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THE INFLUENCE ON ORGANIZATIONAL ACCIDENT RISK BY INTEGRATED OPERATIONS IN THE PETROLEUM INDUSTRY

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ABSTRACT

Transition into IO, integrated operations, (introduction of new technology, new organization of work and increased automation) in petroleum activities in the North Sea influence the ability to accommodate failures and disturbances without producing organizational accidents. The paper describes the main expected changes in human and organizational aspects related to IO, and present both positive and negative effects from these changes on organizational accident risk.

1. INTRODUCTION

Integrated operations (IO) is not a term that is possible to define in a strict sense. It carries a lot of "fluid" meaning that encompasses a diversity of needs and agendas, not least because at the current time it aims at how future operations will look like. Hence, at least for the time being, it is a pragmatically functional "buzzword" that serves as a gravity point for many different expectations, question and discourses. One of the fundamental discourses in that respect is how the possibilities of Information and Communication Technology (ICT) will affect the industry. This discourse is however mediated by other aspects, such as:

- the economy of production and management of knowledge in a networked, knowledge-intensive business environment
- the implications of a forthcoming generation shift in personnel, and accordingly, the types of experience, skills and knowledge that will be available for the industry in the near future

In addition, there are a number of mediating issues that no commercial player can ignore, e.g. (OLF, 2003):

- the potential for increased profit by cutting costs
- the potential for increased production and exploitation of fields and reserves
- the potential for enhanced competitiveness
- the virtually ever-increasing societal demand for increased production, as well as exploration of future resources

The shaping of IO is thus neither a deterministic effect of technological possibilities, nor a matter of rational choice among clear alternatives. The key point is that the players do not have the option to hesitate, despite the lack of clear alternatives. IO – in the "fluid" meaning – is a strategic perspective that the players

employ to address sustainability in terms of economy, competitiveness, operational efficiency, and access to skills and knowledge. A majority of actors in the Norwegian context (OLF, 2006) emphasize *rate of change* as an important feature in itself, and the importance of staying at the leading edge.

Hence, development, deployment and application of Information and Communication Technology (ICT) and digital infrastructure in the petroleum-related activity on the Norwegian shelf continue with unabated intensity. The petroleum industry have declared that this application of ICT is a prerequisite as well as a driving-force for the development of more integrated work processes within all main activity areas, such as drilling, operation and maintenance (OLF, 2003). The drive towards integration affects activities onshore and offshore, the relation between operators and contractors and between national and international actors. The development towards increased integration is signified by increased bandwidth in the digital infrastructure, standardisation of data, integrated ICT applications and work processes utilising the digital infrastructure, as well as new work processes aimed at achieving improved and more efficient analysis and decision processes. This line of development is strongly linked to a number of other signifiers at the business level, such as more efficient reservoir exploitation, optimization of exploration and operation processes, and ambitions for long-term, managed development of fields and installations (OLF, 2003).

This development of IO establishes new, tight operational collaboration between various actors in the industry, and spurs substantial changes in work patterns on the continental shelf, as well as in the onshore support services. New actors are also introduced to the industry, related to ICT-supported applications and services. Development of IO also facilitates the transfer of functions from offshore to onshore, thus a number of onshore activities gain increased importance for operational safety at offshore installations. In relation to this, unions have voiced a clear opposition to the relocation of crucial control functions on manned offshore installations, to onshore control centres.

From being primarily focused on technology development and application, the development of IO now takes new directions:

- increased focus on challenges related to new work processes, integration of information throughout whole value chains and ICT vulnerability
- wide recognition of the prime significance of human and organizational factors for the success of IO
- development of "virtual plants" comprised by onshore and offshore elements that are transformed into a fully integrated functional community

On this background, it is important to identify, evaluate and mitigate IO-related risks concerned with the working environment as well as major accidents. The aim of this paper is to address human and organizational factors related to IO that have an impact on the risk of organizational accident, i.e. "..rare, but often catastrophic, events that occur within complex modern technologies, …[with] multiple causes involving many people operating at different levels of their respective companies" (Reason, 1997:1). A selection of IO-related human and organizational factors will be investigated more thoroughly, spelling out both positive and negative effects. The paper, which is based on Grøtan and Albrechtsen (2008), will be focused on human and organizational factors, and on the IO-driven *changes*. Thus, it will not address the full risk picture, and it will not attempt to quantify any net effect on risk.

The paper is written within the RIO (Inter disciplinary Risk Assessment in Integrated Operations) project, sponsored by the Norwegian Petroleum Safety Authority (www.ptil.no), the IO-Center at NTNU (http://www.ntnu.no/iocenter) and the PETROMAKS program of the Norwegian Research Council (www.forskningsradet.no/petromaks).

2. APPROACH

Figure 1 illustrates how the aim of the paper is approached. The main expected IO-developments regarding human and organizational aspects are discussed according to six perspectives on organizational accidents and resilient organizations. The outcome of the discussion is a range of possible positive and negative effects on organizational accident risks related to IO.

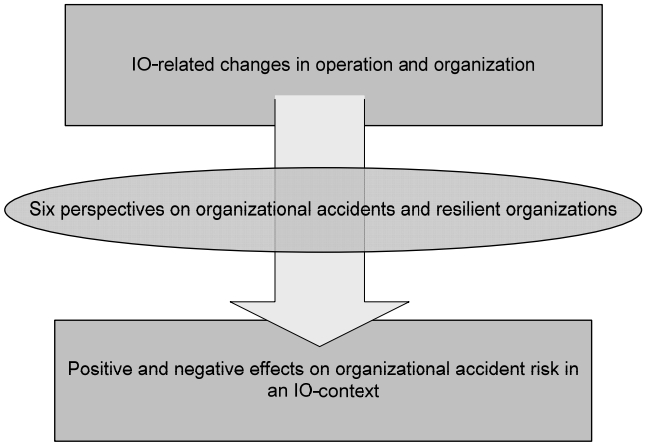

Figure 1: Analytical approach

Due to this approach, Section 3 presents a brief review of possible positions in what we denote the IO change space. A diversity of change elements can be derived from these positions, however for the purpose of this paper a rough selection of change elements is construed to be representative. This multifaceted transition into integrated operations is the source of both positive and negative effects on the organizational accident risk in petroleum activities. These effects are outlined in Section 4, and discussed in Section 5.

Risk is essentially about something that has not yet happened. Anticipating risk means anticipating what might happen, what might go wrong, how the system might be prepared, and how it will cope with unexpected variations and events. The discussion in Section 4 thus requires a diverse understanding of the nature of organizational accidents. Our understanding of organizatonal accidents is based on six different perspectives on organizational accidents and resilient organizations, and corresponding control questions (see Box 1).

Box 1: Control questions

The six perspectives are:

- The *energy and barrier perspective* understands and prevents accidents by focusing on dangerous energies and means by which such energies can reliably be separated from vulnerable targets (Gibson, 1961; Haddon, 1980).
- *The information processing perspective*, taking Turner's theory of Man-made disasters as a starting point (Turner, 1978; Turner and Pidgeon, 1997), understands an accident as a breakdown in the organizational flow and interpretation of information that is linked to physical events.
- The *decision-making perspective*, with a focus on the handling of conflicting objectives. E.g. Rasmussen's (1997) model of activities migrating toward the boundary of acceptable performance.
- Perrow's (1984) 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 organization responsible for controlling the technology.
- The theory of *High Reliability Organizations* (HRO) (Rochlin et al., 1987, LaPorte and Consolini, 1991) is grounded in intensive studies of organizations that have demonstrated an outstanding capacity to handle fairly complex technologies without generating major accidents. Important concepts from this research tradition are organizational redundancy and a capacity of organizations to reconfigure in adaptation to peak demands and crisis.
- The theory of *Resilience engineering* is a new concept developed as a response to shortcomings in traditional safety management approaches. It focuses on a socio-technical system's ability to attend to, monitor and cope with performance variability (Hollnagel et al., 2006).

Control questions to consider the influence on organizational accident risk in IO

The energy and barrier perspective:

1. Are barrier functions strengthened or weakened?

The information processing perspective:

2. How is an organization's ability to utilize safety-relevant information, observations and ideas, regardless of position and status of the person or group who possess this, influenced by the IO development?

The decision-making perspective:

3. Is an organization's ability to make decisions concerning risk strengthened or weakened?
4. Is the likelihood for drift towards the limit for acceptable risk increased or reduced?

The theory of Normal Accidents

5. Does the IO development create complex interactions and tight couplings between system elements?

The theory of High Reliability Organizations

6. Is organizational redundancy strengthened or weakened?
7. Is the ability to change operational modus in crisis situations strengthened or weakened?

The theory of Resilience Engineering

8. Is the ability to expect and be prepared for the unexpected strengthened or weakened?

The first five perspectives are based on a review by Rosness et al. (2004) and the latter one is built on Hollnagel et al. (2006). The perspectives have a central part in practical safety management or have had a major impact on the safety science discipline. The perspectives focus on different but complementary aspects when they account for organizational resilience. The analytic approach of the paper thus produces different understandings of effects on risk.

For the purpose of our discussion of positive/negative effects, each perspective is represented by specific control questions (see box 1), each of which captures an essential property of a specific perspective. By relating each control question to the selected change elements, we generate a variety of theoretical arguments of positive/negative effects. These effects constitute an indication of how the transition into IO may influence the organizational accident risk.

3. IO-RELATED CHANGES

3.1 Exploration of the IO change space

As we have indicated above, IO is in many respects an open process, an ongoing development that can take many directions, in which many factors mediate each other. Novel as well as "old" practices combine and gain new meaning and significance in new contexts. The actors however cannot afford to hesitate, and have to try to enact some form of strategic choice. That is, they have to attempt to define some (joint) objectives and accordingly identify, establish and pursue some causality that fulfils those objectives. The historic lesson is however that overly ICT-centric organizational development in such a scale is full of surprises and unintended consequences, surprises that can be ascribed to inherent covariance and mutually mediating factors, or *complexity*

in the fundamental sense (Ciborra 2000, Hanseth and Ciborra 2007). Many aspects of the IO development will only be *retrospectively coherent* (Kurtz and Snowden, 2003).

Our attempt to capture some change elements related to IO is thus not based on deterministic models, nor on imagined clairvoyance. Our strategy is to establish some key positions in what we denote a possible IO change space, and derive some specific changes from those positions. Hence, our aim is to identify a set of change elements that can be construed to be of relevance for the evaluation of risk of organizational accidents.

We designed five key positions in the IO change space to form a cluster that intrinsically carries the dialectic between strategic choice and inevitable surprise as indicated above. The cluster hence comprises both the desired development (strategic choice) that we can read out from the literature on IO, and some complex connections that may be sources of surprise.

The core position in this cluster is a strategically decided closure of a new equilibrium, in which ICT enables normatively "ideal" decision processes and continuous development of smooth and streamlined work processes with perfect coordination between heterogeneous actors, based on access to real-time data (OLF, 2003; 2006). Virtual organizations with multidisciplinary collaborative teams are the rule, not the exception. Value chains increase their scope across organizational borders. Flexibility, adaptability and willingness as well as capability to change are ever present. Standardisation contributes to common situational awareness. This core position however requires a number of organizational premises, which is the second position.

The third position is a description of a fundamentally new decision context (Sørhaug 2004), in which

- interfaces are the new foreground (enterprises the new background) for value creation
- knowledge regimes are mixed and fluid (management, collegial and network)
- the knowledge economy is new
- the power aspect cannot be ignored

The third position also emphasises a crucial distinction between work process (what to be done) and work form (how to do it). Work forms are comparatively more challenging to establish and maintain, as they demand a complex MTO (Man-Technology-Organization) balance in which different communities of practice (Hislop, 2004) are founded on separate MTO (sub-) balances and communicate via boundary objects. Boundary objects are communicative devices that are not equally understood by sender and receiver, however they are *sufficiently* equally understood in relation to a pragmatic need. The inherent danger is that they do not remain sufficiently equal when the pragmatic context changes, either abruptly (e.g. in an emergency situation) or slowly drifting towards some critical threshold. The necessary articulation work (Hepsøe, 2006), that is, the inevitable perspective making and taking that is required to reconcile differences and maintain the functionality of the boundary objects in relation to the work form, may be straightforward ignored, be impossible due to available time, or silently suppressed by the comparatively more efficient re-presentation of work processes (Grøtan, 2007) that ICT enables.

The third position is in many respects a dialectical counterpoint in relation to the core position of the ideal decision processes. The dialectical interplay is (using the musical metaphor *punctus contra punctum*) both horizontal (the melody lines are played in parallel) and vertical (they form new harmonies).

The fourth and fifth positions are positive and negative tentative implications, respectively. They are implications (synthesis) of the above dialectic in the sense that they indicate effects on cooperation, communication, decision and safe operations in an IO context. It should be noted that the positive/negative distinction is intermediary in relation to the scope of this paper, because the change elements are not yet combined with the control questions and six perspectives on organizational accidents (section 2).

3.2 Notes on work processes, working forms and decision processes

The terms decision process, work process and work form are central notions in relation to the themes discussed here. The terms are distinct, yet related with each other in many ways. We will briefly try to clarify our use of the terms here.

Work processes is about *what* to do (tasks), while work form is about *how* to do the various tasks comprised by the work process in the actual collaborative context. Rearranging – or "re-engineering" - a work process is one thing, adapting the corresponding work form is substantially different.

Decisions are crucial at many levels in organizations (some scholars even depict the organization as a "decision-machine", e.g. March and Simon (1958)). A work process can be a sheer decision process, in which the

outcome is a decision. On the other hand, decisions, and decision processes, may be inherent within any work process or work form, or change thereof.

Summing up, this means that the work form can be generalized to be a "shadow system" to any work process or decision process involving diverse actors.

3.3 Selected change elements

For the purpose of this paper, which is to combine a number of representative IO change elements with the various facets of organizational accidents and resilient operations represented by the control questions in section 2, we have to make a selection of change elements. Hence, we have made a selection that construes a representative picture of forthcoming IO, as a synthesis from the dialectic described above. However, this is not a plain "harmonious" synthesis. The selection maintains the possibility of breakdown and disharmony in the *punctus contra punctum* of IO. These elements are focused at different levels. Based on OLF (2003; 2006; 2007); Johnsen et al. (2005); Ringstad and Andersen (2006; 2007); Hepsøe (2006); Tveiten et al., (2007; 2008); Holst and Nystad (2007); Drøivoldsmo et al. (2007); and Henriquez et al. (2008), the following main changes with possible influence on organizational accidents and resilient operations can be identified:

A Changes at the business level

A.1 More explicitly defined operations based on defined scenarios. Increased focus on value-chains and logistical aspects of operations, and on integrated planning

A.2 Emphasis on high tempo in continuous change processes. Continuous experimentation and adaptation with a special focus on accountability

A.3 Increased presence of integrated vendors with total responsibility for larger chunks and clusters of activity

B Changes related to improved decision processes – implications for work forms

B.1 Great expectations related to the development of efficient and "ideal" decision processes, resulting in enhanced collaboration. This together with new constellations of new and old actors (individuals, groups or organizations) will raise a number of issues related to a potential tension between the wish for new, effective decision and work processes, and the inevitable need for more time-consuming development and maintenance of work forms in which functional boundary objects are a requisite part.

B.2 The rise of new arenas (e.g. virtual collaboration rooms) for decision making, based on access to extensive real-time data and unhindered access to expertise. Information overload may occur, as well as discussions on authority.

B.3 New context for decisions related to power, new foregrounds and backgrounds, and mixed knowledge regimes.

C Changes related to new conditions for knowledge sharing, communication and interaction

C.1 Increased focus on development and dissemination of information and knowledge. The economics of information and knowledge will reflect its position as a partly scarce resource. The optimisation of production and consumption of knowledge is more complex than a sheer commodity. The resources that are able to exploit the knowledge will possibly be more expensive than the knowledge itself.

C.2 Increased potential access to a broad repertoire of knowledge, resources and expertise through electronic collaborative interfaces, both in normal routine and emergency situations.

C.3 Increased potential for facilitation of multidisciplinary teams, across organizational and geographical affiliation.

C.4 New forms and patterns of communication, and new group/team constellations will imply use of both richer and poorer communication channels. Familiarisation with new "boundary objects" will be required.

C.5 As an implication, a need for careful attention to the creation and maintenance of new work forms (new work processes requires new shadows, and maybe new "IO-species" of shadows).

C.6 As an implication of C.5, increased potential for diversity in situational awareness

C.7 A constant temptation to rush the development of work processes at the expense of work forms, as an implication of ICT capacity to re-present work processes (re-presentations are more malleable than the reality they represent!).

D Changes related to HSE

D.1 "IO-fication" of safety management, including access to real-time safety data, new methods for collection and presentation of such data, and improvement of analytical tools and safety management processes.

D.2 Increased complexity increases uncertainty in the overall risk picture

D.3 Possibilities of increased interactivity and complexity in emergency situations

4. A DIVERSITY OF EFFECTS ON ORGANIZATIONAL ACCIDENT RISK

The combination of IO-related change elements presented in Section 3 above, and the control questions derived from the six perspectives on organizational accidents and resilient operation in Section 2 (Box 1), may give rise to a number of positive and negative effects on the risk of organizational accidents. In this section, we present a subset of the possible effects identified by Grøtan and Albrechtsen (2008).

4.1 The energy-barrier perspective

On the positive side, IO makes it possible to establish barriers according to the current risk picture by use of real-time data, information about future situations and access to expertise. Real-time data also makes it possible for tighter follow-up activities of established barriers. Together with available expert knowledge, possibilities for faster detection of failures, and normalization of deviations arise.

However, there are also some negative issues concerned with IO in a perspective of energy and barriers. Reduction in offshore workforce can weaken the human barrier element proximate to the potential hazards. Use of acontextual (non-IO), historical data for planning of barriers may give another negative effect. A similar effect arise if barriers are based solely on models of work processes, without reflecting the changes in work forms.

4.2 The information processing perspective

One of the key premises for new types of operation in the North Sea is real-time data and distribution of information. IO thus makes it possible to have a proactive safety mindset by access to real-time data available for many actors; simple presentations and processing of data; and access to expert knowledge. In collaboration rooms, many different actors from different organizations will see and have access to the same information thus having a potential for strengthening the safety work.

Altogether the IO-development support an organization's ability to utilize safety-relevant information, but there are also some negative influences on organizational accidents in an information processing perspective. Distanced work and relocation of functions can imply that personnel who today communicate face-to-face must communicate by leaner channels, as a consequence non-verbal communication might be lost. New ways of work can also remove important arenas for information and experience transfer, such as coffee breaks and personal contact. Furthermore, the increased request of information may disturb sharp-end work. Successful work forms can blur differences that can be critical, as different interpretations of boundary objects can create a belief of being harmonized, while actually not.

4.3 The decision-making perspective

More efficient and better decisions are one of the key expectations of the IO development. It can be argued that integrated operation lead to better and safer decisions by real-time data and detailed understanding of situations; multidisciplinary teams involved in the decision making; access to expertise; and parallel activities. Such decision-making contexts also makes it possible to involve safety personnel/experts and safety information in decision-making processes. Altogether the emphasis on decision-making, sharpens the focus on work processes as this improves the decision-making support.

Lack of attention to the implications of a new decision-making context and suppression of work form can have negative effects as well. Work and decision-making at distance can be hampered by different situational awareness and hands-on-knowledge at the sharp and blunt end. Group-based decision-making and distributed decisions can blur the responsibility for action. When many different actors, independent of discipline and organization, are involved in decisions, some challenges arise: different actors with dissimilar rationale for safety; role and responsibilities in crises; decisions and actions beyond the actor's own domain; and more rapid decision-making with less room for second thoughts. To sum up, when operations become tighter and more complex, decision-making may become complicated, particularly in crisis situations.

4.4 The theory of Normal Accidents

If operations are well-planned, which is one of the main objectives of IO, the degree of complex interactions and tight coupling can be reduced by linear operation and few unforeseen interactions. However, this is an ideal picture of IO; there are several indications of more complex interactions and tighter couplings in IO. Every socio-technical system that implements network-based information technology as a core element is likely to become more complex and tighter coupled (Perrow, 1999). Furthermore, compressed and efficient operations, long and flexible value chains, in general generate potentially high degree of complexity and couplings. A small deviation can trigger off unexpected interactions. Low emphasis on work forms combined with lack of experience

and knowledge in boundary objects can cover up complex interactions between functions. Emphasis on work processes creates unexpected ripple effects, such as information-out-of-information (Hanseth and Ciborra, 2007) and lag of work form.

4.5 The theory of High Reliability Organizations

The capacity for organizational redundancy is improved in IO as more actors can observe, participate and contribute in boundaries between disciplines and organization. Multidisciplinary teams and different situational awareness can be an arena for creation and maintenance of both cultural and structural redundancy. However, it might be difficult to establish organizational redundancy over distance. It can also be a challenge to establish organizational redundancy in boundaries between different actors with different interests, particularly as teams are brought together when the situation requires them to. As a consequence there are no stable constellations in the teams, informal procedures such as keeping an eye on what the neighbour is doing becomes difficult to establish. Information channels for work processes that suppress work forms can be an obstacle for organizational redundancy.

The ability to change operation mode in crises can be improved in IO as flexibility is an important feature in IO. However the ability to change mode must be planned in advance. Faster detection of failures by real-time data and experts implies that the response time to the crisis is reduced. Furthermore, integrated contractors can be given extended authority in crisis; the operator can step aside in crises and let the contractor handle the crises. On the other hand, complex structures of authorities over cultural and geographical borders can create challenges regarding responsibilities in crises situations. Another challenge regarding crisis handling is blurred responsibility and lines of command in integrated work processes based on distributed decision making. Changing the work form is substantially different from changing the work process. Suppression of work form in the IO development is again a key challenge for handling risk of organizational accidents.

4.6 The theory of Resilience Engineering

In general IO has a proactive focus, thus strengthening the ability to discover and be prepared for unexpected situations, by real-time data; integrated planning; and more actors creating and a larger total situational awareness. More people can be trained for handling of complex situations, by “on the job training” as well as by more realistic simulation and training. However, by emphasising work processes that aim at efficiency and lack of attention to work forms, the unexpected situation might as well be the undeveloped work forms. The ability to be prepared for the unexpected has a price tag. If the knowledge economy is not clarified, this can create obstacles for the ability to discover and prepare for unexpected situations.

5. DISCUSSION

The energy-barrier perspective displays a blend of positive and negative effects. Improved planning capability and access to real-time data give a primarily positive effect, while the negative effects stem from high tempo in change processes, a high number of integrated contractors, lack of focus on work forms, and increased complexity.

The information perspective, the decision perspective as well as the normal accident perspective indicates that the majority of change elements have both a positive and negative effect. They however reaffirm the specific observation that a lack of attention on creation and maintenance of work forms, as well as the new decision context, has a negative effect.

The HRO perspective indicates the same picture. In addition, this perspective indicates that the use of ICT actually may enable a number of positive effects, such as trigging coordinated change of operational mode, prepare a “take-over” by en integrated contractor etc). The precondition for this is however *trust* in ICT solutions.

The combination of HRO and Resilience Engineering perspectives does not by any means contradict the findings above, but adds the positive effect of using IO for simulation and training. However, a precondition for this is that actors are willing to accept a price tag for the preparation for the unexpected. If the knowledge economy remains unclear, this problem may remain unsolved.

5.1 The Unlucky Luke effect

The issue of work forms is recurrent throughout all six perspectives. We have called this the *Unlucky Luke* effect. If Luke[1] (the work process) actually manages to outperform his own shadow, the shadow (the work form) will shoot back immediately after!

The anatomy behind the Unlucky Luke is indicated in Figure 2 below. The general premise is that a proper balance between work process and work from requires an IO-specific MTO-balance (Ringstad and Andersen 2006). In the IO context however, neither M, T or O is monolithic, but fragmented. A greater MTO balance requires a set of sub-balances constituting ecological niches (Hepsøe 2006), between which boundary objects mediate communication. (Re-)defining a work process across niches is straightforward, compared to the establishment/maintenance of work forms, which require continuous focus on boundary objects, and attention to articulation work. The balance between work process and work form is the crucial issue.

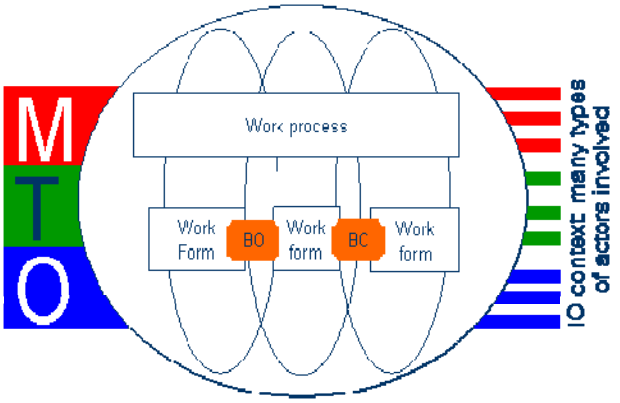

Figure 2: Work processes, work forms and boundary objects (BO) in MTO-balances in an IO context

6. CONCLUSION

The IO development in the North Sea creates a mix of positive and negative effects on the organizational accident risk. No change elements have an unambiguously positive or negative effect. Some of the change elements seem to have a predominantly positive effect:

- improved decision-making processes and -support
- increased use of ICT for use of real-time data; triggering of changing operation mode; and planning and preparation
- possibilities for simulation and training

Furthermore, some of the change elements have predominantly negative effects:

- complex structures (e.g. more integrated contractors with adjacent responsibilities)
- lack of understanding concerning new decision-making contexts
- lack of emphasis on work forms in MTO balances

The approach used to anticipate the effects on risk in this paper has been based on theoretical reflections on the IO development. One should thus bear in mind that the results presented are theoretical estimates about future states of operation in the petroleum industry at the Norwegian continental shelf.

This work provides hypotheses for empirical studies, a basis for reflection in the industry and the safety authorities, and a background for determining the need for safety analysis tools and methods in the IO context.

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[1] Lucky Luke is the cartoon figure who draws his gun faster than his own shadow

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