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SHORT REPORT

Interdisciplinary operational decisions in the subsurface domain: An exploratory discussion of information requirements and support from integrated technologies

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SAMMENDRAG

Denne rapporten utforsker mulighetene innen IO når det gjelder potensialet for å støtte operasjonelle beslutningsprosesser i reservoardomenet. Utgangspunktet er at modellerings og simuleringsteknologi i dag først og fremst brukes for beslutninger med lengre horisonter f.eks. reservoar og geomodell. Reservoar-, og geoinformasjon inngår ofte i operasjonelle beslutninger f.eks. under boring men real time data tilbakeføres i liten grad til modeller og simuleringer. Denne rapporten gir et glimt av den ”informasjonsøkologien” evt nye verktøy i retning av *”closed loop reservoir management”* må forholde seg til om de skal bevege seg inn i det tverrfaglige operasjonelle domenet. Rapporten er dels en teoretisk diskusjon og dels basert på uformelle intervjuer og besøk i undergrunnsmiljøer i StatoilHydro.

STIKKORD	NORSK	ENGELSK

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Interdisciplinary operational decisions in the subsurface domain: An exploratory discussion of information requirements and support from integrated technologies[1]

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1 About this report

The purpose of this report is twofold. Firstly it aims to outline some topics that we intend to focus on in future IO research within the "work and decision making processes"[2] part of Program 2 at the IO center. The intention of this is both to develop independent research on integrated work processes, but also it is an intention to provide input to other research and innovation, to help situate it within an operational context. This brings us to the second purpose of this brief report. Within the reservoir domain, StatoilHydro's Norne field is our industry case partner, and this report also seeks to outline some impressions from a short visit there as to which operational challenges within, or maybe more importantly, on the boundaries of, the reservoir domain may be possible areas of interest for the IO center's new technologies and work processes.

2 Background

New information technologies and new organizational principles have to some degree, though there are several issues to be handled,[3] already helped facilitate improved interdisciplinary work and decision making processes in the subsurface domain. Improved access to information[4], collaborative computer systems and data sharing platforms, and a paradigm of organizational design centred around the value chain (and not the disciplinary boundaries) has been important in this development.

[1] Elements of this report will also be integrated into a general report on decision making processes under Program 4 at the IO centre.
[2] This report focuses mostly on the first stages of a decision, the sense making and aligning of information needed to make the right decisions. The subsequent stages, for example implementation and communication will not be discussed.
[3] Hepsø (2006) notes that the initial expectations have not been met. There are several issues to be handled in the work-technology interface concerning work processes and change management. In addition to this, issues related to the integration of proprietary software from different vendors is also a frequently mentioned obstacle in the industry.
[4] In this report "information" is regarded as any kind of expression with a meaning, whereas "data" is a subset of information, referring to standardized types of information.

For the subsurface department of an oil field, the value chain is centred around the wells. Consequently the gains of IO in the subsurface area can be expected to found in decisions regarding wells (see OLF, 2005). This is where all disciplines meet, and almost all decisions regarding a well are heavily influenced by input and considerations from more than one discipline. A classical example is how a decision of production strategy for a new well normally involves at least considerations from the well-, production- and reservoir engineering discipline. (All in turn rely heavily on input from other disciplines. Also topside restrictions.) The best strategy from a production optimization point of view may not be the same as for reservoir management and both must be weighed against the limitations and possibilities a technically robust well design. The decisions taken are often more or less informal or NPV-supported weighing of risks and scenarios from these different domains. Though methods and guidelines do exist, it is still a field where the work processes are hard to standardize and where human judgment and expertise is a key component.

To make integrated decisions is a domain of its own consisting of more than the sum of its sub-disciplines. As it will be argued, it is important to recognize the importance of experience and contextual knowledge within each discipline, but maybe especially for complex decisions in the interdisciplinary domain.[5] Especially one should be cautious to avoid a stereotyped view of the complex process of sense making involved in interpretation of data, and the role of contextual knowledge in it. Many of the potential gains in terms of IO lies in the integration (interdisciplinary, onshore-offshore, operator-vendor) of the work and decision making processes of decisions concerning the wells: planning and execution of drilling, completion and production optimization. (OLF, 2005: 6ff). Here we will consider how the new flows of information from the reservoir, and the new tools to handle this, should be handled to best support integrated decisions and work in the subsurface domain.

3 New information ecology[6] in Integrated Operations

One must concede that, no matter the increased data volumes, a perfect representation of the reservoir cannot be made, at least not one to fit all purposes. All data and all models are representing certain aspects of the reservoir, usually indirectly, with different resolution and based on different physical properties and principles. Brought together as an information system, the multitude of sources gains its strength through the advantages multiple description. Multiple sources representing the same reservoir in different ways gives both a more profound understanding of the reservoir and a possibility for correction of errors in individual sources. A typical example of this is how the well data allows the seismic from the same area to be corrected and "tied in", while the seismic simultaneously provides the opportunity to asses how far the observations in the well may be extrapolated. Thus, the diversity in representations of the reservoir is a resource for gaining new knowledge about it, that is only available in the *combination* of the data types.

[5] See also Almklov (2006: 209ff) and Almklov (2009 forthcoming).
[6] See Nardi and O'Day (1999). The concept is applied here to stress the importance *interactions* between different technologies and forms of representations and between these and human knowledge. That is, one should not only be concerned with creating the perfect animal in itself, but one must do it with an understanding of the environment it is supposed to live in.

Integrated Operations has some implications in terms of what information the subsurface personnel on shore has to work with:

1. Improved access to real time information.
    a. Data from sensors. Increased amounts and availability and new types.
    b. Access to people through videoconferencing etc.
2. Accumulation and integration of data from various sources. (Hereunder improved modelling and simulation)

The advances within these fields have an obvious potential for improved prediction and control over the reservoir. A challenge posed for the future development of new IO technologies is not only to develop improved decision support for the different disciplines, but also to assist the interdisciplinary considerations and decisions. (OLF, 2005) In general the number of data sources and the volume of data is increased, for instance as a result of new down-hole sensors and improved logging bandwidth, and this also gives more opportunities for technologies able to refine, accumulate and integrate data. An explicit aim of much IO research is to make use of these opportunities to make better operational decisions.

One faces, however, an underlying dilemma in this situation. This dilemma is always there in some sense or another, and it must be considered when trying to implement new IO technologies. Seen from the point of view of a human decision maker trying to make sense of the oil reservoir, one may call it a *dilemma of transparency versus blackboxing*. Blackboxing is a phrase borrowed from cybernetics, often used in science studies[7]. It refers to a system or entity whose inner workings is unknown (or one chooses not to consider them), and which is characterized only by its input or output. Transparency on the other hand here refers to the opposite, that the human has access to the raw data "behind" the tool, as well as an understanding of its inner workings. Whereas total transparency would completely overload the human, too much blackboxing would lead to what some reservoir engineers call "Nintendo Engineers", engineers that blindly use the reservoir model without understanding the reality behind it, its constraints and limitations and its relations to other sources of information. More raw data, new data types, better data quality and more real time data gives the engineer more to work with. IO presents him with more information about the reservoir. The different points of view posed by different data types, provides a quality check and flexibility of interpretation that is often needed. The amounts of data are, however, too much to handle for a human. Modelling, simulation, data integration and accumulation techniques helps him "refine" his data, but these methods may also obscure details in the raw data. Such techniques, presenting the human with a black boxed accumulation or a simulation based upon raw data, may reduce the leverage for flexibility of interpretation and it can possibly make it harder to cross check sources against each other. Still, some degree of reduction and black-boxing is always necessary. It is not a matter of either – or, but the development of new technologies must always be done with a keen eye on this dilemma.

A simple example: Automatic or semi-automatic integration of new geological information from well logs into the geomodel would in most cases be a good idea to obtain an updated geomodel. Say, however, that the readings in a certain part of a log could point in two different directions, that the well is in zone A *or* zone B. In the geomodel, one would have to have one. The ambiguity that would be problematic in the model, could very well be a resource for people using the log for interpretation in other cases. Maybe new information will come later,

[7] See e.g. Latour (1987)

maybe they are able to make qualitative inferences based on coupling with other information (e.g. production data from nearby wells) or maybe they can cross check it against data types that are not included in the geomodel.

At Norne 4D seismic is often held up against the reservoir simulations and seen as independent indications of fluid movements.[8] Hence, if they both indicate the presence of oil in an area, they support each other and gives a robust foundation for decisions. This gives reason to proceed cautiously when implementing future tools that may include automatic integration of 4D data (through history matching) in the reservoir model. The diversity of information sources has advantages that must be weighed against those of integration. A possible (and maybe the most common) solution is to try to do both, and treat the integrated data set as an supplement to the underlying data. Also, it is important that there is transparency into the coupling process, so that those that make decisions based on these information sources are able to evaluate them independently in cases where this is necessary.

The integrated drilling simulator that is under development at the IO center also demonstrates this dilemma of blackboxing versus transparency.[9] While integrating drilling data to one visual representation and diagnostic tool, there is always a danger of loosing (sight of) potentially important information on which this tool is based. While I am in no position to evaluate the success of the drilling simulator in terms of this challenge, I would dare to claim that, like for all data-integrating technologies, this is a challenge it will have to pass to be a successful tool in future works processes.

4 Articulation work

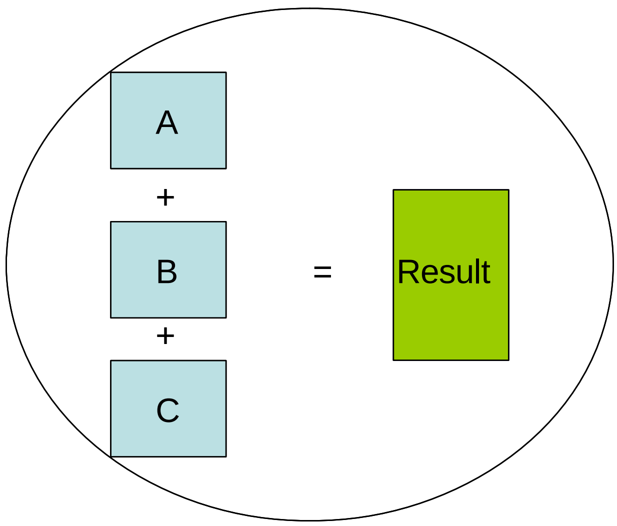
The concept of "articulation work"[10] provides a key to understanding some of the challenges posed by interdisciplinary work and decision making. Anselm Strauss[11] coined the concept to bring forth the consequences of the extreme division of labor one sees in modern workplaces. Articulation work is the work of, chaining work together, of aligning resources, tasks and information necessary to perform one's primary tasks. Though every single task may be standardized and planned, articulation work is needed when they are implemented into a reality with several concurrent work processes going on at that specific time. Hepsø exemplifies this with the how the standard operation of performing a well-test, a procedure with a defined task chain, is implemented in the overall workflow of a platform at one specific moment. This articulation task is highly specific to that moment in time, to the peculiarities of the wells at that moment, and the concurrent operations that are going on.

The subsurface department of an oil field is strongly based on a disciplinary division of labor, and the aligning of resources, information and tasks is a dominating challenge when addressing interdisciplinary issues. All work involves elements that can be regarded as articulation

[8] This is work that is, as I understand it, to some extent based on qualitative comparison. To be fed into reservoir simulation, 4D has to be expressed in terms of quantities. In this sense the dilemma we are discussing also involves which role of the human interpretative capabilities of qualities or patterns in may have in the work process.
[9] See Rommetveit et al (2007) or Korsvold and Nystad (2007: 12 ff) for a overview of the simulator. The latter report is a work process oriented discussion.
[10] The word *articulation* should be understood in the sense of chaining elements together (like an articulation joint), and not in its more common sense of formulating or expressing something.
[11] Strauss (1985) see also Hepsø (2006) and Gasser (1986)

work, and it can be found an all levels of scale, from booking a meeting room to hiring a drilling rig, but the relevance of the concept is maybe most striking when it comes to interdisciplinary decisions, for example like the production strategy considerations mentioned in the introduction here. One may have procedures and guidelines for how to prioritize and how to join information from different sources, but every decision will have its own peculiarities to which they must make adaptations. For example: in my PhD thesis[12] I described a situation at the Statfjord field (2001-2002) where every subsurface decision had too take into account that the field probably, though this was not yet formally decided, would be subjected to a blowdown and be converted to a gas field. Hence, every normal prioritization, for instance in terms of well design, sand control and drainage strategy, would be influenced by considerations the well's possible role in a gas field. Even more common are special considerations due to faulty equipment, topside restrictions, unreliable sensors and other small issues relating to only one decision on one well. And this is also where human experience and contextual knowledge is important, as resources to handle the adjustments and alignments necessary to perform the tasks successfully in real life. People who know the field, the equipment, the people, and have experience from similar operations, are invaluable in this work. In terms of IO it is important to keep this in mind: Every decision, though simple on a workflow chart, has numerous peculiarities and constraints to which adaptations must be made. This means that technologies supporting such workflows must be adaptable to changing circumstances.

Work process: Generalized structure



Articulation work, framing, adjustment, interpretation.

- Which data are most important?
- How should we align the data, combine them and weigh them against each other?
- What is the quality of the data A, B and C?
- What information can we disregard?
- What do we do if data type A is missing?
- What if A and B are contradictory?
- How can we include information "D" in our decision?
- What are the special conditions given by the situation here and now?
- How should our own understanding and decision be formulated?
- How do we express uncertainties and risks?
- Do we have the knowledge to make the right decision?
- What are the typical mistakes we tend to do in this kind of decisions, and how do we avoid them now.

Figure 1 A generalized work process. A, B, and C signifies different information types typically used to make a decision. The column to the right contains some (of many possible) questions that will typically be relevant when this generalized structure is enacted in practice.

[12] Almklov (2006)

A key point here is that work process as described in a work process description and as performed are to quite radically different things.[13] In terms of developing and implementing IO solutions, it is important that this is done with a realistic view on the work process as performed, the sense making and decisions IO aims to support.

Especially with regards to operational decisions, where one has to think quick, it is important that information about the reservoir is available in forms that are both time efficient to use, relevant for each task and allow for flexibility. By flexibility it is here meant that a tool supporting a decision should be easy to adjust to what one needs to know for that specific decision.[14] For example, the level of detail necessary for a reduced near well reservoir simulation may vary from case to case.

Another challenge in terms of using simulation based techniques to support operational decisions is that the task of mathematization of the problem to be addressed can be a very consuming task.

To sum up so far, it has been suggested that IO technology intended to support integrated operational decisions should be developed in light of some considerations:
First all data and information types should be regarded in light of the blackboxing vs transparency dilemma. That should in turn be addressed in light of the requirements of operational decision making settings where they need to be aligned (by the people using it) with other resources and where there is a need for time efficient availability, instant task relevance and flexibility.

5 Some tentative observations from Norne Petek

The primary intention with a short visit in Harstad was to get at quick glance at the work processes in the subsurface department. In a long term perspective, the work process study is meant to explore some of the questions above about the interface of new technologies and the workflows they are intended to enter.

Much lies in the details when it comes to work processes. The things taken for granted, and therefore seldom expressed explicitly, are often crucial. The observations and thoughts noted from my visit are highly preliminary, and may due to the cursory nature of this study be anything from incomplete to flat out wrong. Still, the visit and the informal interviews, paired with the experience gained from a previous prolonged field study at the Statfjord RESU department[15] and a study of a few Norne RTD documents, the visit can be said to be quite informative as a pre-study. It was probably a good thing that it was undertaken in a period of

[13] Actually, this is a very real problem that I have experienced when working with safety related issues in the oil industry. For safety, the difference between the formally described work process (e.g. a procedure) and the actually performed work can be a matter of life and death. In interviews related to safety issues, the conflation of terms between work process descriptions and work process as the actual work performed has often made it quite troublesome to discuss how work is really performed.

[14] A more ambitious strategy is to implement paramount tools or methods that radically transform the work process as it is, and thus tries to standardize the work process (in terms that making the decision making process adhere to the requirements of the new technology). This text is written under the assumption that interdisciplinary operational decisions in the subsurface domain are so diverse that this is not currently an option. It should be noted that it has not been evaluated either, since it is outside my area of expertise.

[15] See Almklov (2006)

relative low activity, so that people had time to talk to me, but it will be necessary to do a follow up with observation of operational work.

The Norne field has now been 10 years in production. The wells are drilled from floaters and produced from the Norne ship via templates. It consists of a main field and a few satellites. Since Harstad is a bit off the beaten track, the lean, small organization seem to rely much on the experience of key personnel in Harstad, as well as some support mainly from Stjørdal. The reservoir is generally regarded as well described and understood, and it is expected to be a good case for the IO center's research on the use of 4D data in reservoir simulation (history matching).

One of the overall aims of Program 2 within the IO centre is to push the boundaries in terms of closed loop reservoir management, and to use automatic or semi automatic simulation technology to integrate real time information into existing models to improve prediction and control. The field study was undertaken to see which informational environments new IO data and tools would enter, and also to explore possible niches already there to be filled. Of particular interest was to look for parts of the work process at Norne, and the industry in general, where SINTEF's work on fast, simple and adaptable simulators could be put to use.

Below is a schematized timeline of decisions horizons within Petek.

1. Field strategy: New templates, major topside investments etc
2. Reservoir management strategies: Injection, IOR etc.
3. Identify targets for new wells. (TRO in StatoilHydro)
4. Detail planning of new wells. Well path, risk and volume evaluation. (RTD in StatoilHydro)[16]
5. Major decisions during drilling: e.g. sidetracks.
6. Normal decisions during drilling: Geosteering, choice of perforation interval.
7. Production planning.
8. Production control.

At Norne, as with most other oil fields, the geomodel and reservoir model have quite large grids, they are static (ie: updated stepwise with long intervals) and they do not incorporate all relevant information types. As a consequence, they work better on large scale, and their relative importance for "local" decisions drop rapidly as soon as the log data and production data is available. They are most important in the early stages of well planning and on a large area or full field basis. For the first three to four[17] decision horizons above the Eclipse reservoir simulator and 4D seismic data are used extensively.

While there is high reliance on reservoir simulation aided by 4D seismic in planning, these resources are less important on a smaller scale, for single wells, when drilling and for local production optimization. As information sources for operational decisions these information types are mainly input to the main strategies and pre-planned contingency options (e.g. item 5 above) outlined in the RTD, and they are not aligned with new data. For identifying and planning well locations, exploratory pilot holes are also an important source of information at Norne. One of the interviewees noted that they "do not get many big surprises" while drilling

[16] The RTD is an input to the detailed plan for the well made by the B&B department.
[17] In RTD documents the 4D and reservoir simulation data are an important part of the justification of the recommended well, but it I got the impression from the interviews that much of this work was done in the earlier phases and that this information is basically taken as input for the RTD work.

when it comes to the geological structures, that they have a pretty good understanding of the geology. Besides LWD, most wells are not logged (e.g. by wireline) due to cost benefit considerations. Nor is it common to use Resistivity logs or down hole production logging for wells in production. Hence, the movement of fluids in the reservoir (e.g. the oil water contact) is monitored mainly trough production data and 4D seismic.

During drilling operations, most weight is put on interpretation of drilling data and the running interpretation of the LWD, including the Periscope log (based on Resistivity contrasts) which is currently very detailed and precise. The typical Norne well is a long horizontal well geosteered just a few meters below the sealing top of the oil bearing formation. In this, there is great reliance on the periscope tool, that yields detailed and trustworthy information on the whereabouts of the formation top. For decisions during drilling, both placement of the well within the reservoir and length of perforation interval, the real time data are the dominant inputs.

Hence, for operational decisions concerning the reservoir, the possibility provided by IO technology for pairing real time data with existing models of the reservoir is not developed. There are of course several good reasons for this: Firstly, the quality, relevance, and instant availability of raw data, completely outweighs models and simulation based techniques, which have to be fitted into each context and currently are based on coarser grids[18]. Many of the decisions during drilling or well operations at Norne will occur within one or a handful of grids of the normal simulator or the geomodel. An ambitious and challenging task for IO research would be to explore the possibility to push the envelope of simulation and to see if it is possible (and of any use) to utilize the high volumes of detailed data retrieved during drilling and production in simulation and modelling tools that can instantly support decisions during operations and production. Currently data from new wells are not easily integrated into the existing geomodel and reservoir model and due to the coarse grids simulations made on these are not very likely to be very useful. It is currently not common practice to adjust the geomodel and reservoir model during operations.[19]

An interesting question is also how today's methods will work in a long term perspective. For example: For short term production optimization the overall picture I got was that today Norne was basically quite easy to handle, but with increasing water cuts a more challenging situation on the interface of the reservoir and production domain (including topside) may call for more complex considerations here in the future. Also a more water flooded reservoir may pose some challenges, since the oil zones will be thinner or more diffuse, both for the 4D seismic and the Periscope log which are very important information sources today. In addition, a general development for oil fields is that one will get more production and well data, data complexity (a mix of old and new types, different reliability, from different contractors) increasing water cut, old process plant, and maybe that the precision in terms of volume allocation will change?

[18] The fitting of the tools into the specific context in many cases that also means that the problem to be solved must be translated into a mathematical problem.
[19] There are also some limitations due to proprietary software here.

6 Some conclusions and propositions

A pre-study, the visit in Harstad has not lead to any conclusions on its own merit. But it has informed the more theoretical discussion of the paper and provided a glance of the "information ecology" of a subsurface department.

A crucial element of IO is to improve work- and decision making processes that cross disciplinary boundaries. This report has discussed some challenges on the man-technology interface that should be addressed when developing tools to support interdisciplinary operational decisions.

- What I coined the *dilemma between blackboxing and transparency* should be considered when developing new technologies. It is really about what should be delegated to machines and what does the operator or decision maker need to have detail knowledge of. Of course, to address this dilemma successfully one must have a detailed knowledge of the workflow one seeks to support. Especially of importance is to understand how different information types through multiple description of the reservoir are utilized in qualitative interpretation.
- Another topic was how resources, tasks and information are made to fit into specific situations. The relevance here is that one should not base new tools on "idealized" workflows, but rather develop them (if possible) for flexibility and quick adaptation to reduce the burden of articulation work. It is in the nature of the interdisciplinary operative decision processes that they are singular, that they each have peculiarities (also in terms of information requirements and information available) to which adaptations must be made.
- Another conclusion to be drawn upon this is that workers with operational expertise and know how, people that have experience in the local articulation work and in the variability of decision making settings, should be involved both in the development and in the implementation of integrated technologies.

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