REPORT

Building Safety

Human and Organizational Contribution to Resilience

Summary report

F. Størseth, R.K. Tinmannsvik, E. Albrechtsen, T.O. Grøtan,
R. Rosness, M.H. Rø, A.B. Skjerve, K. Øien

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TITLE

Building Safety –
Human and Organizational Contribution to Resilience

Summary report

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ABSTRACT

The overall objective of the Building Safety project, *Building Safety in Petroleum Exploration and Production in the Northern Regions,* is to produce knowledge to build resilient operational organizations for petroleum production in the northern regions, with the ability to prevent unwanted events through early warnings/indications.

One of the research activities in Building Safety is entitled *"Human and Organizational Contribution to Resilience",* and has as its defined objective to develop knowledge concerning how humans and organizations contribute to the resilience of a technological system; including knowledge on how to train capacity for improvisation.

The report presents an overview and key findings from the following research tasks:

1. Literature review on resilience, Resilience Engineering, and improvisation
2. A theoretical study on the relationship between resilience, adaptation, and improvisation
3. An empirical study on successful recovery of high-risk incidents (in the petroleum industry)
4. Case specific advice (for operational organization of the Goliat field)

The Building Safety project is funded by The Research Council of Norway and Eni Norge AS.

KEYWORDS	ENGLISH	NORWEGIAN
GROUP 1	Safety	Sikkerhet
GROUP 2	Organization	Organisasjon
SELECTED BY AUTHOR	Resilience Engineering	Robust organisering
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1 Introduction

The Building Safety project addresses safety opportunities and challenges in petroleum exploration and production in the northern regions[1]. Building Safety aims to provide knowledge for building resilient operational organizations for petroleum production in the northern regions, and the principal objective is to reduce risk to personnel and environment. The project is funded by the program "Health, Environment and Safety in the petroleum sector" (HMSFORSK) by The Research Council of Norway and Eni Norge AS. The research work is carried out in close cooperation between SINTEF, IFE (Institute for Energy Technology), NTNU (Norwegian University of Science and Technology), and Eni Norge AS, using the development of the Goliat field as case studies.

The project has three main research activities:

- Human and organizational contribution to resilience
- Resilient decision processes in Integrated Operations (IO) Teams – Adequate prioritization of safety goals
- Early warnings of major accidents

This report presents an overview and key findings from the first research activity in the project: Human and organizational contribution to resilience.

2 Human and organizational contribution to resilience – introduction

The objective of this research activity was to develop knowledge concerning how organizations and humans contribute to resilience of an existing technological system, and knowledge concerning how improvisation may contribute to resilient organizations.

Resilience and *Resilience Engineering* (RE) are currently receiving attention within safety science and management. In psychology, the term resilience refers to a characteristic of the individual. A resilient individual manages to cope with severe strain and stress. In psychological terms then, resilience refers to an ability to both endure and "bounce back from" strain. Similarly, a resilient organization can be thought of as a system that possesses stress tolerance abilities. Resilience, as organizational or system resilience has been described in various ways. The following are examples:

> **"The essence of resilience is (…) the intrinsic ability of an organisation (system) to maintain or regain a dynamically stable state, which allows it to continue operations after a major mishap and / or in the presence of a continuous stress"**
> **- Hollnagel, 2006, p. 16**

"Resilience (…) describes also the characteristic of managing the organisation's activities to anticipate and circumvent threats to its existence and primary goals" (Hale and Heijer,

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[1] www.sintef.no/buildingsafety

2006, p. 35); The system capability to prevent or adapt to changing conditions in order to preserve its control over a system property (Leveson et al., 2006, p. 95).

The concepts of resilience and RE can be distinguished by thinking of (i) 'resilience' as a set of theories or ideas, all concerning coping abilities of sociotechnical systems; not as some static property that the organization possesses – but more along the lines of what an organization does; and (ii) 'Resilience Engineering' (see Hollnagel et al., 2006) as a specific approach working to manage risk in a proactive manner. Resilience Engineering is based on findings concerning failures in complex systems that involve both organizational level risk factors and factors that may affect human performance (Woods, 2003).

'Resilience refers to the capability of recognizing, adapting to, and coping with the unexpected'
- Woods, 2006

The term 'resilience' often sets off some association in the direction of *adaptability*. According to Woods (2006), however, this is a quality that all systems, in some way or another possess. This means that resilience cannot simply describe the adaptive aptitude of an organization. Woods' use of the term resilience is restricted to how a system copes with variation and disturbance that are placed outside of the organization model, i.e. incidents that are not part of the defined mechanisms and procedures. Resilience refers to the capability of recognizing, adapting to, and coping with the unexpected (Woods, 2006).

3 Research tasks

3.1 Problem description

This task involved a preliminary review of research and theoretical approaches regarding resilience, Resilience Engineering (RE), and robust organization. The primary objectives in the problem description phase were to (1) explicitly state research questions, and (2) establish the scope for the literature review.

Delivery: Problem description memo (Størseth et al., 2008a), completed, 28th February 2008.

3.2 Case description

The purpose was to describe a set of cases which could be used as a basis for research within all research activities in the Building Safety project. Three accidents / incidents were selected as cases: (1) The Texas City refinery explosion and fire accident, (2) The Eirik Raude hydraulic oil leak event experienced by Statoil in the Barents Sea, and (3) The Ocean Vanguard anchor chain incident.

Delivery: Case description memo (Øien and Tinmannsvik, 2008), completed, 12th January 2008.

3.3 Literature review

The literature review covered the concepts of resilience, Resilience Engineering, and improvisation. The scope of this literature review was to provide (1) a broad review of the literature on *resilience*, (2) the articulation of a specific approach to resilience – based on *Resilience Engineering* perspective (Hollnagel, Woods, and Leveson, 2006), (3) a broad comparison between different perspectives on organizational accidents and resilient organizations, (4) a broad review of literature on *improvisation*, and (5) a preliminary investigation of the relationship between *resilience* and *improvisation.* Please confer section 4 for a synopsis of the literature review; and section 5 for details on the relationship between resilience, adaptation and improvisation.

Delivery: Literature review memo (Grøtan et al., 2008a) completed, 21st February 2008.

3.4 Successful recovery of high-risk incidents

An empirical study was designed and performed in order to explore successful recovery of high-risk incidents as a source for understanding human and organizational preconditions for resilience. Please confer section 6 in the report for a presentation of the case study.

Delivery: Project memo (Størseth, Rø, Albrechtsen, 2008), completed, 23rd June 2008.

3.5 Case specific advice

The research results served as the basis for providing specific advice to the establishment of the operational organization of the Goliat field.

Delivery: Project report (Størseth, 2009), completed, 23rd January 2009.

3.6 Generic knowledge

The main findings have been published in the following papers:

Grøtan, T.O., Størseth, F., Rø, M.H., Skjerve, A.B., 2008b. Resilience, Adaptation and Improvisation – increasing resilience by organising for successful improvisation. Presented at the *3rd Symposium on Resilience Engineering*, Antibes, Juan-Les-Pins, France, 28 – 30 October 2008.

Størseth, F., Albrechtsen, E., Rø, M.H., 2008c. *Successful recovery of high-risk incidents – case study* (submitted for publication in international journal).

Størseth, F., Tinmannsvik, R.K., Øien, K., 2009. Building Safety by resilient organization – a case specific approach. *ESREL 2009*, Prague, Czech Republic, 7 – 10 September 2009.

Abstracts are presented in Appendix A, B and C.

See also:
http://www.sintef.no/Projectweb/Building-Safety/Publications/

4 Literature review

4.1 Different perspectives on organizational accidents and resilient organizations

In order to specify both the organizational and human side of resilience, the first task in Building Safety was to perform a literature review on resilience and Resilience Engineering. Mirroring the defined objective in the research activity, the literature review pursued a scope that covered a review of relevant literature on improvisation in addition to literature on resilience / RE. In fact, the literature review had as its point of departure that the capacity to improvise is somewhat of a key premise in resilience. This served as a hypothesis, and direction for the literature review. Figure 1 below illustrates the scope of the literature review.

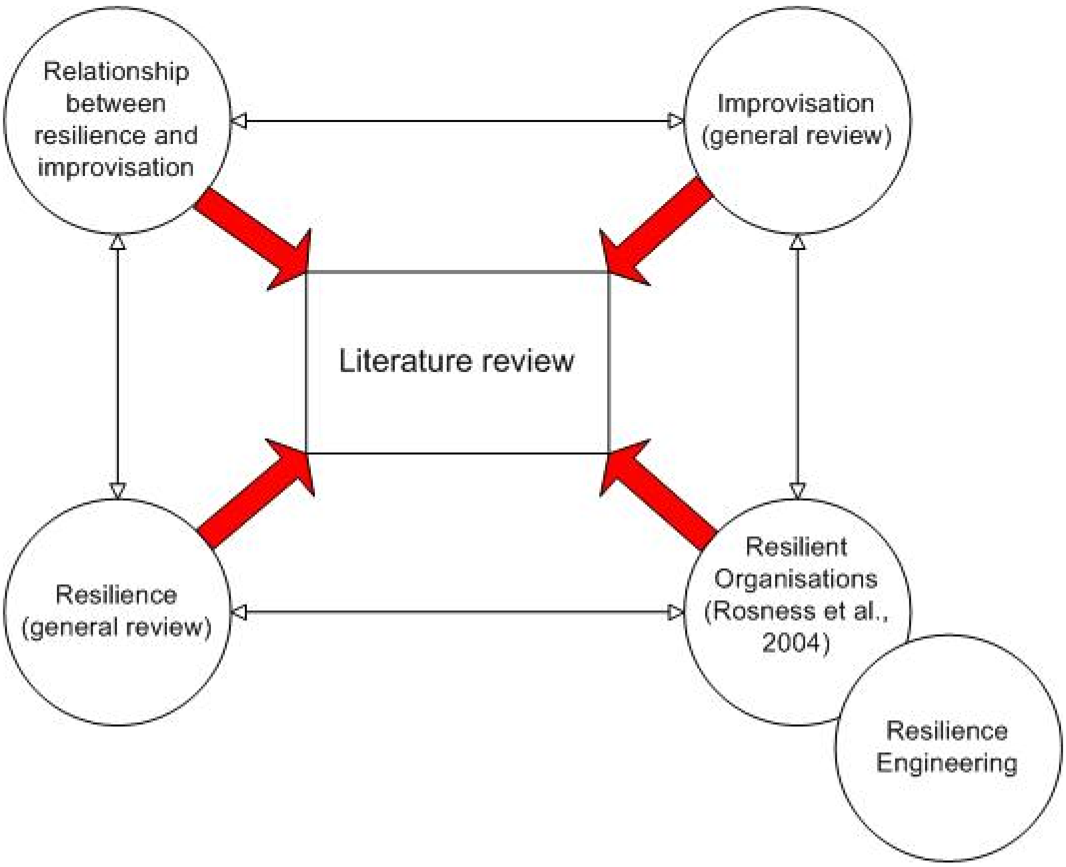

Fig. 1: Scope of the literature review on resilience and improvisation.

As shown in the figure, the scope of the literature review was to provide: (1) a general review of the literature on the notion of resilience, in relation to the overall agenda of the Building Safety project, (2) the articulation of a specific approach to resilience – based on Resilience Engineering (Hollnagel et al., 2006) – as a sixth perspective on organizational accidents and resilient organizations, in conjunction with the five perspectives as described and discussed in *Organisational Accidents and Resilient Organisations: Five Perspectives* (Rosness et al., 2004) – see box 1 below for a short presentation of the five perspectives, (3) a broad comparison between the resulting six (5+1) perspectives on organizational accidents and resilient organizations, (4) a general review of literature on improvisation, relevant to the specific objective in Building Safety, and (5) a preliminary investigation of the relationship between resilience *and* improvisation.

THE FIVE PERSPECTIVES

1. The *energy and barrier perspective*, according to which accidents can be understood and prevented by focussing on dangerous energies and means by which such energies can reliably be separated from vulnerable targets (Gibson, 1961; Haddon, 1970; 1980). This perspective has been included because of its impact on practical safety management.

2. Perrow's theory of *Normal Accidents*, which explains some major accidents in terms of a mismatch between the properties of the technology to be controlled and the structure of the organisation responsible for controlling the technology (1984). This theory has provoked a lot of fruitful controversy, mainly because it concludes that some technologies should be abandoned in their current form because they cannot be adequately controlled by any conceivable organisation.

3. The theory of *High Reliability Organisations* (HRO) was developed partly as a reply to the challenge posed by Normal Accident theory (Rochin et al., 1987, LaPorte and Consolini, 1991). HRO theory is grounded in intensive studies of organisations that have demonstrated an outstanding capacity to handle fairly complex technologies without generating major accidents. Important concepts from this research tradition are *organisational redundancy* and a capacity of organisations to reconfigure in adaptation to peak demands and crisis.

4. *The information processing perspective*, taking Turner's theory of *Man-made disasters* as a starting point. (Turner, 1978; Turner and Pidgeon, 1997). In this perspective, an accident is viewed as a breakdown in the flow and interpretation of information that is linked to physical events.

5. A *decision-making perspective*, with a focus on the handling of conflicting objectives. Here we introduce Rasmussen's (1997) model of activities migrating toward the boundary of acceptable performance, as well as the notion of distributed decision-making.

Box 1: Overview of the five perspectives on organisational accidents and resilient organisations (Rosness et al., 2004, p. 10).

4.2 Resilience Engineering as the sixth perspective

> **'Thinking in terms of resilience shifts inquiry to the nature of the surprises'**
> **- Hollnagel and Woods, 2006, p. 356**

Resilience, in terms of organizational or system resilience has been described in various ways. The following are examples: According to Hollnagel (2006) ...*"the essence of resilience is… the intrinsic ability of an organisation (system) to maintain or regain a dynamically stable state, which allows it to continue operations after a major mishap and / or in the presence of a continuous stress"* (Hollnagel, 2006, p. 16, in Hollnagel, Woods, and Leveson, 2006). Hale and Heijer (2006) suggest that resilience concern …*"the characteristic of managing the organisation's activities to anticipate and circumvent threats to its existence and primary goals"* (Hale an Heijer, 2006 p. 35, in Hollnagel et al., 2006). Leveson et al. (2006), understands resilience as the system capability to prevent or adapt to changing conditions in order to preserve its control over a system property (Leveson et al., 2006, p. 95, in Hollnagel et al., 2006). Hollnagel (2007) emphasizes that a resilient system is a system with an inherent capability to adjust its functioning. This adjustment can be done both before and in response to changes and disturbances. These system alterations allow the continuity of operations, even when facing major accidents or continuous stress. A resilient system is able to respond to regular and irregular threats in a way that is both robust and flexible, it is able to self-monitor its performance, and it is capable of anticipating disruptions, pressures, as well as their consequences.

The descriptions above suggest some qualities or abilities that a resilient system should possess. Specifically, it is suggested that a resilient system has the abilities to:

- endure stress
- anticipate threats
- circumvent threats
- prevent change
- adapt to change
- adjust its functioning
- self-monitor its performance

Breaking the line: In a traditional approach, accidents are according to Hollnagel typically explained by referring to malfunction and human or machine performance deviations. In this approach, risk is interpreted as the linear combinations of such malfunctions. The main risk source is the possibility of component failure; with combinations of such failures creating linear chains of cause and effect (e.g. in the form of a fault tree). The notion is that events develop in predefined relations. This tradition of linear decomposition is characterised by the following (see Hollnagel, 2007):

- The system is decomposed into elements and events.
- Each element (with its probability of failure) is individually described.
- The element functions are bimodal in nature (e.g. either it works, or not).
- The system is characterised by a predetermined and fixed order.
- There are linear combinations, and no interactions.
- The influence of context / conditions is limited.

A premise in the resilience engineering approach is however that some accidents escape the linear form. Consequently, it has repeatedly been emphasized that accidents may be the result of unexpected combinations or aggregated conditions or events (see e.g. Perrow, 1984). Concurrence is a term that has been coined in these respects. Here, concurrence refers to the simultaneous occurrence of two events, resulting in a mutual influence on each other. In this vein of thought, accidents are by some held to be non-linear phenomena emerging in a complex system and are therefore termed systemic accident models (Hollnagel, 2006). As resilience engineering is based on this specific system understanding it is useful to look into premises for resilience engineering, see Box 2.

THE PREMISES FOR RESILIENCE ENGINEERING

1. *Underspecified performance*. Socio-technical systems are recognized to be so complex that work situations are always underspecified. Designers can not anticipate every contingency in advance. Functions cannot be assumed to be bimodal (that is, either functioning or not functioning) and normal performance carries by implication an inherent variability. It thus is impossible to specify work operations exhaustively in advance, and organisations (as well as the people in them) are in a state of constant flux. Both organisations and their inhabitants are constantly changing and adjusting to the circumstances at hand. Adding to this is the fact that time and resources are scarce, something that forces adjustments to be approximate. Hence, work operations will always be underspecified to some degree.

2. *A dual perspective on variability*. Since it is not possible to describe in detail all operations and resources are limited, performance variability is inevitable - as well as *necessary*. The overall point is that this variability that precludes specification is not a safety threat per se. Variability represents both a source for success and failure – it has a dual role.

3. *Accidents and intractable events*. Intractable events are events that are the consequence of some unanticipated combination of the normal variability in socio-technical performance. Hence, adverse events and accidents are not necessarily related to some sort of collapse of the normal system components and functions, they may (also) result from intractable combinations of adaptive behaviour. Intractable events are thus the flip side of the necessary adaptations to variability. Failures and successes *alike* are results of adjustments to cope with complexity. By implication, intractable events also represent *opportunity*.

4. *Proaction at a systemic[1] level.* To be effective and efficient, safety management cannot be based solely on hindsight, error tabulation, and failure probabilities, that is, what constitutes sequential accident models. Intractable events demands a kind of proactivity that goes beyond the premise of linear, sequential modelling of failures, faults and their subsequent effects. The dilemma and the challenge is that while risks emerge from non-linear, interactive combinations of performance variability (intractable events), safety can not be achieved by constraining or eliminating normal performance variability. Safety management must therefore employ a unified (dual) view of both success and failure, and find ways that reinforce variability that leads to success, and dampen variability that leads to adverse outcomes.

[1]That is, not limited to the component-level, but incorporating system-level effects of variability and its propagation. An unsafe state may thus arise because system adjustments are insufficient or inappropriate, rather than because something fails.

Box 2: The premises for Resilience Engineering (Grøtan, Herrera, Størseth, 2009, p 3).

RE aims to create processes that are robust and flexible, to monitor performance and revise risk models, and use resources proactively. In doing this, RE takes into account that systems are not only linked to their environment, but also interacts with their environments.

It is beyond the scope of this report to go into detail on every aspect of RE[2]. The following are 'short versions' of the system(ic) approach in RE as included in Grøtan et al. (2009):

Managing emergent phenomena: Rather than looking at accidents as resultant phenomena, RE considers accidents as emergent. Resultant phenomena are predictable by the system components, decomposed and analysed by cause and effect modelling. Emergent phenomena results from complex system interactions. A systemic approach is thus needed to look for the unusual dependencies, in addition to taking into account common performance conditions and monitoring the normal system variability (Reason, 2008). Normal performance variability of one function is rarely large enough to be the accident cause or even to constitute a malfunction. But, the variability from multiple functions may combine in unexpected ways, leading to large consequences, hence produce a non-linear effect. Both failures and successes are emergent rather than resultant phenomena, as neither can be attributed to or explained only by referring to the (mal-)functions of specific components or parts. Socio-technical systems are intractable because they change and develop in response to conditions and demands. It is impossible to describe all couplings in the system, hence impossible to anticipate more than the common or regular events. While the couplings are useful, they can also constitute a risk. In accordance with this view, accidents should be understood in terms of unexpected and unintended combinations of normal performance variability (Macchi et. al, 2008).

Managing Performance Variability: System complexity implies that situations are underspecified and to some extent unpredictable. There is hardly any work task that can be performed without adapting the procedures and tools to the situation at hand. Performance variability is both normal and required. As variability is a premise for effective work, a problem will not be solved by removing variability (Hollnagel, 2007). Demands for efficiency create a need for change which in turn induces coping strategies such as trade-offs and short cuts. These strategies represent potential risk sources. But, performance variability is also a necessary premise for work task execution. Dynamics of performance variability is contributory for *both* success and failure. According to Hollnagel (2007), the challenge is to understand the nature of variability, i.e. the why, when, and how. This creates the possibility to limit variability when the pendulum swings towards risk and danger (i.e. when performance fails) and enhancing variability when the pendulum swings towards success. Performance variability should be approached by addressing: *Why* (i.e. the reasons for variability), *When* (i.e. observing and monitoring), *How* (i.e. understanding potential consequences).

Functional Resonance: The concept of functional resonance is used to emphasize the focus on understanding dynamic phenomena. Specifically, the concept is meant to target analyses of events that are impossible to explain linear causal relationships between system's elements (e.g., Woltjer and Hollnagel, 2007). Functional resonance denotes that the variability of individual functions may combine in ways that are both unwanted and unexpected way (Grøtan et al., 2009).

[2] A detailed presentation of resilience and RE can be found in SINTEF report A12404 (Grøtan, Herrera, Størseth, 2009).

Knowledge and control: A critical aspect in terms of control is *knowledge* regarding when unexpected events are likely to occur. This is because it informs us about when loss of control is likely to occur. Knowledge is important both for anticipating what might happen, and for knowing what to look for or where to focus, i.e. knowledge affects both attention and perception. Hollnagel and Woods emphasize that knowledge goes beyond experience, and that knowledge includes the ability to expect the unexpected, and look beyond the obvious. This ability is known as 'requisite imagination' (Westrum, 1993; Adamski and Westrum, 2003), which is a mandatory principle for resilience. Having control involves knowledge (about past, present, and the future). Control involves knowledge about what has happened, what happens, and what might happen. Adding to this, control also implies knowledge regarding what to do as well as the necessary resources, time, knowledge, competence (Hollnagel and Woods, 2006). Figure 2 below shows three system qualities that a system, according to Hollnagel and Woods (2006) needs in order to be resilient.

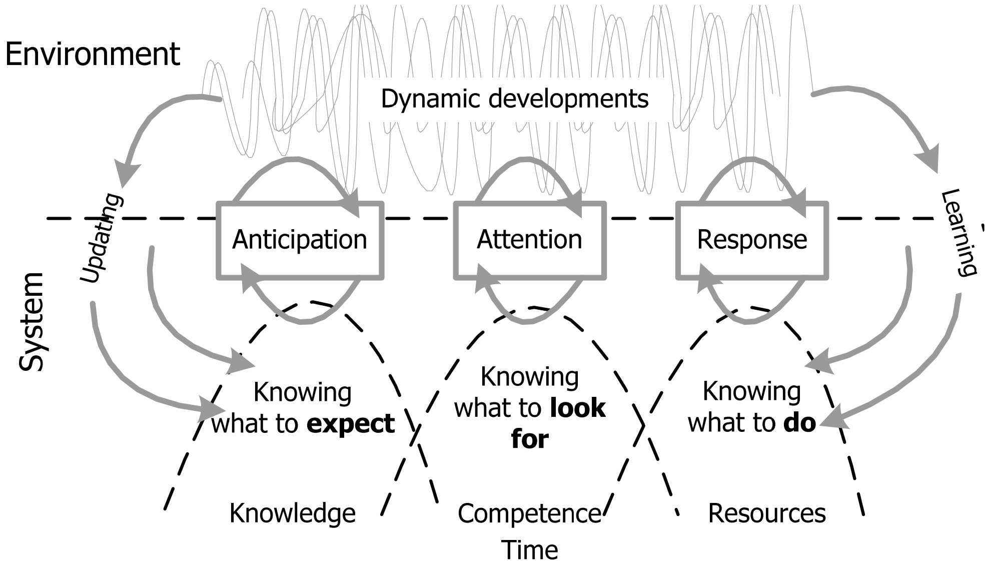

Fig. 2: Required qualities of a resilient system (Hollnagel and Woods, 2006, p. 350).

Figure 2 shows that the three main qualities (knowledge, competence, and resources), are not linked in a way that suggests a chronology (e.g. anticipation precedes attention, which then leads to response). Rather, these qualities are constantly applied. A resilient system is watchful and prepared to respond. This readiness is enabled by a constant updating of knowledge, competence, and resources by learning from own as well as others successes and failures (Hollnagel and Woods, 2006). As the distinct activities are interwoven, there is an implicit holistic premise in Figure 2, suggesting that the process produces results beyond the sum of the individual constituents.

Hollnagel (2008) contrasts RE with (traditional) Safety Management Systems (SMS) by referring to a control engineering (cybernetic) framework. The SMS may be proactive in terms of a feed-forward control that leads the system from actual state towards some desired future state. Here, pro-action is designed actions to anticipated disturbances. The limitation is thus that there will be no action if the disturbance is not designed into the model. The successful proactive SMS may experience the "fundamental regulator paradox" (Weinberg and Weinberg, 1979 p. 250). The paradox is here the fact that the better the regulation job is performed – the less information is provided to indicate the actual success of the regulation. Put differently, if there is no variation to regulate against (due to the absence of errors), this may be interpreted to indicate that the process is under control, while the reality is actually the contrary.

Summing up, resilience concerns the ability (of a system) to deal with the new premises (see Box 2). Consequently, Resilience Engineering is the engineering practice that has resilience of systems as its objective. A central aspect here is the aim to incorporate humans, technology and organization on an equal basis in a functionally oriented, systemic perspective; without making the error of portraying humans as machines (Grøtan, Herrera, Størseth, 2009).

4.3 Improvisation

A separate literature review on improvisation was performed. From the reviewed literature, answers to the following questions were attempted:

- What is improvisation and why is it needed?
- How does improvisation relate to nearby concepts and terms?
- How can improvisation be made effective and secure, - when and how to improvise?
- Can improvisation be learned - how to train for the capacity of improvisation?
- How can improvisation be investigated empirically, and what have previous studies shown?

Several definitions of improvisation were found, mainly covered by the following conditions:

- Behavioural and cognitive time-constraining activity to meet certain objectives
- Nearness in time between planning and execution of an action
- Deviation from existing practice or knowledge

The various definitions may serve as complementary approaches to the concept of improvisation. Other concepts and terms mentioned in the literature, e.g., intuition, adaptation and problem solving, may share characteristics associated with improvisation and constitute a part of the improvisational process, and the other way round. Improvisation is needed to cope with unplanned, non-routine or emergency situations when proper procedures are lacking. Thus, improvisation may be viewed as a way of avoiding, saving or recovering from a critical situation. However, improvisation requires effort and implies risk. Improvisation may solve a problem or worsen it. This raises a question of when and how improvisation can evolve effectively and secure. Although empirical studies of improvisational related risks are limited, establishing meta-routines has been shown to reduce harmful improvisation in product development (Miner et al., 2001). The literature review highlights the need for more research, both qualitative and quantitative investigations, to identify premises for effective and secure improvisation. Generally, improvisation is viewed as a skill that can be learned. An empirical study of 50 work teams support this notion, showing that improvisational training may increase the incidence and quality of improvisation (Vera and Crossan, 2005).

To increase the capacity of improvisation, training is required at individual, group and organizational levels. The employees should have insight into all levels of a system, being familiar with procedures and possible consequences of breaking them. Improving the situational awareness is highlighted on both individual and group levels. A culture characterized by safety, trust and openness should be aspired continuously, developing a robust system with specific roles and responsibilities. Good communication, coordination and cooperation are considered as crucial for handling critical situations.

The reviewed literature includes qualitative studies of improvisation, together with broad suggestions for studying the phenomenon. Target areas for maintenance and improvement of safe improvisation are indicated. However, the reviewed literature lack concrete principles for good improvisation, when and how to improvise, and how improvisation can be trained individually, in groups and organizations. More nuanced and thorough knowledge is needed, and with that, established methods for quantitative and qualitative approaches to study improvisation.

5 Theoretical study: The relationship between resilience, adaptation, and improvisation

The results of the literature review served as the theoretical point of departure for a study on relationship between resilience, adaptation, and improvisation. Here, the assumption that resilience has improvisation as a key premise was examined further. The Resilience Engineering approach covers a lot, also literally. That is, the far reaching scope of the theory may conceal or overshadow key premises. The study on resilience, adaptation, and improvisation was based on the presumption that improvisation is one such key premise. Improvisation is typically associated with the handling of exceptions. As Resilience Engineering emphasizes the constantly changing environment, one could argue that all operational activity should be considered from the non-routine perspective. To some extent the ideas of resilience advocate a sense of "letting go" that jeopardise traditional assumptions of staying in control. Focusing on improvisation will not bring more comfort in that sense, but contribute to a more realistic view on the challenges of managing complex systems.

> **'To some extent the ideas of resilience advocate a sense of "letting go" that jeopardise traditional assumptions of staying in control'**
> **- Grøtan et al., 2008**

The study examined the presumed link between resilience and improvisation, and concludes that elements of improvisation are an integral part of resilience. The study examined three themes. First, the presumption that improvisation is embedded in the concept of resilience was tested by a theoretical analysis. Second, the role of improvisation in the concept of adaptation (a central principle within Resilience Engineering) was examined. Adaptation concerns knowledge in terms of Anticipation (what to expect), Attention (what to look for), and Response (what to do) (Hollnagel and Woods, 2006, p. 350). These elements (A-A-R) are not positioned such that anticipation precedes attention which in turn precedes response. Rather, they all are involved in a continuous process. It is suggested that improvisational elements may be seen as being part of this adaptation process.

Third, the Cynefin framework (Kurtz and Snowden, 2003) – a sensemaking framework for understanding systems – was used in order to recast both resilience and improvisation. In other words, Cynefin was used as a framework for looking into what system(s) are suitable for Resilience Engineering. The study concludes that if properly addressed and facilitated within an organization, improvisation could be made a booster for resilience. On the other hand, there is always the possibility that improvisation may go wrong, pointing towards inherent vulnerabilities in complex systems that cannot be avoided, whatever sophisticated methods we employ in order to reveal the most intricate secrets of their behaviour.

This study is reported in the paper: "Resilience, Adaptation, and Improvisation – increasing resilience by organizing for successful improvisation[3]" (Grøtan et al., 2008b).

See Appendix A for more.

6 Empirical study: Successful recovery of high-risk incidents

Having completed the theoretical analyses on resilience, RE, and improvisation, the next important step was to apply the results in empirical investigation. A defined objective in this respect was to study successful recovery of high-risk incidents.

Focusing on incidents is no novelty in safety work. The learning potential for studying incidents and near-miss cases is fully recognized. It is however acknowledged that there are challenges attached to this approach. For instance, the possibility of ending up as the scapegoat is a real threat for establishing a culture willing to report and reveal errors, mishaps, near-misses and incidents. In addition to the justified fear of finger-pointing, a challenge to focusing on incidents is the almost pre-programmed feeling of relief when "nothing serious happened". As "nothing happened", incidents rarely receive the attention and scrutiny that are given to accidents (see Hale, 1997). Recognizing the potential for learning, a case study was designed in order to focus on precisely these kinds of incidents.

…, a challenge to focusing on incidents is the almost pre-programmed feeling of relief when "nothing serious happened"
- Størseth et al., 2008

An empirical study was designed to look into the processes of incidents that were successfully recovered. The objective was to examine how a set of predefined factors could be "mapped on" to cases of successful recovery. The study can be thought of as a first, explorative validation of a set of resilience factors assumed to be contributory in a risk scenario of successful recovery. The factors were intended to mirror key elements in the theoretical framework known as resilience and Resilience Engineering (see e.g. Hollnagel et al., 2006). According to Hollnagel, "the essence of resilience is (…) the intrinsic ability of an organization (system) to maintain or regain a dynamically stable state, which allows it to continue operations after a major mishap and / or in the presence of a continuous stress" (Hollnagel, 2006, p. 16). In other words, the resilient organization is able to both endure and *successfully recover* from severe strain. RE is literally about engineering resilience in organizations and safety management approaches, by providing methods, tools and management approaches that help to cope with complexity under pressure to achieve success (Hollnagel et al., 2006).

Based on a literature review of resilience and Resilience Engineering, a set of contributory variables were identified. The theoretical basis for these variables is presented in the following.

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[3] Presented at the 3rd Symposium on Resilience Engineering, Antibes, Juan-Les-Pins, France, October 28-30, 2008.

The underestimation of risks is a significant factor in producing drift towards failure. Accordingly, making sure that risk awareness is maintained when facing high pressure situations is an important stepping stone for an organization to become resilient (Woods and Wreathall, 2003). Adaptation is an important element in resilience. The capacity to adjust and adapt comprises knowledge in terms of Anticipation (what to expect), Attention (what to look for), and Response (what to do). These three elements (A-A-R) are not positioned such that anticipation precedes attention, which in turn precedes response. Rather, all three should be continuously applied and kept active. This constant alertness is made possible by a constant updating of knowledge, competence, and resources (Hollnagel and Woods, 2006). Based on the above, the following variables were hypothesized as potential contributors for successful recovery: *Risk understanding; Anticipation; Attention; Response.*

In relation to the adaptation process of A-A-R, it was interesting to look into how aspects of *improvisation* would tie in with these three elements. Improvisation quickly becomes a controversial topic in scientific contexts, perhaps even more so in a safety context. It is here to be argued that improvisation is embedded in the resilience approach. In RE a resilient system is characterized with watchfulness towards the constantly changing environment. Concerning the operational end this describes certain abilities in terms of performance. Adaptation (A-A-R) is a clear example here. The process of A-A-R is dynamic, intertwined and ongoing. Furthermore, it suggests the handling of exceptions beyond day to day routine operation. Considering the resilience focus on constant change, the need for this flexible coping ability is ever more evident. In other words, adaptation is a necessary means to face and cope with change and unexpected events. Adaptation (A-A-R) denotes being ready for the next surprise. As this preparedness represents a way to meet unexpected (non-routine) situations, the handling / response may well also be outside of procedure. In other words, the process of adaptation includes aspects of improvisation.

During (safety) critical events, improvisation may be crucial for a response as a way to complement and compensate for insufficient automatic security systems and unsuitable or lacking procedures (Cunha, Cunha, and Kamoche, 2002; Mendonça, Beroggi, and Wallace, 2003; Mendonça and Fiedrich, 2006). Mendonça and Fiedrich (2006, p. 350) define improvisation as: …"a combined behavioural and cognitive activity that requires serial creativity under tight time constraint in order to meet performance objectives." The adaptation process in the RE framework suggests a level of creativity that enables the agent to both foresee and be aware of unexpected occurrences. This element of creativity is reminiscent of the capacity to improvise. Also, the response in the adaptation process (A-A-R), implies that both skills and creativity are matched on a level that enables the agent to "let go", to move outside of the procedure box; to improvise. Anticipation, attention, and response are simultaneously active elements of coping. The emphasis on thinking, interpretation, and action (response) as tightly tied activities is close to Cunha et al.'s description of improvisation as "thinking in action" (Cunha et al., 2002). In this line of reasoning, the current study hypothesized that improvisational aspects are embedded in the resilience adaptation process of A-A-R: *Improvisation is part of the adaptation process (A-A-R).*

For an organization to be resilient, there must be a practice of decision support related to the production / safety trade-offs. Specifically, this implies that there must be specific guidance for when to reduce or stop production in order to reduce risk. These kinds of "sacrifice judgements" (i.e. when production demands are sacrificed to maintain necessary safety standards) must be supported (Woods and Wreathall, 2003). *Decision support* was thus hypothesized as a contributor for successful recovery.

Tierney (2003, p. 2) defines resilience as "the capacity for both physical and social systems to withstand forces and demands generated by disaster events (e.g., earthquakes, hurricanes, human induced events) and to adequately cope with such events through employing effective response and recovery strategies". Both physical and social aspects of resilience can be further specified as being comprised of *robustness* (ability to withstand stress/demands without suffering damage, degradation or loss of function); *redundancy* (the extent to which elements, systems, and other units of analysis exist that meet functional requirements in the face of disruption, degradation, or loss of functionality); *resourcefulness* (capacity to identify problems, establish priorities and mobilize resources to avoid or cope with damage or disturbance); *rapidity* (capacity to meet priorities and achieving goals in time). Accordingly, these variables were hypothesized as recovery contributors: *Robustness; Redundancy; Resourcefulness/rapidity*[4]

Having identified a set of contributory variables, the next step involved categorizing the variables into a hypothesized factor structure. Based on the content (meaning), they were classified into a structure of three Contributing Success Factors for recovery and prevention of incidents (in the following CSFs). See Table 1.

Table 1:
Hypothesized set of Contributing Success Factors for recovery and prevention of incidents.

CSF1 Risk Awareness	**CSF2 Response capacity**	**CSF3 Support**
1.1 Risk understanding	2.1 Response	3.1 Decision support
1.2 Anticipation	2.2 Robustness	3.2 Redundancy
1.3 Attention	2.3 Resourcefulness /rapidity	

These hypothesized CSFs were applied as starting point for looking into three incident / near-miss cases. The aim was to examine how themes in the CSFs were related to, or contributed to successful recovery. The empirical study was designed as a three-part research interview: The *first* part was open in form. There was no structure or guideline beyond attaining an understanding of the interviewees working experiences and history within the industry, as well as discussing incidents. The *second* part of the interview was designed to pursue one such incident in more detail. This more focused part of the interview was centred on mapping out the sequence of the incident as it happened; as well as identifying key actors that were involved. This was attained by plotting the incident in a STEP-diagram (Sequential Timed Events Plotting, see Hendrick and Benner, 1987) in collaboration with the respondent. In the *third* part of the interview, the interviewees were asked structured questions from a CSF questions battery that was developed specifically for this study.

The participants had varied petroleum industry experiences ranging from the late 1960's up until today. What is more, their experiences covered a wide range of the petroleum industry, from offshore operational work, to onshore top management leadership.

The study concludes that the contributing factors (for successful recovery) appear promising as an approach, both for studying cases that has happened (post hoc analysis),

[4] As Resourcefulness and Rapidity both revolves around the ability to prioritize they were collapsed into one hypothesized variable.

and as part of a proactive effort to expose implicated risk hubs in new scenarios, i.e. consequences of new technology and new ways of organizing work. Key results of the study are reported in the paper "Successful recovery of high-risk incidents – case study" (Størseth, Albrechtsen, and Rø, 2008c).

See the abstract for the paper submitted for publication in an international journal in Appendix B.

7 Case specific advice

Based on the main findings from the research activities, the following recommendations are suggested for the establishment of the operational organization of the Goliat field. The recommendations are focused on four conceptual themes: (1) training and development, (2) integrated operations (IO), (3) work teams, and (4) external resources.

7.1 Training and development

Approaches as applied in the HSE Awareness programme[5] could be used to introduce new personnel to the Eni emphasis on risk awareness. Specifically, the HSE Awareness concept "Share and Win"[6] can be incorporated into recruiting and training processes.

Recommendation # 1 – Apply scenario analyses:

Engage in scenario analyses on real cases of incidents / near-misses with an established focus on the values of cooperation, communication, and learning / sharing knowledge.

- The purpose would be to become aware of how Risk Awareness, Response Capacity, and Support (i.e. the three CSFs) are linked and dependent upon each other in their contribution for successful recovery of incidents.
- This kind of scenario analysis should be targeted towards improving the ability to anticipate and pay attention to patterns of system behaviour.
- The scenarios should be specific, detailed, and imply that the boundaries for acceptable performance become visible.

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[5] SINTEF assists Eni Norge in their development / implementation of a HSE Awareness programme, targeted towards different groups within Eni Norge and collaborators. The HSE Awareness programme works to develop and implement a common awareness, way to think; a common Eni mindset concerning HSE.

[6] In 2007, Eni Norge and SINTEF (in the HSE Awareness programme) held a workshop on the handling of critical decisions involving conflicts and trade-offs between safety and competing goals. Based on the values of sharing knowledge, experiences, and disagreement – the workshop was entitled "Share and Win". "Share and Win" refers both to the values of sharing knowledge etc., but also to the concept / methodological approach in this workshop. The "Share and Win"-concept is currently assessed for further development and application in the HSE Awareness programme.

Recommendation # 2 – Prepare for successful improvisation:

Prepare for improvisation, as this is needed in situations where unforeseen events occur.

- To respond adequately in a situation involving improvisation, personnel should have available, and efficiently master a set of response options that allows flexible intervention, depending on the particular needs in the situation at hand.
- For successful improvisation it would also be important that the operators obtain feedback (as immediately as possible) on the effects of their responses, to allow them to adjust their course of action.
- Improvisation is needed in situations were unforeseen events occur. By the consequence of being unforeseen, it falls outside of the organizational design. The ability of an organization to reconfigure spontaneously in demanding operating situations is a key characteristic of high-reliability organization (e.g., LaPorte and Consolini, 1991). This suggests that "improvising organizations" should allow for reconfiguration of their work organization when required.

7.2 Integrated Operations

Integrated operations (IO) creates new tight operational collaboration and substantial changes in work patterns offshore and in onshore support services. Eni Norge is currently developing a specific strategy regarding IO for the Goliat field. Assessing the safety effect of changes in work patterns and collaboration is desirable, but also challenging. One contribution to such an assessment would be an evaluation of the foreseen positive and / or negative effects on the attributes of resilience as expressed through the CSFs (see Table 1). The CSFs may in this way be used as a form of anticipatory scenario analysis.

Recommendation # 3 – Assess IO effects on resilience attributes*:

Use the CSFs as specific themes to look at how IO potentially contributes to strengthen or represents a threat to a resilient organization.

- Use the CSFs as themes to analyze the potential for *situational awareness* (understanding the situation, overview of the circumstances and allocation of resources at the 1st line of emergency) during a crisis.
- In a crisis handling, interactions between actors change and new people may be brought in for support. Use the CSFs as themes to analyze the *transition from normal operation to crisis*.
- During a crisis handling, opinions may differ and informal *roles and power issues* may come into play. Use the CSF themes to look at potential group mechanisms in the IO setting.

*For more information regarding situational awareness, transition from normal operation to crisis, and roles and power issues, see Skjerve, Albrechtsen, and Tveiten, 2008.

Note: The CSFs may also be applied in an IO training context; in terms of specifying themes (Risk Awareness, Response Capacity, and Support) that illustrates the interdependencies between onshore – offshore.

7.3 Work teams

The incidents in the three cases referred to ended all with successful recovery. As the incidents were recovered, it is easy to move on without questions. Conversely however, one might ask how the development of such scenarios could have been prevented in the first place. Herein lays the rationale for the CSFs. A common finding that can be derived from the cases is the importance of knowing / understanding how risks emerge in interaction. These findings may be used in order to understand work team dynamics. Specifically, the findings demonstrate the need to bring awareness to the “total picture” of the work process.

Recommendation # 4 – Ensure awareness of ongoing work processes at all levels:

Ensure that personnel becomes aware of the “total picture” of the work process, i.e. awareness of “the others”, and awareness of the fact that the sum of a complex set of processes creates a complex set of risk possibilities.

Redundancy (CSF 3.2) is an important issue here, in terms of designing for necessary buffer capacity. This buffer capacity concerns several levels:

- Ensure that knowledge is spread out to the individuals in the work teams.
- Ensure that the work teams have a knowledge level that is sufficiently robust.
- Ensure that the “total picture” is present in the onshore – offshore cooperation.
- Ensure that knowledge is shared across organizational borders (e.g. collaboration between work teams from different organizations).

7.4 External resources

A strategy for the use of external resources is that contracts should be based on sharing risk and reward in achieving common objectives. This will promote collaboration across organizational borders, aiming at a unified operational organization. This operational organization is to some extent “virtual” since some of the external resources may be located far from the production site. The question is therefore how to introduce and communicate the “Eni Way” to the external resources. Recommendation # 4 (see above) is relevant here; i.e. the value of becoming aware of the “total picture”, beyond ones own isolated work task. The CSFs may be used as guideline topics when this is communicated. Additionally, the “Share and Win”-concept (i.e. the value of sharing knowledge / experiences) from the HSE Awareness programme may be used to ensure successful incorporation of external resources.

Recommendation # 5 – Share risks and objectives:

- Introduce external resources to the “total picture” (see recommendation #4).
- Use the “Share and Win”-concept to communicate and exemplify the values of sharing knowledge and experiences.
- Give access to data / information (regarding new work processes related to integrated operations, Øien and Schjølberg (2008) found that entrepreneurs experience lack of data access as a problem; and that they would like a closer collaboration and to be more involved).

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Appendix A: Paper - Symposium on Resilience Engineering 2008

Paper presented at the 3rd Symposium on Resilience Engineering. Antibes, Juan-Les-Pins, France, October 28-30, 2008.

Resilience, Adaptation and Improvisation – increasing resilience by organising for successful improvisation

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Abstract. The paper discusses how the concept of resilience has improvisation as a key premise. The paper aims to map out where aspects of improvisation are inherently part of resilience. The results are discussed in terms of possible organizational consequences in high risk environments. Three different approaches are applied; First; how resilience and improvisation are related in general. Second; improvisation in resilient adaptation, in which sensemaking plays a key part. Third; recasting resilience and improvisation onto the Cynefin framework for making sense of complex systems and organizations. The paper integrates the three approaches to resilience and improvisation, and outlines what types of initiatives it may be relevant for organizations to take with respect to design, work organization and training to facilitate successful improvisation. By suggesting improvisation as an engine of resilience, it follows by implication that resilience as such does not preclude the possibility of inadequate improvisation. Hence, the potential for serious safety breaches remains, regardless how resilient we may be.

Link to the paper:
http://www.sintef.no/project/Building%20Safety/Publications/3rd%20RE%20symposium,%20resilience_adaptation_improvisation,%20TOG.pdf

Appendix B: Paper submitted for publication (international journal)

Successful recovery of high-risk incidents – case study

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Abstract: Results from a study of incidents in the offshore petroleum industry are reported. The aim of the study was to examine incidents that could have gone wrong, but was successfully recovered. A case study was designed to examine how a set of predefined 'contributing success factors' (CSFs) could contribute to recovery or prevention of incidents. The CSFs were based on theoretical contributions in resilience, Resilience Engineering, and improvisation. The hypothesized contributory success factors are Risk Awareness, Response Capacity, and Support. The results of three cases from offshore installations are discussed. Case 1: The rig sectioning incident, Case 2: The piping system incident, and Case 3: The simultaneous operations incident. Although each case had their own unique path of scenario development, the study identifies common features that cut across the cases. The contributing factors (for successful recovery) appear promising as an approach, both for studying cases that has happened (post hoc analysis), and as part of a proactive effort to expose implicated risk hubs in new scenarios, i.e. consequences of new technology and new ways of organizing work.

Key words: Offshore petroleum industry, high-risk incidents, successful recovery, Resilience Engineering, improvisation.

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Appendix C: Paper – ESREL 2009

Paper presented at ESREL 2009, Prague, Czech Republic, 7 – 10 September 2009.

Building Safety by resilient organization – a case specific approach

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Abstract: The paper presents key findings from the research project "Building Safety". Building Safety aims to generate knowledge for building *resilient* operational organizations for petroleum production in the northern regions. The results of the study should serve as input for Eni Norge, in their current preparation for petroleum production at the Goliat field in the Barents Sea. The paper presents how resilience was operationalized and empirically tested in a case study of successful recovery of incidents. Based on theoretical contributions on resilience and Resilience Engineering (RE), the following 'Contributing Success Factors' (CSFs) were operationalized and examined: CSF1 Risk Awareness, CSF2 Response Capacity, and CSF3 Support. The paper concludes with case specific advice for building a resilient organization: (1) apply scenario analyses, (2) prepare for successful improvisation, (3) assess IO (Integrated Operations) effects on resilience attributes, (4) ensure awareness of ongoing work processes at all levels, and (5) share risks and objectives.

Link to the paper:
http://www.sintef.no/project/Building%20Safety/Publications/Building%20Safety%20by%20resilient%20organization%20(ESREL%2009).pdf

The Building Safety project has produced the following summary reports:

- Human and Organizational Contribution to Resilience (Størseth et al., 2009)
- Resilient Decision Processes in Integrated Operations (Kaarstad et al., 2010)
- Development of new models and methods for the identification of early warning indicators (Øien et al., 2010)

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