is increased. This is a consequence of the extensive use of sub-contractors and specialist coming from different companies with different cultures.

Most assessment methods are based on the experience/knowledge of those present supported by experience gathered within a company in the form of handbooks/in some cases databases.

On the question of *entrainment* problems most of those working as offshore operators/equipment specialist and offshore supervisors felt that they had sufficient time to work safely. The general notions where that it was stated that *“Shell want us to work safely, they say take the time”.*

On a few occasions some had felt that they had been pushed on tempo to finish jobs according to schedule. This was on occasions with failures in equipment or other delays occurred. The push had come from offshore supervising personnel. I did not observe nor did any of the onshore staff report that they felt tempo to be too high.

If there is tempo pressure it seems to be the offshore supervisors who are most “in the squeeze”. One of the supervisor explicitly stated he would like to be more in action, hands on with the team on the drill deck as supervisor he ended up spending to much time with office work.

The role of being a leader, coordinator between groups of contractor teams and being responsible for communication to land (which obviously takes up quite a bit of time) seems the most challenging in relation to tempo.

One supervisor stated that he would like to be more in action hands on with the team on the drill deck. As a supervisor he ended up spending too much time for office work while offshore. Logistics and equipment took much time.

An underlying notion of the need to keep up tempo is still there. The following quotations give an indication;

> *"Time saving is important but not a reason for pushing. We have to work smart " (offshore supervisor)*
> *"They say we have all the time in the world, but that is not really the case....you can't just sit around not doing the job*
> *Shell is paying for a service and they expect to get that service we have to act professionally" (offshore operator/equipment specialist)*

This notion seems be more common to the whole branch than related to this project

Also an element of *conflictual framing* can be observed**,**

> *"A lot of politics involved in this project, and it hampers the decisions…Very political, even Shell finds it quite challenging to plan for this project"*
> but then the interviewee goes on to say***;***
> *"Background of fairly high pressure on the Ormen Lange team...very high profile job, [Shell] still seems to be taking their time ...good to see, even there are lot of pressure on the project they are at times taking a step back ...you don't always see that with other companies"*
> *(Onshore manager)*

The impression that Shell has to manage two potential contradicting views on the Ormen Lange project is reinforced by another of the interviewees;

> *"Much focus on the [Ormen Lange – completion phase] project, so Shell takes no chances" (Onshore manager***)***

The *complexity* of the project can clearly been seen in two areas. First it is the technical challenges, this is the deepest sub-se wells on the NCS, the wells are also of a larger than normal dimension, and the technical design is of a new unique type.

Looking at the organizational choices the project organization is larger than normal. There are a total of 11 companies with a total of 17 different departments supplying equipment or providing services (rf. the organization sketch above, some supply equipment through other companies). The number of participating companies is far larger than normal for a well completion project. Leading managers tells that it is challenge to manage and coordinate among so many actors. The large meetings preparing the judged by some slightly rigid CWOP (workplan) are by key management at Shell considered a way to mitigate on the problem of complex organization.

There has been difficult to get an answer on whether the complex organization was a calculated choice or just a consequence of the choice of using those companies that had the most expertise/best equipment/best contract conditions. As one of the key onshore managers said;

> *"Uncommon project organization, never met it before in the industry ….Don't know why this organizational model was chosen, difficult to comment on why this was cut up the way it was, I am aware that Troll was done in a kind the same way. There was an unusual allocation of work".*

It is also clear that the complex organization put some more strain on the offshore supervisors in their coordinating role. As a bi-effect of the organizational complexity we see that this leads to a higher than normal number of personnel onboard the West Navigator drilling ship, in itself a general exposure to higher than normal risk.

To transfer the views on how the interviewees experienced the project also has to include the positive attitude and expressed trust in the other groups/companies.

Technical challenges and complexity can also affect safety positively by increasing the motivation, one young offshore operator made a statement that can be illustrating also for the view of some of the other interviewees;

> *"A big challenge for us to participate in such a path breaking project as long as it is so much new equipment and new things happening, its interesting".*

Looking at how the interviewees as whole answered; when it comes to the role of the Norwegian authorities safety control organization we see that Norwegian standards for offshore operations (NORSOK) are used by the onshore planers for reference to quite often, but equally if not more often are company guidelines used. The one providing the highest standard is preferred according to statements from key onshore managers.

Offshore NORSOK is not used for reference, but company guidelines and the CWOP work programme are used extensively. These references are supported by on site risk-assessment tools like for instance the Task Based Risk Assessment (TBRA) used by Seadrill.

The Norwegian offshore oil/gas safety systeme is based in an indirect model, where the companies are responsible for their own safety assessment, reporting and control. This must be the reason why the direct influence of PSA through inspections seems to be meagre at best. Of the 13 interviewees who answered, two onshore mangers had briefly met PSA personnel. None of the offshore personnel had met them during offshore work.

5.3 Cross case analysis – three accident/incident cases and the case of normal operation

Comparing across cases problems of sensemaking is the most striking feature. Sensemaking problems are found in the build up to all three accident cases, in the non accident case (Ormen Lange) there is not sufficient evidence to determine clearly if sensemaking problems are present. The general set up with remote sensing into what for the normal human senses looks like a deep black hole, demands interpretation to be understood to reasonable degree to operate equipment safely provides a major challenge to human sensemaking. This is inherent attribute of this type of technological system.

In Carl Weicks theory (1992) the notion of the social conditions determining role in letting alterative ways to make sense of a situation come to expression is central. We find a common situation of hierarchal system where alternative views were difficult to bring forward in both the Bravo accident and the Snorre A incident. Contrary the openness and possibility to ask for verification observed in the Ormen Lange project seems to be of mitigative effect.

Disharmonic entrainment was clearly present within the Bravo organization. This inside effect seems to be gone from the organization in the later West Vanguard accident, Snorre A incident and Ormen Lenge normal operation. But in all three accident/incidents there has been problems with the at distance onshore planning/management vs offshore operation. We also se some indications that there are some pressure in the normal operation situation at Ormen Lange. The distant onshore planning/management vs offshore operation/execution is a clearly vulnerable system. Improvement in communication systems and information transfer seems from the Ormen

Lnege observations to be helpful, but this technology was also available at the time of the Snorre A incident. Human/social organization in this spatially distributed system is still important.

Trust at distance is a key element, but there is not a linear function between trust and safe operation. The crew on Snorre A trusted the distant planners to much. At West Vanguard offshore crews trusted plans and planners trusted offshore crews to interpret partial indications of shallow gas transferred with the drilling plans, they both failed in their trust. Safe operation seems best achieved when there is trust but with a full independent review offshore. The openness and possibility (at least partial) to communicate back questions and needs of clarifications seems to be important in the Ormen Lange project. In other words *balanced trust, combined with sufficient time and openness in communication* seems to be working best.

Practical drift with alterations of SOPs has been present in both the Bravo accident and to a degree the West Vanguard accident. The best explanation seems to be the newness of both projects, and I find it reasonable to weak competence among operating personnel both at operator and supervising personnel. Lack of experience and/or lack of formal education were present in both instances.

Looking at the technical design and complexity and coupling we se that offshore oil/gas rigs in general are complex and quite tight in coupling. This can be seen by studying the integration and structure of different technological designs (rf. chapter 2).

The combined production and drilling platforms are more complex and by combining those two functions on the same limited size platform the tightness of the coupling increases considerably and the major disaster potential of an accident increases beyond destroying the rig.

The movement to smaller spatially spread sub-sea modules decreases the tightness in coupling in oil/gas production systems. But during the drilling, completion and workover phases which still will be done from a drilling rig/ship the coupling remains the same.

The fact that I have only been able to identify conflicts in framing of the role of the technological systems in the Ormen Lange case seems to be a weak indicator. This might be related to method, the lack of indications on conflictual framing might be caused by limitations in the scope and content of the investigation reports. Only Ger Wackers (2006) report and the Scheifloe et al (2005) report look into the framing among outside actors of influence. And both reports show indications of effects from conflictual framing within the organization operating the platform. Ger Wakers (ibid) hold conflicts in framing between economic interests and operation demands as a key explanation of background causes.

Looking at all four cases whether accident occurred or not, *newness* seems to be central across all cases.

Bravo was new platform in a new industry; it was so new that safety rule-set for operation was not ready yet.

West Vanguard was a new platform in a new sector of the NCS, controlled from a relatively new operation management office with the quite new feature that it was a fully Norwegian manned operation.

Snorre A did not happen with a new platform, but the platform was the first of this type of technical design on the NCS, the technical design had certain weaknesses that could increase the damage potential of an accident. Due to several alterations in the operation organization and change of drilling contractor the organization around Snorre As management end operating organization were new.

Orman Lange is also new, Water depth, technical design and organization of completion crew is new.

I will leave the description of newness here but it is relevant for further discussion.

Finally I will look at the *safety authorities' influence* or lack of influence in some cases. The 1977 Bravo accident shows a new organization that was not able to keep up in an expanding industrial sector. There is limited information except on the formalities in relation to the West Vanguard accident. The safety authorities inspection of Snorre A giving "no remarks stamp" a year before the incident and then returning with a list of 28 breaches leading to a large fine a year later is a blatant example of lack of organizational self conciseness in a agency that is important for the welfare of a large number of people.

To me this gives an indication that the safety authorities have developed into a more distant administrator and legal management agency than a hands-on emitter of good safety culture. The Ormen Lange material indicates that company safety standards has bypassed much of the formal regulations in influence. In itself this is not necessary bad, it connects the economic with demands of safe operations within the same organizational unit. But we can end up in a situation where there are major differences between companies and/or installations. Both looking at what the interviewees said in the Ormen Lange material and comparing Ormen Lange and Snorre A as cases of the same time period, can indicate so.

6 The Socio - technological Context of the Blow-out Accidents

6.1 Theories for understanding the contexts effects

Social Construction of Technology

Wibe Bijker and Trevor Pinch forwarded their theory on how technology went through a phase of shaping and selection where technology had to fulfil certain needs for the users before the technology were selected. The technology which fulfilled the needs best would through a process of selection but also alteration as a consequence of inputs before it was selected as the bearing technology (Bijker & Pinch 1987)

6.2 The Socio – technological development of the Norwegian offshore industry

In the anthology Oljevirksomheten som teknologiutviklingsprosjekt (The oil industry as technology development projec) (Olsen & Seiersted eds 1992) describe the socio-technological historical development of the Norwegian Offshore oil/gas industry. Through the basis of SCOT-theory the authors describe three historic phases in the development of Norwegian offshore oil/gas industry; a *technology import* phase, a *Norsefication* phase and a *diversification* phase. These are main trends and the shift from one phase to another is not exactly on date, but happened over some time. In the transfer periods between two phases technical and organizational trends from both trends could be visible. Also as I noted in chapter 2, the older designs of platforms and well systems had so long life spans so they continued to exist alongside newer technical designs and organizational structures. Modifications were done, but sunk cost set limits to how rapid technical structures could pass out of the industry.

I will describe the social technological context in the time leading up to the three blow-out accidents/incident. I will describe main development trend, technical design trend, social/organizational trend and the safety control authorities for each of the three phases.

I have used Olsen and Seiersted (1992) and Lie (2005) as general sources

From start in the 60s to 1975 – technological import

During this period the main development trend was the import of foreign knowledge primarily from the major oil companies. The Norwegian government went into a exchange system by letting the companies take part in the exploitation of oil/gas resources perceived to bee public property in exchange for money in the form of taxes, assets in the form of investments and transfer of knowledge.

The main technical design trend was transfer of designs utilized in the then only developed offshore oil/gas province, the Gulf of Mexico (GOM). From GOM came floating drill rigs and steel jacket structures (se section 2.3), but due to different operating conditions in weather and sea conditions some modifications were done. One class of technical design of rigs, the jack-up rig, made only a brief appearance on the NCS, before it disappeared. Equally important but not so visible is the transfer of organization models, knowledge, and safety standards. The organizational model was a hierarchical model within operating crew with extensive use of specialist contracting companies. This organizational model was different from the Norwegian model of industrial organization with more equal structures and where competence was more in-house. During this period the safety control authorities had to be organized and manned. There was a heritage from the safety control of ships and this probably lead to two things. The safety control regime for floating rigs became divides with ship-control authorities control the “ship” capabilities and that the newly established Norwegian Petroleum Directorate gave priority to establishing safety standards and rule set for floating rigs first. In the later part of the period effects in the transfer of knowledge started to take effect. The Norwegian shipbuilding company Aker, developed their own floating rig design and the early Condeep structures appeared.

Looking more specific at the time running up to the Bravo Accident in 1977; and looking at economic indicators, the oil price surged from 4 to 10 USD/bbl in 1973 while the platform were in the early stages of construction. In the 3 years before the accident the price continued to climb from 11 to 14 USD/Bbl. Also the rate of offshore investment was in the range of 14-18% of total Norwegian investments, and the share of government revenue from offshore production picked up from 0 to 5 % in those years. (for revenue /investment data rf. Claes 2005: slide 19)(for price data rf OPEX statistical bulletin) .

In other words the Ekofisk Bravo technological system were constructed, manned an came on operation during a period of rapid expansion and continued to operate in an still expanding industrial sector for two years before the accident.

The next phase starting in 1975 and lasting to 1986

The main technological trend was the sc. “Norsefication”. The effects of technology transfer kicks in and production of the large Condeep platforms pick up. Condeep is adopted for utilization of Norwegian technology concrete and post-shipbuilding technology leading to a high number of Norwegians employed in the industry and revenues lead into the Norwegian society: A winning combination in relation to the needs in Norwegian society. The long legged condeps opened up for platforms in the middle depth areas of the Northern North Sea. To keep up expansion and divide the benefits of offshore expansion to the parts of society further north along the coast, exploration drilling starts in the Norwegian Sea from 1984.

During the late 70s we get a number of strikes on offshore installations with demands for change in work conditions, pay and representation through trade unions. Organizational structure starts to get influenced by Norwegian culture of equality and participation, and Norwegians advance to leading positions in the offshore operations. The dependence of foreigners to provide knowledge is rapidly sinking. The New Norwegian public oil company Statoil also develops into having a dominating role through this period. After years with high rates of smaller accidents often with fatal outcomes, the 1977 Bravo blow out and in 1980 the grave Alexander Kielland accident with loss of 123 lives, the Norwegian safety control authorities are reorganized. Post 1981 the companies bear responsibility for its own safety control system and reporting. Where there are many contractors involved, the operators of a field are given a special role for safety coordination and control. The safety control division of the Norwegian Petroleum Directorate assumes a role of controlling the companies’ safety organizations

Looking at the economic conditions in the years leading up to the West Vanguard accident we se that the oil price were swinging in the 27 to 29 USD/bbl range and that Norwegian oil production increased from 490 000 bbl/day to approx 800 000 bbl/day between 1982 and 1985. Offshore industry's shares of total Norwegian invest hovered just below the 20% mark. Share of government revenue climbed rapidly from approx 15% to the late 20s%. The share of export rose in those years to the mid-thirties. (for revenue /investment data rf. Claes 2005: slide 19)(for price data rf OPEX statistical bulletin)

We see that the West Vanguard accident happened after a period of rapid advancement of the offshore oil/gas industry. Share of total invest had become high, revenues were high and the oil price were good. But this high level of investment had forced structural adjustments in the production industry. In 1983 the Norwegian government started to use stable investment rate as a messure for how many field developments the government approved (Seiersted et al: 262). A necessary consequence is that new fields had to be found so there were room for keeping the investment rate into the future, another type of expansionism.

The third is the post 1986 diversification phase

The main technological trend is *diversification* and a little later internationalization. Post the 1986 dramatic drop in the oil prize, different designs started to appear on the NCS. New designs like sub sea production units, Tension Leg Platforms (TLP), FPSOs and divided offshore – onshore processing (se section 2.3) appeared as solutions to keeping the cost down while simultaneously moving production into deeper waters. Advanced drilling techniques to utilize the fields better and improved transport solutions for unprocessed gas was a part of this development. In this phase we still se a continued element of expansion on the NCS, but by the early - mid 90s both Norwegian equipment/services suppliers and oil companies moved were also moving out into other oil/gas regions and the international market.

After the drop in the oil price in 1986 from the high 20sUSD/bbl down to 8USD/bbl, a short drop in offshore industry’s share of total invest happened. Before the commissioning of the Snorre A in 1991 the price had partially recovered to the 14-18 range. The offshore industry’s part of invest quickly picked up to the level of before 1986 and in 1991-92 passed this level and went beyond in spite of the now lower oil prices. At the same period government revenues picked up from the low level of 1986-88, but at a lower level in the 10%range. National production figures for oil continued to increase from 1,8 mill bbl/day in 1991 to 3 mill bbl/day in 1996 for then to stabilize at this new level.(OPEC Statistical review –table 39) Gas production also increased in the same period.

This was achieved both by more production units being commissioned/more fields started production, and increased production on the developed fields by among other efficiency improvements, enhanced drilling techniques (se section 2.4) The oil/gas part of government revenues, though shifting a bit, increased more than the climbing oil price in the period leading up to the millennium. In other words production efficiency and results measured by economic outcome increased.

In the 1999 – 2004 period the oil price first surges to high in the 20s then drops to mid 20s for two years for the to rapidly surge to mid 30s in 2004 (OPEC Statistical bulletin- table 73) Offshore industry's part of investment decreased and stabilized at mid-low 20s during the later part of the nineties and the first years of the new millennium.

Snorre A was constructed and commissioned in a period where the offshore oil/gas industry recovered from the effects of the price drop of 1986, where in operation at the time the Norwegian offshore industry both continued to expand and production increased both a result of new field s coming into production, but also because increased production results from each production unit.

Social construct of safe operations

Supported by the theoretical basis from Bijker and Pinch (1987) and supported by empirically by Olsen & Seiersted eds (1992) we have seen how social conditions have been shaping technology in the offshore oil/gas buissiness. Technical designs, social organization and are not only shaped by the availability of technology or determined by technological development. Equally social conditions shape technology. As we have seen under certain conditions we can trace ellemnets that causes vulnerability to a technological system. Vulnerabilities can be seen as embedded across the whole industry across time, differences in technical deigns or organization. As example we see that with the problems of sensing what's going on inside a well that to the human eye literately is a black hole going deep into the earth; independent of platform designs or organization of the workforce the operators have problems with interpreting what's going on. New instrumentation has been added, but so has scope, possibilities and dimensions in drilling the wells also, the ability to sense comes out about equal.

As a second example, putting people drilling equipment processing plant, helicopter platforms, etc. onboard such a concentrated area as an oil/gas platform is to make a technological system that has built in tight coupling. The environment in the form of sea and water depths called for this. Independent sub-sea modules improved this somewhat, but still there are considerable chances of problems causing major destruction to platforms. Platformless designs might solve this problem, but these technological systems are still to new to draw any reasonable experience to verify this.

When studying the three accident cases we also saw that causes related to the organization varied from case to case. Technical items whether failing or operating correctly were involved, but certain aspects of social organization could be linked directly to why technological systems failed.

As I have kept the basic notions that the technical design, social interactions within the associated organization and the social-technical interactions within a technological system must function for the system to operate safely. As we have seen technological systems is being affected by outside social conditions, whether we look at technical design or social organization, so I find it reasonable to say that there is a social construct of safe operation.

Vulnerabilities can be avoided or mitigated by design or by social organization.

Safety is not operating as the sole independent condition one want to achieve. Safety is competing against other central condition one want to achieve with a technological system. There will be a number of conditions competing for priority in the development and operation phase of a technological system. Also these conditions are often dependent of each other.

7 Technical, Social, Socio – technological Context and the Major Blow-out Accidents - Assembling it All.

7.1 The individual blow-out accidents/incidents

Bravo

Direct causes to the Bravo accident, faulty installation of the Down Hole Safety Valve, the lack of ready Blow out Preventer and the inability to react to the slowly flowing well, can be traced back to set of underlying causes in the social organization or the socio- technical integration. The negative outcome of rapid expansion and quick technology transfers manifested itself in the organization in the form of *entrainment* and *deviations*/inabilities to follow *operating procedures* leading to vulnerabilities. Organizational elements that could act mitigative to the dangers posed by rapid introduction of new technological systems like the security control organization and also knowledge gain were *out phased.*

West Vanguard

The rapidly expanded role of the oil industry's share of national income, the high level of an need for continued investment, and need for district incentives all worked in conjunction to create conditions contributing to the conditions of vulnerability observed in the West Vanguard case. Drive for exploration drilling in a new area and more complex land management organization, leading to loss in the information transfer between land and offshore. Also the *Norsefication* process lead to this being a total Norwegian accident, this raises the question of whether sufficient knowledge was transferred.

Comparing to observations in safety assessment processes on the Ormen Lange project we se the central role of *experience among those present*. It is reasonable to view this as central organizational attribute onboard the West Vanguard also. A question is if the now Norwegian organization had matured sufficiently to have sufficient knowledge onboard.

We can also se a technical element left over from the technological transfer phase. The inherited emergency diverter system was left with the usual design on this kind of platforms. The knowledge that these systems were not reliable as safety precautions were not transferred from the GOM to the NCS An increasing number of different design elements were through expansion going to be mixed with alteration of the supporting organization.

7.2 Across cases

Complexity

The embedded problems of humans in making sense in the complex coupling between the natural, sea, engineering knowledge and human organization can be seen across all cases whether there are accidents or not. This can partially be attributed to the complexity of offshore platforms and rigs as technological systems. The lack of direct access and need for sensing through instruments seems to be a key parameter

Trust at distance

The onshore – offshore planning –execution system is dependent on trust to function, but looking at Bravo, West Vanguard and Snorre A cases the level of trust has been to high. On the other hand with too little trust there will be zero benefits of the onshore – offshore planning execution system. The crew of the rig would be cut of from management support and competence. Trust at distance seems to follow a inverted U – shape in relation safety. In the middle where there is sufficient trust to function efficiently, but still checks and control with material the best function of trust at distance seems to be.

Expansionism

In describing the Snorre A incident, Ger Wackers has attributed the grave incident to problems in stable *performative closure* between the Economic and Engenering realms. Framing the operation in these two opposing ways caused pressures on the organization and causing vulnerability and ultimately exposing the technological system to a grave incident. I agree with Wackers that economic vs. engineering framing is a good explanation to the Snorre A case. But neither in the case of Bravo nor the West Vanguard accident were there economic pressures. On the contrary the accidents happened after periods with high market prices and almost unlimited access to investment money. I am also of the opinion that reducing the problems down to two conflicting frames, though well augmented for by Wackers, is to reduce the complexity of background causes to much. *Complexity* and development paths leading to complexity are in it selves interesting as causes.

The phases of technological import and the Norsefication process marked the period leading up to the accidents on Bravo and West vanguard. I have sais earlier that *newness* is a repeating attribute between those cases. Comparing to the historical development (ch 6) and looking at the many technological designs introduced in short time (ch 2) *expansionism* is the unifying descriptive term. Snorre A was the first of its kind of technical design on the NCS. Troll A with its divided offshore-land processing and Ormen Lange are in reality prototypes. In its eagerness to establish the offshore oil/gas industry as sources of welfare the Norwegian state/society has showed an aggressive expansionism.

At times leading up to the Bravo blow-out accident safety control authorities and most likely, necessary operating knowledge were lagging behind. These elements balancing expansionism and protecting against vulnerabilities were not present to a sufficient degree.

In the West Vanguard accident the complexity of a newly expanded operation management system was not able to transfer the knowledge of potentially dangers to the crew and possibly the crew had insufficient knowledge to absorb the dangers and act accordingly. Critical supporting structures and key knowledge related to safety did not develop in pace with the rapid expansion. On the other hand high engineering competence worked both as driving force, but for many development projects also as mitigative to accidents by engineering standards and safety design checks.

7.3 Generalization

Methods

First it is relevant to look for vulnerabilities and causes of vulnerabilities when explaining causes of accidents. Vulnerabilities can be found coming from both inside and outside a given technological system, it is in halting interaction between the different elements I have found the explanation. The interaction between the different elements can be inside, outside or through the technological systems boundaries. Equally the causes of vulnerabilities can be manifested in organization, social surroundings and the technical design/technical sub-systems or in the interaction between these elements. Though conclusions can seem to be complex and not clear cut to the reader I uphold my starting point of *multi faceted analysis* to identify causes of accidents. It is also necessary to analyse by the step of vulnerabilities.

General Causes

Looking at these cases of accident within the offshore industry on the NCS the striking feature is that accident happened quite rapidly after either expansion or changes. New conditions outpacing the organizational structure have been a repeating pattern.

The drive for introduction of the new technology, first by import of technology and know-how, then by taking over and running the business on Norwegian hands has lead to rapid expansion, especially in certain phases of surge. The social drive for establishing and sharing spatially the effects of this expansion can be seen. Maybe in reliability and accident sciences we can do away with the picture of the old run down facility as the prime cause of accident

For the individual - An onion of risk attribution factors

Returning to the introduction to this thesis and Ulrich Beck description of risk distribution and the individual, we se through the examples from this accidents that risk to the individual worker inside these examples of advanced technological systems, that risk is constituted through social organizations and effects in several social layers around the individual.

Ultimately, in the long run the drill deck worker is not only affected by her/his relations to those whom she/he works with or the machinery in the immediate surroundings. The risk is constituted by the technological system and its key sub-components of technical structure shaped by design, organization including knowledge and situational interpretations. But again the technological system is part of larger industrial sector shaped by demands from a larger society and solutions for fulfilment of these demands. Operational safety of potential dangerous systems and safety of the workers has both been important features in design and operation of technological systems. But safety is not a sole individual and independent feature above the rest of a technological systems design and operational criteria's. Safety is a feature that is partly built in and partly upheld in the heavy socially influences processes of design, selection and operation of technological systems. In this process vulnerabilities and hence risk to the workers and other individuals relating to the technological system is consciously or unconsciously moved within the system and between the system and its surroundings. The individual workers ability to assess risk and to control risk and hence affect her/his exposure to risk is limited as consequence of the complexity and interactions of modern technological systems.

ATTACHMENT A

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System description - Omen Lange - Completion operation	**NOU 47/1977 Bravo rapporten** *Norw.Gvmt.Investigation 47/1977 The Bravo report*	**NOU16/1986 West Vanguard Repporten** *(Norw.Gvmt.Investigation 16/1986 West Vanguard report)*	**Brattbak, M., Østvold, L-Ø., Zwaag, C. v.d., Hiim, H. Granskning av gassutblåsning på Snorre A, brønn 34/7-P31A 28.11.2004** (*Investigation of gas blowout on Snorre A, well 34/7-P31A 28.Nov.2004)*	**Årsaksanalyse etter Snorre A hendelsen 28.11.2004** (*Analysis of background causes of the Snorre A incident 28 Nov 2004)*	**Vulnerability and robustness in a complex technological system: Loss of control and recovery in the 2004 Snorre A gas blow-out**
Test against hypothesises					
H1: (Giddens) Considerable trust at distance	p: 28 Onshore planning Offshore execution system p: 42 Lack of redundancy in assessment of quality of procedure p:50 Distributed Onshore planning - offshore execution described P:50 Weak information transfer, Onshore to offshore	p: 54 AS a consequence of the systems described on this page, considerable trust in the onshore planners are needed from the offshore personnel p:67 problems in transferring information on the geology/well condition to drill crew	p:14-15 Fragmented system of planning well operations p:23 "A challenge or weakness in RESU is the quality assurance. The engineers are sitting so tight together in the planning process that we get no one to double-check: We are humans altogether, and possibly we are not good enough to challenge each other" p: 26 Alteration in the sequence of pulling scab-liner and punching hole in 2 7/8 tailpipe, caused loss of initial barrier with BOP (second barrier) open. This sequencing is the same as planning with only one barrier (the primary barrier - casing + mud) p:29 Drill crew do not stop operation and check procedures before pulling scab- liner. Trust in onshore planning. (related to lack of proper revision by drill supervisor and drill chief two-three days before.	p:9 NEGATIVE Difficult to question onshore planning from offshore p:19 Group think in relation to conditions of well ??? p: 30 NEGATIVE Differing perceptions on technical condition of equipment between onshore and offshore p: 31 NEGATIVE Offshore personnel view land personnel to know to little about the offshore status and conditions p: 35 NEGATIVE Lack of integration between SNA/Onshore and the rest of Statoil/RESU p: 46 Lack of integrative decision processes both onshore and offshore	p:52 NEGATIVE The lack of involvement of drill organization lead to loss of information
H2. (Weick) Difficulties in sensemaking	p:31/39/40 Wireline tools causes problems in sensing what's going on when setting DHSV valve. After seventh attempt DHSV is assumed to be set p:31/42 Problems with interpreting causes of slow mud flow out of the well p: 42 "Drilling engineer were guilty of ..errors . In the choic between temperature caused expansion and instability in the well as an explanation for the increased pressure, he choose the least dangerous alternative, hence the temperature expansion" (my translation) p: 43 *"Drill chief tells that he found no reason to inform his superiors, as he was not sure there were floating more out of the production tubing than through the control line, and he viewed it possible that the cause could be the same. The commission finds his reasoning wrong and can hardly understand how an experienced drill chief could not recognized this clear warning of a blowout"* (my translation)	p:27/p: 37 Problems with making sense of drill break combined with high gas measures in mud 2 - 1hour before well blew out. p:37 around 2200hours, Unclearity on whether mud was lost or gained p: 39-40 Problems with assembling the different data from instrument readings p: 46 Lack of understanding in weakness in gas test of mud procedures - problems with interpretation p 54 Complexity of drill programme posed challenges to sensemaking p:59 Problems with understanding and interpretation of gas measure/readings in mud p:72 *" The drill crew have in this instance not seen and/or understood danger signals which with sufficient time could called their attention on what were developing"* (my translation) p:73 "Presentation of drill data should be made better" (my translation)	p:15 deviations from expected pressure reactions in mud system caused no reactions p: 16 problems with relating first gas detections to a gas leak, erroneous readings attributed to failure in process equipment in the Vigdis gas processing module p:19 2 hours and 6 min after first gas alarm were blowout to sea confirmed p:25 No one in the planning process were able t grasp that both the first barrier (casing + Mud) and second barrier (BOP) would be open at the time of the puncture of the down-hole 2 7/8 inch tail pipe		p: 55 Not understanding consequences in puncturing 2 7/8 inch tailpipe before pulling 7 5/8 Scab liner p:56 "to the crew on the platform the problems presented themselves as a strange pattern of pressure surges in the various compartments of the well and tubing at the drill deck" - problems in sense making
H2 B. (Weick) Controversies over signals of dangers	p:29 Discussions over reliability of DHSV vs. other equipment between OTIS operator (wireline contractor) and acting drilling superintendent p:33 OCT- operator perceive something is wrong with pressure balance in the well, says he contacted drill supervisor p:42 "Drilling supervisor choose to accept drilling engineer explanation and decided to carry on with his work without seeking advice with his superiors" (my translation). p:43 On the Drill chief *"It is surprising that none of his subordinates , including the shift supervisors, put forward no objections against continuing the work when mud came up through the production tubing"* (my translation)	p:52 No challenges to perception from fear of destroying rock structure by using heavy mud for safety, and the continued use of (sg. 1,08) mud p: 67 Conflictual views	p: 29 Controversies over whether pulling scab liner through BOP were a dangerous operation requiring special permission	p:9/ 20-21 Difficult to pose questions onboard the rig p: 32 Difficult to pose critique	
H3. (Ancona & Chong) Disharmonic sequencing or tempo caused by entrainment	p: 28/42 Some contractors had 20 and 30 hours work period because there were no night shift p:43 Drilling supervisor slept for 1 hour during last 36 hours p: Drilling supervisor and Drill chief are on single shift - disharmonic cyclic entrainment with two-shift for rest of crew	p:55 Little time for preparations for offshore drill crew due late arrival of drill programme from onshore. P: 67 NEGATIVE no report on insufficient time and time pressures to carry out the drilling	p:13 Programme approved by all necessary instances p:37 Temporal adjustment in planning and approval procedure (due to drilling of previous well were finished earlier than expected)	p: 20 Disharmonic cyclic entrainment in planning work operations p: 26 Disharmonic temporal entrainment in time for leaders and central persons to read documentation and go through the mandatory procedures for safety control p: 28 Prevailing answers to the reasons for procedural breach. Not sufficient time to use safety documentation or not sufficient time to do as required in procedures p:38 Confliction framing between production and time to work structured and after overall plans p: 40 Insufficient time for both onshore and offshore leaders to supervise because of large burden of administrative duties	P: 55 Need for more time to coordinate complex operations p: 56 The two day early finishing of previous drill job and the decision to start work on 34/7 P31A two days earlier and skip final safety assessment - sequential disharmonic entrainment
H4. (Vaughan) Conflictual framing or view on role				p:10 Conflictual perception on role of leaders onshore and offshore - administrative duties vs. actual on site leadership p:20 Conflictual framing on the role of risk assessments in Saga vs. Statoil p: 29 Cross pressure between short term production demands vs. the need for long term systematic maintenance p:38 Conflictual framing between production and time to work structured and after overall plans	
H.5(Snook) Alterations of SOPs	p: 29 deviations from plan to use DHSV and not to use salt water before killing with mud p:29 Drilling superintendent decides to change plans and install DHSV with out conferring p: 30 deviations from plan when installing DHSV in mud p:34/38/43 BOP not assembled and ready when well is opened p:38 Mud weight not as stated in workover programme p: 39 *"A pre- planned on programmed workover job , in accordance with the demands of safety regulations par 99, where now replaced with improvisations, Differing views surface among the actors on which solution should be selected , and the decision process is not assuring"* (my translation) p:51 Provisions in Phillips safety handbook not followed	p:41 deviations from Both Smedvik and Statoils drill manual Circulation break (from drilling) not carried out last two hours despite occurrence of "drill break" p: 46 Lack of trust in gas measurement and use of improvised "hand test" in mud	p:14 Puncturing down hole safety valve without sufficient barriers. p: 32 Deviations from drill operators SOP of having safety back up equipment (kill stand) ready when piping are pulled through the BOP	p: 37 Offshore personnel on SNA dependent on constant adjustment and micro coordination	p:54 Locally decisions on the well recovery work plan look smart
H6.(Perrow) Complex interactions and-or tight coupling	p: 28 Contractors and organizational complexity p: 30 Mixing of very similar parts in BMH- plug - causes malfunction p: 37 Insufficient detail information about wells technical solutions and conditions available p: 49 Discussion on the complexity of the organization	p:61 Ventilation intakes in close proximity of drill deck helped to spread gas before explosion p:41 Complexity in organization cause confusion when Smedwigs Asst Drill Chief thought that Statoils Asst Drill Supervisor had done circulation check after dri break and vice versa	p:3 SNA is a *floating TLP* platform anchored *above a well frame of 42 wells. Tight coupling by design.* *p:13 Programme approved by all necessary instances* *p: 23 Potential of destruction of well frame of 42 wells* p:21/41 Impossible to close pilot flame on flare when main power were cut p: 26 failure of transformation about knowledge of wells weaknesses. Complexity in information handling systems p:31 Lack of overall overview barrier safety after alterations to initial drill programme p:33 Kelly cock (Driveline safety valve) blocked by skirts around top drive (in derrick) To tight coupling p:41 Emergency power supply to small to run the necessary pumps for the emergency kill operation when main power were closed down and engines of the cement mixing machines took air from underneath the platform. Tight coupling x 2	p:11 Floating TLP platform anchored above well frame of 42 wells p:28 To complex safety documentation. The individual user are not able to utilize safety documentation p: 44 Lack of understanding of the reality of failed outer casing (13 3/8 casing) under the failed pressure test in 2003	p:54 Locally decisions on the well recovery work plan look smart p: 55 Tight coupling in a well workover operation p: Uncoupled decisions in a tightly coupled system
H7 .(Bijker & Hughes) Negative design effects because of social influence on technological choice	p:21 1200 wells drilled in the North Sea 5 known blowouts + a few more p: 21 First Blowout on the NCS p: 23 Deep of Industry/Oljedirektoratet responsible p: 26 platform 2 years old p:59 Lack of inspections from authorities	p:21 Law demands on the use of marine riser and diverter system for this type of drilling :p23-26Three positions of knowledge on the rig/ in the drill organization held by foreign nationals (remains of the technology transfer project) p:36 From GOM data - Diverter systems known to fail in11 out of 18 incidents/accidents. Still by regulations the mandatory solution p:62 the deviation systems leading of gas to the platform deck - the whole set up of marine riser and deviation system is in generally to unreliable. p:54 Complexity of the organization and weaknesses in transfer of data p: 68 Statoils internal safety organization p:70 complexity of government safety organization	p:9/36 Rapid change of operators Saga-Hydro-Statoil p:9 Change of drill operators p:22 Accident potential p:24 Internal safety revision (Statoil) did not reveal weaknesses in planning procedure for drilling and well operations - weak execution of government regulations	p:7/ 20-23 Rapid organizational changes in period leading up to the accident p:11 Floating TLP platform anchored above well frame of 42 wells p:34 Fragmented organization with contractors. Contractors dependent on getting renewal of contract and find it difficult to raise critique	
Additional information					
	Date 22 apr 1977 lasted for 8 days	p:34 Shallow gas eruptions were viewed as a known risk when doing exploration drilling p:69 *"Not at least exploration drilling for oil and gas by experience considerable dangers for accidents"*	p:28 Weak system for distribution earlier HMS data.	p:4 Breakdown in multiple levels and units in the organization	p:21 Reference to the Norwegian welfare state
	p:21 Challenging to get information on blowout accidents because of operators secrecy about accidents	p:34 7reported shallow gas eruptions 20 known incidents before 1982 + some additional up to 1985 Known to be in the same area (Haltenbanken)	p.:9 High activity on SNA	p:5 Incident description	p: 22 Laws and standards, description of the hierarchy
	p:22 amount of oil 22500 tons (157500bbl)		p:10 Known weaknesses in well casings	P:5 Technical condition of SNA	p:30 Government ownership in Norwegian oil companies Statoil 100% Hydro 51% Saga Private + Some history
	p: 50 The role of work programs described		p:13 Programme approved by all necessary instances	p: 11/29 History of SNA	p:40 Contract conditions Driller - operating company
	p:54 Internal control system		p:23 Potential of maximum damage + number of persons involved	p:13 Well scheme of 34/7-P31A	p:50 Drilling of sidetracks
				p:17 Formal vs. informal organization (as relevant for analysis)	p: 51 Information on the well 34/7-P31A
				P: 38 Effects of informal organization	p:52 Description of alterations to original drilling plan with consequences

	Observation of Shell Daily Teleconference 22/8/2004	***Observation of Shell Daily Teleconference 28/8/2004***	***Observation of Seadrill Daily Teleconference 28/8/2004***
Test against hypothesises			
H1: (Giddens) Considerable trust at distance			
Good communication and influence on planning from offshore to onshore Good communication and influence on other companies planning from Indication of good communication - improved trust at distance	Detailed information (report) on past 24 hours and plans for next 24 hours shown on screen gives detailed status Status is comparable with Shells operation document Complete Well On Paper (CWOP) (brought by some participants)	Detailed information (report) on past 24 hours and plans for next 24 hours shown on screen gives detailed status Status is comparable with Shells operation document Complete Well On Paper (CWOP) (brought by some participants)	Information about upcoming critical flow test (of well) were in the process to be given to the crew
Clear leadership and quality in open planning from onshore to offshore Uncontested clear leadership improves trust at distance	Detailed discussion with rig supervisor around technical issue of safety relevance - Onshore Well services Team leader underlined safety	Detailed discussion with rig supervisor leading around questions about settings on an alarm system on drill floor - several aspects of this minor case discussed until agreement	
Good work relation with those one can talk directly to Poorer with those distant (clear/marked difference) Much higher degree of preffer{ence} for direct contact indicates lack of trust at distance			Discussion about when operation of third well would be finished Offshore set conditions accepted by onshore HQ Discussion raised from HQ around a riser chute - West Navigators view that operator error was a part of the problem and a procedural review were quickly accepted
High degree of trust in onshore plans when they are being executed offshore Indicates trust at distance	Supervisor on rig were leading the discussion when it came to a point with technical discussions of safety relevance	Rig supervisors view were upheld in discussions around alarm settings	
Deviations from plan without approval Practical drift - deviations from SOP	One safety issue raised from supervisor on West navigator about personnel being in to close proximity to heli deck when helicopter landed - support for rig supervisor for reporting and supervisors plan for action on the issue		
High amount and good quality in communication onshore- offshore and offshore - onshore Improves Trust at distance			
H2 A. (Weick) Difficulties in sensmaking			Discussion about unexpected values of pressure testing on well - questions on how this should be interpreted
H2B (Weick) Controversies over signals of dangers		NEGATIVE Information from offshore supervisor around unexpected pressure readings when testing - supervisor did not see any dangers and wanted to continue - calm discussion in HQ ended with the conclusion that values were within limits and operations could continue	
Low barriers for individuals to halt operations when problems arise Indications of low conflict level in relation to sensemaking problems			
Commonality in risk assessment methods High degree of commonality improves sansemaking in crisis			
H3. (Ancona & Chong) Disharmonic sequencing or tempo			

H4. (Vaughan) Conflictual framing or view on role		
H.5(Snook) Alterations of SOPs		
H6.(Perrow) Complex interactions and-or tight c	Question from rig supervisor on "Who's going to sign the work permit" The mitigation procedure for doing the risky work with open well (work permit from control room) is not fitted to new technological design structure (platform less) at Ormen Lange	Considerable uncertainties on West Navigator and Seadrill HQ about how much time Shell would devote to testing of x-mas three and BOP (well equipment components) - discussion in HQ inconclusive
Clear understanding of own role and own groups role as part of the whole		
High degrre of understanding has mitigative effects on complexity Low degree of understanding indication on complexity		
Common perceived risk/danger picture		
Common view on consequences of worst case accidents		
Common scale and scope of worst accident risk		
Commonality indicates reduced complexity Fragmentation show indicates complexity		
Good cooperation between companies		
Mitigative effect on complexity		
H7.(Bijker & Hughes) Negative design effects because of social influence on technological choice		
Outside influences affects the choice of technical, organizational and procedural solutions		
Indications for analysis of SCOT (CH 6)		
Government control		
National vs. Company vs. Rig/ship safety culture	Substantial time devoted to security reports on minor things	
Impact of national safety regulations		
Impact of Company /Rig/Platform safety regulations		
Use of official safety regulations/standards		
Gommonly used - higher effect of national safety standards		
Control or personal contact with PSA		
Effects of government safety monitoring through direct control		
Additional information		