How Can Remote Operations Become More Resilient?

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Abstract. Remote operations of offshore Oil and Gas installation are increasing. The motivation for remote operation is increased income, cost reductions, increased resilience, and more effective support of offshore activities and reduced hazard exposure of the employees. Our goal is to identify factors and issues that can make remote operations more safe and resilient. These factors and issues are going to be included in a methodology to be used to assess remote operations and identify areas of improvement. We have based our work on a survey within the Oil and Gas industry and relevant issues and best practices from other industries. We have also based our work on theories from high reliability organisations and resilience engineering. Several findings were common across the industries, suggesting that it seems to be possible to learn from other industries about remote operations. Key issues are to develop technical solutions coordinated with organisational development and training in collaboration with the key stakeholders, focusing on robust routines and rich systems for information sharing. Scenario analysis cross organisations should be used to improve resilience. We are proposing to use the result of our work in methodologies to be used by the oil and gas industries in Norway.

1 INTRODUCTION AND PROBLEM DEFINITION

During the last decade new technology have made it possible to increase remote control in many industries and the focus on remote control of offshore oil and gas installations is increasing. In the oil and gas industry the main motivation for remote control is the potential for operational cost reduction and increased income or yield from the fields, but also the possibility of reduced hazard exposure to humans. In addition it has been important to increase resilience in operations. The experiences with remote control have increased and the best practices are of great interest in the oil and gas industry.

Our main hypothesis is that the safety and security of remote control can be improved by the use of “best practice” from other industries and suggestions from the oil and gas industry itself.

Definitions

E-Operations:
The use of Information Technology to change work processes to improve decision-making, perform remote control and allocate functions in an optimal manner.

Remote Control:

Part of the operation is managed and operated remotely. Such remote control can cover a wide spectrum of possibilities, from control of parts of the process in a normal situation to a full control of the installation in an emergency situation. Scenarios where operators on the installation are occupied with field operations, while the process is controlled from an onshore-based operation centre are possible. CCR (Central Control Room) operators are present at the installation.

Remote Operations

The whole of the operation is managed and operated remotely.

1.1 Problem Definition

Our goal has been to gather experiences across different industries to identify common challenges and common best practices related to remote control. We have also based our approach on the theory and practice of High Reliability Organisation (HRO) and resilience engineering as described in [Weick, 2001] and [Hollnagel, 2006]. HRO is a designation of organisations that manage to stay stabile and avoid major accidents even though they operate in a complex environment where deviations can create serious consequences, i.e. they are resilient. Elements' supporting HRO and/or resilience has been of special interest to us during our work.

Our hypothesis has been:

- It is possible to identify common challenges and common best practices related to remote control from different industries
- Common challenges and common best practices can be explored in the oil and gas industry to increase the resilience of remote control

We have performed a qualitative study of several industries such as the aviation industry, the railway industry, AMK (Acute Medical Communication), telemedicine and the Oil and Gas industry

We focused on the use of central control rooms and the issue of collaboration and cooperation within the central control room and between the central control room and outside operations. In all industries there was extensive cooperation between operators in the control room and operators at the plant/site as well as with external experts.

Several findings were common across the above-listed industries; see [Andersen, 2005] suggesting that it seems to be possible to learn from other industries about remote operations. The relevant findings are described in the following and have been discussed in relation to remote operations in the oil and gas industry.

2 CHALLENGES AND BEST PRACTICES IN REMOTE CONTROL

We found some challenges and best practices in remote operations based on common findings from several industries. The challenges was due to poor routines related to handling of conflicting messages; errors due to poor quality of information sharing; lack of human resources to check and correct each other; poor ability to spontaneously adapt to unexpected and demanding situations; lack of redundancy in technical systems and/or human resources; missing warning when an unwanted incident happened; and missing training. To each of these challenges we have suggested best practices based on experiences.

We have also found some challenges and best practices based on 10 years of experience with telemedicine. The challenges identified from telemedicine have been related to organisational changes, not enough focus on training and not enough focus on technical support. Best practices have been related to improved availability of competence when it is needed and improved work processes and improved responsibilities between the organizational levels. These issues are relevant in remote operations.

We have also found some challenges and best practices based on interviews and discussions with the oil and gas industry. Increased resilience or increased safety has not been a clearly stated goal to implement remote operations. Technology has been prioritised before man and organisation in an MTO perspective. Development of work processes, training in cooperation and worker involvement across companies is delayed after implementation of the technology. The organisation has not used a methodology to allocate functions between onshore and offshore with a focus on resilience and safety. The organisation has different work processes and procedures among the drilling platforms (rigs), these are not standardised. Training and support should have been prioritised more. The use of video equipment has improves communication and collaboration among the employees across onshore and offshore. CRIOP, with the e-operation checklist and suitable scenarios, should be used by the industry to verify and validate cooperation in control rooms between the different actors. See [Johnsen, 2003].

2.1 Relevant Challenges and Best Practices Based on Common Findings

2.1.1 Establish Robust Routines

In the industries it was observed that routines were not robust enough. There were weaknesses related to sharing of safety information and weaknesses when there was mismatch between information given by the technical system and messages from the operators. It is important to make clear what should be done when the system and operators are giving conflicting messages. This is especially important if it the situation is time critical and there is no time to double-check the messages. Serious incidents and accidents could be traced to poor quality in developing and maintaining routines.

a) Routines need to be unambiguous and understood by all operators. Ideally the routines should be developed and refined in cooperation with the operators to ensure robust and resilient routines.

b) Routines about how to handle conflicting information from operators vs. the technical systems are important to establish. It is also important that all operators working with the remote operation system have similar and common understanding of how these incidents should be handled.

c) Routines for sharing safety information and incidents should be established, both inside the company and between companies. Incidents and safety information should be exploited to improve the routines.

2.1.2 Establish Robust and Rich Systems and Routines for Information Sharing

In the industries it was observed that routines and systems for information sharing were not good enough. Serious incidents and accidents could be traced to the quality in communication channels, redundancy in communication channels or in routines for use.

d) The communication channels must be of good quality and free of noise and interferences.

e) Information should be able to be double checked by the receiver when the message is critical, or when it may be difficult to understand the message.

f) To ensure redundancy in communication; information should be communicated as rich information, sent and received in parallel by different medias (sound, pictures and indicators) in several channels.

g) To create common situational awareness, all the control room operators must have possibilities to share and see the same information.

h) Changes of the communication system (temporary or permanent) need to be handled with great caution. Changes resulting in poorer capacity in the communication system should be avoided.

i) It is important to have defined service level in the communication channels and alternative communication media. There should be established a defined service level agreement (SLA) related to stability of communication.

2.1.3 Analyse High Workload Situations to Avoid Safety Critical Incidents

Remote operations and transferring tasks to other sites also means change in the tasks or responsibilities. In the beginning it may be difficult to know exactly how many tasks

can be handled in the remote control room during a crisis or unwanted incident. Experiences show that high workload and fatigue could lead to severe incidents.

j) Situations of simultaneous change of tasks and a raise in workload should be avoided or handled with great care.

k) Random peaks or stress endured over long time can lead to operators' limits for high workload is exceeded. These situations should be avoided by performing workload analysis, scenario analysis or by extensive training. If the control room operators have possibilities to regulate their workload themselves, it is important that this is communicated to them as an important safety issue.

l) High workload may affect the use of routines negatively and sometimes routines are totally avoided. Such issues need to be identified and resolved with the operators.

2.1.4 The Ability to be Flexible and to Improvise is Important to Safety.

The ability to be flexible and improvise is important to ensure that unexpected situations are handled. The two most important issues to accomplish this are cross-disciplinary knowledge and to know what other experts are needed to resolve the issue. A prerequisite is that experts are available and can be contacted if needed. The AMK centrals are coordinating and using knowledge and experts related to the particular situation in a highly effective manner and often by improvising, even though the operators are not specialists. Some important lessons from the AMK centrals are given in the following.

m) The control room operators' ability to improvise when unexpected incidents occur should be emphasised. To be able to improvise the operators must master the technical systems and have comprehension for other operators' tasks and the whole picture of activities going on. They must be able to get an overview of the situation, use other operator's knowledge, cooperate and coordinate, be creative and dare to make decisions. Improvisation is a skill to be developed and sustained by good training. CRM could be utilised to attain this.

n) In some situations it may be appropriate to let the control room operator decide how to use procedures. Examples of this are when procedures are used as guidance in tasks or as verification afterwards. Or when it can be more effective to delegate tasks based on the situation rather than based on pre-defined rules.

2.1.5 Redundancy in Technical Systems and in Human Resources Should Be Established.

Lack of redundancy is a returning element in the different industries. Either as lack of technical solutions capable of taking over if something fails, or that operators are alone in executing their tasks and other people are not present to spot if something is wrong.

This represents an essential lack of barriers, which makes the organisations vulnerable for single errors, either in the systems or by single persons. Redundancy in technical systems or in humans will help sustain barriers and reduce errors. A combination of redundancy in systems or humans may give defence-in-depth with barriers both taking care of active and latent faults [Reason, 1997].

o) Redundancy both in human and technical systems should be established as well as warnings if redundancy is missing.

p) It must be established a culture that encourages utilisation of human redundancy and resilience. The operators must be trained to correct, support and assist each other when needed. Operators must understand the importance of reporting suspicious situations, as well as the importance of follow each other's work. It must be a culture for giving each other corrections and comments, both positively and negatively to improve resilience.

2.1.6 Build Redundancy by the Remote System's Active Warning Functions and Alarms.

Active warning functions means functions that is automatically activated, or functions that is activated by an operator and is warning other operators through the technical system. It is highly important that active warning systems are installed to build redundancy, in addition to having operators. It is risky to only rely on operators to detect and prevent all dangerous situations. Good and adequate warnings and alarms are important for the control room operators to be attentive of situations in time. There were several incidents related to missing "active warnings".

q) The remote system needs to be able to warn if something risky is about to happen. It must be able to give instantly warnings both thorough sound and light. Redundancy in reporting is important. However, without stressing the operators.

r) It is important that the remote operation system is giving clear indications about the actual status and is signalling if safety critical functions are lost.

2.1.7 Continuous Education and Sharing of Experiences to Increase Resilience in Operations.

New systems will require new and maybe challenging ways of working for the operators. Operators will use much time just to handle the new systems, and they are more focused on their own tasks than situational awareness e.g. the sum of actions happening in the central. Until they feel safe and comfortable using the new systems it will most likely occur situations, which is difficult to gain overview of and to handle correctly. It is important to assure adequate education in new technical systems. Also, existing systems may need some repeated education as some functions are seldom used or the operators develop a practice not according to the intentions.

s) When new systems are installed, including remote operating systems, focus has to be placed in education and possibilities to gain experience. Both the employer and the employees should be able to initiate education.

t) It is important to give education in routines designed to correct shortcoming in the remote operating system. Situations where the system is not working may occur, and correct operation is completely depending on the operators. It is therefore important that such routines are made and understood.

u) When operators are performing critical tasks normally not used, training and education should be given before performing them.

v) The training of operators should address the possibility to build up common situation awareness among all the involved operators.

2.2 Relevant Challenges and Best Practice from Telemedicine

Remote operations within the health services have been implemented by telemedicine, using IT to support cooperation and problem solving in a geographically dispersed environment.

2.2.1 Relevant Challenges from Telemedicine

Some of the challenges related to Telemedicine, see [Lindstad, 2004], has been:

- Focus on the organisational challenges in addition to technology.
    - Telemedicine can be used to improve cooperation between the levels in the organisation and across several organisations. The change process should involve the affected organisations, and participants from the different levels should be involved to ensure that all stakeholders are involved in good participatory processes. The change processes must involve the important stakeholders, and management must take responsibility. The benefits of the changes must be highlighted. [Kotter, 1996] is a key reference to help guide the change process.

- Training must not be ignored.
    - There must be a focus on training and continuous support/training to ensure that the new technology and routines are used as planned. There must be allocated enough resources to training and continuous support during operations, it is however important to allocate resources at the initial phase when new work processes are implemented.

- Technical support becomes critical due to the increased importance of technology
    - The routines related to technical support must be clearly defined related to responsibility ands service levels. A clearly defined SLA (Service Level Agreement) should be specified related to all technical components

These challenges are mostly related to Human Factors and factors related to Organisation.

2.2.2 Relevant Best Practice from Telemedicine

Some of the best practices related to Telemedicine, see [Lindstad, 2004], has been:

- Improved availability of competence when it is needed.
    - In general more uniform knowledge and higher availability of expert knowledge across the institutions, because teleconferencing and remote systems are used much more. Focus on establishing a competence network, with clear responsibility and availability to be used when needed. The competence network should have defined availability and response intervals to be able to aid in an emergency.
    - Increase of competence at local institutions. Experts are more easily available, leading to increased local knowledge and competence in areas where this is relevant.

- Improved work processes and improved responsibilities between the organizational levels. (Geographical distance is no longer a barrier to improved workflow.)
- Decrease of travel expenses, and decrease of stress related to travels

2.3 Relevant Challenges and Best Practice from Operators in the Oil and Gas Industry

We have been working together with several operators having implemented a remote operating centre. We have interviewed several persons and we have discussed our findings in open meetings. See [Andersen, 2006] and [Hjellestad, 2006].

2.3.1 Increased Resilience or Increased Safety has not been an Initial Goal

Increased resilience or increased safety has not been a clearly stated goal to implement remote operations. This should be corrected. To improve resilience, it is important that the whole organisation has a common focus on both issues.

There seems it is a great deal of complacency related to the implementation of new technology used in remote operations - there is a time horizon of 4-6 years.

2.3.2 Technology has been prioritised before Man and Organisation in an MTO Perspective

Using an MTO (man, technology and organisation) perspective when remote operations are discussed and implemented, we have observed that the focus is on technology. Safety barriers and issues related to organisation and man is discussed later. Development of work processes, training in cooperation and worker involvement across companies is delayed after the technology is chosen and partly implemented. However remote operations are affecting all aspects of MTO, there is increased use of technology in daily operation, but also new ways of working and structuring the organisation. Therefore all aspects of MTO are important to consider in work with remote operations.

Experiences from fields which have already implemented remote operation showed that it is essential to develop work processes early and in parallel with technological solutions to gain good results in cooperation and use of control rooms. Still there is low focus on developing work processes early and across locations. It is therefore highly recommended that work processes and work practice are made and implemented early in the process, and in parallel with technology.

2.3.3 A Structured Methodology to Allocate Functions should have been used

The organisation has not used a common methodology to allocate functions between onshore and offshore with a focus on resilience and safety. The methodology CORD, see [HFC, 2006], has been developed to do this. Important issues could be clear and precise responsibility between onshore and offshore facilities, or clear and precise responsibility between different firms.

2.3.4 Organisational Changes and Necessary Standardisation has not been Performed

The organisation has different work processes and procedures among the drilling platforms (rigs). This is a challenge related to increase efficiency and a challenge related to the establishment of common situational awareness if remote operations are going to be performed of several platforms. Standardisation could reduce resilience across the different drilling platforms or rigs. The management should prioritise to standardise the different work processes across the different platforms.

The management should change the organisational structures due to the implementation of remote operations. This needs planning and good co-opting procedures.

2.3.5 Training and Support should have been prioritised more

During the implementation process of the centre it seems few resources had been used to training in advance and few resources had been reserved to support during the initial phases. The project should have been planned with more resources allocated to training, and more resources allocated to support during the initial phases.

2.3.6 A Structured Methodology to Verify Solutions should have been used earlier

CRIOP is a methodology to verify and validate the ability of a control centre to operate safely. It considers all aspects of MTO and also considers cooperation in remote operations. CRIOP is based on HF standards such as ISO-11064.

CRIOP was often not used in the aspects of cooperation, leading to low focus on integrating personnel and experts in different locations and leading to fragmented knowledge between different actors that should cooperate.

It is therefore important to point out that CRIOP, with the e-operation checklist and suitable scenarios should be used by the industry to verify and validate cooperation in control rooms between the different actors.

In general it was found that CRIOP and HF analyses often was performed to late in projects, making it difficult to get acceptance for changes in design. By doing CRIOP late, it is more costly to make changes and it is difficult to get acceptance for the changes, although the changes may be important to safety and resilience. Making such analyses at the right time, maybe earlier in the design process, is therefore recommended to get optimal design regarding all aspects of MTO.

2.3.7 Video Conferencing has Improved Communication and Collaboration

The use of video equipment has reduced travel cost and enabled better communication among a broader basis of employees which has increased common understanding and improved communication and collaboration among the employees cross onshore and offshore.

3 SUMMARY OF PROPOSED METHODOLOGY OR STEPS

We are suggesting establishing a methodology or steps to increase resilience in remote operations. The methodology is based on experience from different industries and we have based our suggestions on identified common challenges and common best practice related to remote control.

3.1 Key issues during implementation of remote operations

Key issues during implementation of remote operations seem to be:

- **All major (and minor) changes must be planned, and the implementation process must focus on Technology, Organisation and Work processes in parallel.** The implementation process should be based on the steps suggested by [Kotter, 1996] to ensure good co-opting processes, such as:
  - **Developing a motivating vision and strategy**, e.g. establish a vision that is relevant and communicating the change vision among all the participants. Improved safety and resilience should be a part of the vision. Establish a sense of urgency among the participants in the organisation and in cooperating organi-

sations. Focusing on improved safety, resilience as one result of remote operations, to ensure that resilience is integrated in the project.

- **Creating a Guiding Coalition,** involving management and key stakeholders that can influence and sustain the result. Management and employees must participate both within the firm and between different organisations. Empowering broad-based actions, to ensure that among other tings - work processes are developed together with the users
- **Develop work processes early and in parallel with technological solutions**. This is important to gain good results in cooperation and use of control rooms. It is therefore highly recommended that work processes and work practice are made and implemented early in the process, and in parallel with technology.
- **The function allocation should focus on safety:** A structured methodology to allocate functions between onshore and offshore to improve safety and increase resilience should be used. We are proposing to use CORD, see [HFC, 2006].
- **Communication across boundaries should be carefully designed**, see [Henderson, 2006] and [Johnsen, 2005].
- **Establish redundancy in technical systems and/or human resources**, as well as warnings if redundancy is missing should be accomplished. Also establish a culture that encourages use of human redundancy.
- **Use characteristics of HRO in design of remote operations.** It is important to focus on both organisational redundancy and adaptability. Suggested elements to focus on are: common safety goals, cooperation in change processes, clear responsibilities, technical and cultural aspects of communication, decisions in critical situations, routines and procedures for common work (applied across company borders), common procedures and processes for readiness
- **Rich and diverse alarms should be utilized.** Focus on the remote operating system's active warning functions. The system must warn if something risky happens and be able to give accurate, instantly and diverse warnings and signal if safety critical functions are lost.
- **Provide rich information.** The information sent must be rich and in real time, and available to all operators to encourage a practice for double-checking information.
- **Generating short-term wins**, document the benefits, consolidating the gains and producing more change and anchoring new approach in the culture.
- **Focus on training and support the operators' ability to be flexible and to improvise**. Make satisfactory procedures for continuous education and sharing of experience. Training should include possibilities to build up situation awareness, and correct shortcoming in the remote operating system and new systems. On the job training should be given when tasks is seldom performed. Both the employer and the employees should be able to initiate education. It is also important that the operators have the ability to improvise. Important elements in improvisation is to focus on the operators' ability to be creative,

master the technical systems and understanding of other operators' tasks, as well as the ability to coordinate, cooperate, make decisions and get overview of the situation.

- **The solutions should be validated and verified by exploration of safety related scenarios.** A structured methodology to discuss and explore key safety cases involving onshore and offshore should be used. The safety cases should be chosen to improve safety and increase resilience. Exploration of key safety cases should improve organisational learning among the cooperating organisations. We are proposing to use CRIOP, see [Johnsen, 2003], which has been used to explore safety cases/safety scenarios in the Oil and Gas industry.
    - **CRIOP and/or HF analyses must be performed early in the design process.** Such an early focus makes it easier to get acceptance for changes in design, changes important for safety and resilience.
    - **Train on conflicting messages.** Make routines covering conflicting messages given from the system and the control room, and assure that all operators working with the remote operation system have similar and common understanding of such incidents.

3.2 Key issues during operations of remote operations

Key issues during remote operations seem to be:

- **Establish a competence network in operations**, with clear responsibility and availability to be present when needed. The competence network should have defined availability and response intervals to be able to aid in an emergency.

- **Establish routines and systems to share information and incidents**. Routines need to be unambiguous and understood by all operators. The routines must cover sharing safety information and incidents with all involved stakeholders.

- **Changes in communications systems must especially be planned.** Changes especially on the communication system need to be handled with greater caution. Good quality, stability and coverage are important.

- **Avoid high work load/fatigue.** To avoid safety critical incidents it is important to focus on avoiding incidents giving too high work load and fatigue, both because of local peaks of work and long time stress as well as simultaneous change of tasks and a raise in work load.

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