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New Drilling and Completions Applications for a New Era

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Abstract

Most of the existing drilling and completions engineering applications in use today were designed to compute snapshots at a single point in time for one user, rather than presenting the acceptable operating envelope and its associated constraints over time and supporting interaction of multi-disciplinary teams in collaborative environments.

The massive increase in data now available from real time sensors can make identification of critical factors more difficult and can hinder, rather than enhance the decision making capability and response to alarm conditions. Currently, interaction between individual team members is cumbersome and it takes place outside the applications. Teams are increasingly multi-cultural, which places additional demands on the human-computer interface and cultural and linguistic preferences need to be considered, particularly where collaboration centres span international boundaries. The applications are also part of a growing portfolio, including office and knowledge management tools. Their usefulness and efficiency depends on successful integration. In turn, this depends critically on standards. The working practices emerging from the use of these environments means the earlier applications are no longer optimised for the circumstances in which they are to be used.

The paper contains a discussion of these changes and the new functionality required of the applications using a popular model in industrial psychology. It draws on practices from other industries, observations in collaborative environments and other, earlier work within our own industry that appeared before their time. It is concluded that new applications are needed for this new era and that some may bear more resemblance to gaming software than raw calculating engines. It also concludes that a number of the constraints may be self-imposed, by our failure to keep pace with the rapid and continuing developments in information and communications technology and the business models developed for the virtual world.

Introduction

Observations of working practices and technologies may highlight factors that if addressed, would greatly enhance their effectiveness. In some cases early recognition of these factors may be critical to the project's success. In the 1980's efforts to implement collaboration centres were hampered by inadequate attention to human factors and immature technologies[1]. Now, variations of these centres are in common use in both operator and service company offices worldwide. Even if successful, it is normal for these limiting factors to change over time. As weaknesses or opportunities are identified and addressed, capabilities leap-frog each other leaving another aspect at the bottom of the pile and so the cycle continues. In some cases second generation centres have already been constructed, incorporating lessons learned from the first attempt[2] and we see this cycle applies to drilling collaboration centres too.

Observations over the last seven years in drilling collaboration centres in Norway and Aberdeen suggest the emphasis is now changing. Whilst human factors are still key[3], in established centres greater attention is now being directed towards the technology and tools and how they are used.

Engineering Needs

The primary goal of a drilling and completions team is the safe delivery of a well meeting the time, cost and technical objectives. These objectives are normally established early in the planning cycle and may be prioritised to help determine the best course of action in the event that the objectives are in conflict. During planning, offset data, analogues and equipment specifications are used to establish both the well design and contingencies to meet the objectives. Ultimately, the well design is predicated on design requirements, measurements, equipment specifications and some degree of confidence in the associated assumptions. A key task for the team executing the well is to ensure the limits of the critical elements of the design are not breached during operations. In this context the word critical implies that the breach could compromise safety or the environment or lead to an unacceptable over-run in time or cost.

This rather simplified description emphasises the strong link that must exist between the design and execution of the well and shows that neither the planning nor the execution of the well are linear activities. An important task for the drilling engineer designing the well is to assess the sensitivity of the design to both the measurements and the variation in the assumptions on which the design was predicated. Both the core design and the contingencies must also be implementable. This means that not only must the end points be achievable but all the intermediate steps must be too. For example, if during the running of a conductor it holds up close to TD but the shoe strength is inadequate, is the connector strong enough to pull the string? As another example we should also ask if a tool string will pass through all the intermediate restrictions.

In BP, Turnbull has defined best in class for drilling applications as “being standard across the organization, integrated with the other applications in the portfolio with data is accessible for split teams, knowledge management and auditability and capable of optimising workflow by reducing cycle time”. This defines the criteria by which application changes are decided. He also distinguishes between the applications as safety critical[4], business critical and others which determine the manner in which the 33 applications in the portfolio are managed.

Later, Turnbull reported results from a study, using licence tracking tools to track engineering work by approximately 800 users worldwide over a 12 month period from October 2004. He concluded that only 2.7% of an engineer’s time was spent on engineering applications. He also observed that less than 0.5% of engineering time is being spent on issues that cause significant non-productive time, such as hydraulics and torque and drag. As Turnbull noted, there are a number of possible interpretations for these usage levels. However, other observations show that a significant proportion of the remaining 97.3% of the time is still spent gathering data and using office tools which are now as significant a part of an engineer’s toolkit as the more technical components.

It is interesting to note that these shortcomings are not confined to the drilling engineering community. Hite *et. al*. surveyed subsurface software users and identified similar issues[5]. When interviewees were asked what they believed the top three most important characteristics of analysis tools were, they answered in order: work flow integration, ease of use, visualization / graphics, data compatibility, easy data in / out and open connectivity. Respondents complained that most of their tools didn’t handle some of the new, more complex wells very well and that business tools needed to be integrated with the technical tools. When asked what additional tools or transformations would be most required to address increased workload, respondents recommended more intelligent applications, better data handling and improved work processes.

Situation Awareness

The purpose of a collaboration centre is to enable both individuals and teams to make better decisions, faster. To do this successfully the individuals and teams must have ready access to information, understand its significance and then decide on a response. In industrial psychology, knowing what is going on around you and what is important is termed situation awareness, a term popularised by Endsley[6]. Situation awareness has been referred to in the drilling literature[7] as one of the key command skills required for effective performance together with decision making, communication, teamwork and leadership. Endsley’s model describes situation awareness in three levels, perception, comprehension and projection, linking them to the decision making and action. Workload, system design, stressors and complexity are categorised under the heading of the task and environmental factors whilst goals, knowledge, experience, training and ability are considered under the heading of individual or team factors, **Fig. 1**.

The situation awareness model provides a convenient framework in which to discuss the suitability of existing applications, the future needs of drilling and completions personnel and the factors that influence these.

Perception

This first level involves monitoring, cue detection and simple recognition[6]. Effectiveness at this level is influenced by the volume of data and the clarity with which it is presented. In future, wired drillpipe will be able to transmit data at approximately 1000 times the typical data stream delivered by mud pulse telemetry technology[8]. Data overload is an increasing challenge and a variety of strategies will be needed to handle it effectively. One approach is selective disclosure where greater levels of detail are provided as the user needs them based on actions and goals[9,10]. This avoids overloading the user by presenting all the data at once. Process based screens using this principle are already in use for rig control consoles[11]. Separate screen configurations have been developed for drilling and tripping. Removing superfluous information from the screen not only improves clarity but it improves handling and interpretation and the response to alarm conditions. Perception is also influenced by cultural norms[12]. For example, the gradation of colour from green to yellow to red indicates an escalating problem in some cultures, but not in others.

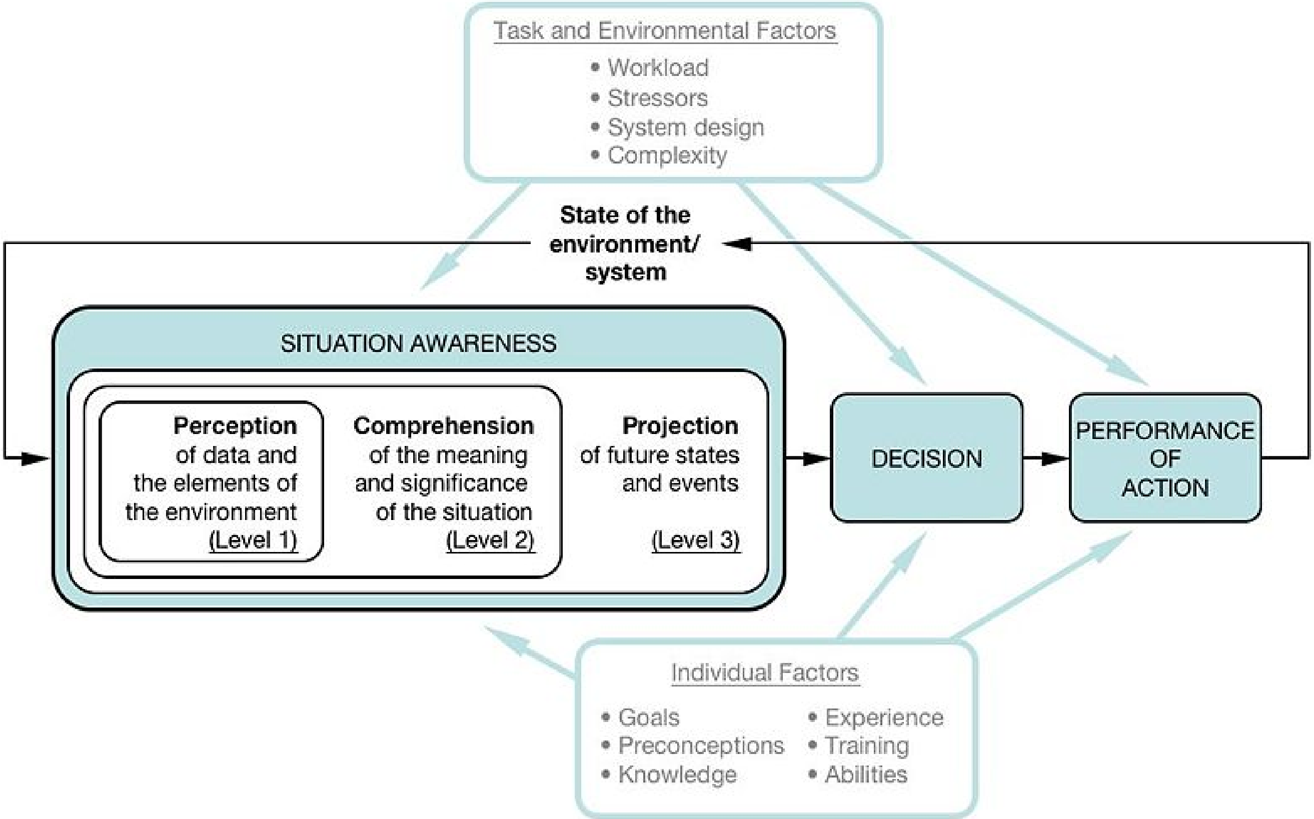

Fig. 1 Endsley model of situation awareness[6]

Comprehension

The second level of situation awareness encompasses how people combine, interpret, store and retain information[13]. This level involves integration of information and the determination of their relevance to goals. Performance at this level is influenced by short term memory, which is typically 20-30 seconds without rehearsing. The number of distinct items that can be continuously and successfully tracked is also restricted to 7 plus or minus 2 items[12]. Again, cognitive ability is influenced by screen design and degrades where information that needs to be integrated is placed in different areas of the display. Distracting information, for example unnecessary parameters or features, such as blinking characters also degrades performance. In both cases the information can be obtained but it requires additional cognitive processing effort on the part of the user. System integration is a major influencing factor where extensive ad-hoc queries are required and interpretation is greatly enhanced by appropriate graphical presentation.

Projection

The third and highest level of situation awareness involves anticipation and mental simulation and is the ability to forecast future situation events and dynamics[13]. Individual's and team's experience, knowledge, ability and training are significant factors at this level. In drilling and completions, applications that can quickly source analogue situations and outcomes and play out what-if scenarios are important aids. Hopefully, the possible analogues will have been identified beforehand as part of the planning process. Most situations that are encountered do not require an immediate response and for those that do, such as well control, the initial response is proceduralised and reinforced by drills. In these cases, the possible dangers of being completely reliant on software, without adequate backup have been documented[4].

Software

The primary requirement of any application is that it actually does the job it was intended to do. The extent to which it does so depends on a number of factors ease of use, reliability, accuracy and fidelity and each of these may be critical to its adoption and success. The application's fidelity or how close it matches real-world situations depends on its mode of use. Simple models with few inputs may be good for scoping exercises or basic training but may be totally inadequate for real time decision making. In this context, Foreman[1] reported that the fidelity of early drilling engineering applications failed to meet user's expectations.

Modelling

In all cases, the availability of efficient and dependable algorithms is a prerequisite and to be credible, applications must keep pace with industry practices. Mason and Chen[14] presented a detailed assessment of the current torque and drag models and concluded that only incremental improvements have been made to the underlying mathematical models in the last 20 years. In general, the models have not kept pace with technology changes, echoing the earlier subsurface complaint that their software does not deal with the more complex well types. Though the requirements identified by these authors were described as either enabling or enhancing, they could equally have been presented in the context of the situation awareness model. For example, the calibration of torque and drag models, model limitations warnings and friction factor database might each benefit from some form of expert system, improving both perception and prediction capabilities. Classifying desired functionality and enhancements in both engineering terms and in terms of the way in which they will be used should help align the application's interfaces more effectively with the intended task and focus development efforts.

The reference in the paper to domain charts to denote zones of drilling operability deserves comment. This 2D chart was created to enable a drilling engineer to rapidly identify rig and drillpipe requirements for a conceptual field development. However, once the design is complete, the chart can be regenerated using as-drilled conditions and actual bottom-hole assemblies (BHAs) and the relevant torque and drag limits for both the rig equipment and BHA can be superimposed on the chart. If this is then coupled with real time data, the chart becomes a useful operational tool, increasing the engineer's perception, comprehension and projection capabilities. A similar construct to the torque and drag domain chart was presented by Lockyear, **Fig. 2** for hydraulics optimization. In this case the operating limits were shown on a 2D graph of pump pressure versus flow rate. The circulation limits for a given bit depth were determined from the maximum available pump pressure and formation fracture gradient and the minimum from the flow required to clean the hole. Bit nozzles could be blocked or unblocked, providing immediate feedback of what the new operating parameters would be in this event. Finally, the envelope representing the hydraulic horsepower at the bit was calculated and displayed to help optimize the drilling process. The confinement of the operational parameters within the design envelope is referred to by Thorogood[15] as envelope protection and the principle is already being integrated into drilling machinery control systems[16].

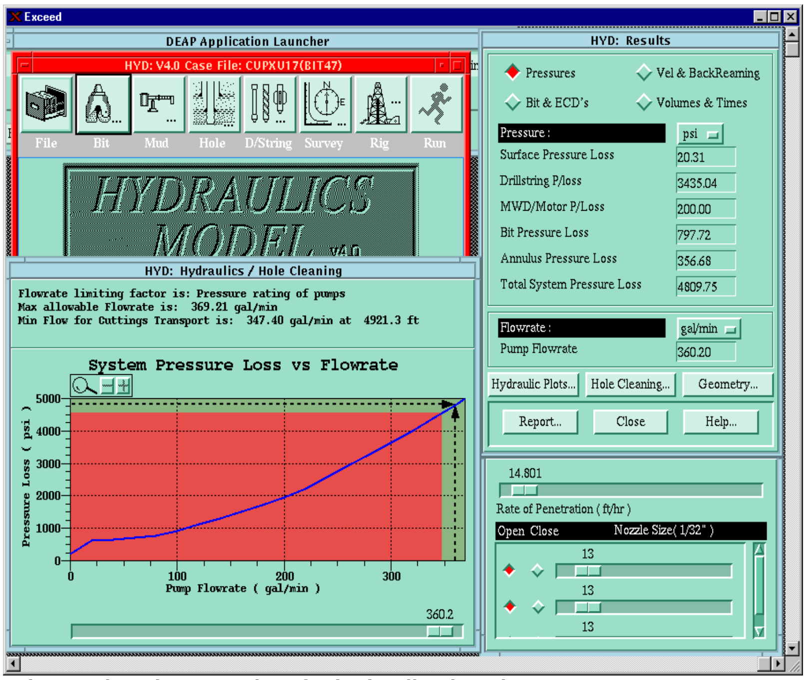

Fig. 2 A domain - type chart for hydraulics (1993)

Rig Status Analysis

The ability to determine, quickly and reliably the rig activity directly from the combination of sensor inputs is key. This technology was pioneered by Parigot and Havrevold[17] in the late 1980s to develop an intelligent kick detection system. It is interesting to note that more than 24000 hours was invested in the project and at that time, the authors referred to sensor data arriving at a rate of one per second. More recently, McClaren *et. al*. have shown that a combination of 14 defined rig states can be used to identify the current action of the rig and drive detailed engineering software[18]. Thonhauser *et. al*. has shown how rig sensor data can be used for operations analysis, providing a practical means of distinguishing invisible lost time and calculating technical limits[19]. By combining the conventional morning reporting applications with sensor data quantifying depths, pump rates, overpulls etc., the pre-population of the morning report is now a real possibility. Such capability would save the rig supervisor between 0.5 and 2 hours a day, enabling attention to be focused on other, more important matters.

External Factors

With the changes in demographics in the industry and introduction of operations centres, teams are becoming increasingly multi-cultural and geographically dispersed. Most of the existing drilling and completions engineering applications in use today were designed to compute snapshots at a single point in time for one user. Their ability to support direct interaction between multiple, simultaneous users is either lacking or non-existent. Simple considerations, such as use of colour, screen layout and language can have an important influence on user's perceptions and comprehension.

The market for drilling and completions software is considerably smaller than the market for business software[4] and cost issues have driven many companies towards commercial, rather than in-house software. A number of innovations, including the envelope-based calculations referred to above have been lost in this way. The extensive integration of applications provides much sought after improvements in ease of use, but comes with an overhead. Changes to one application may precipitate changes in all of them and new versions can then only be offered as synchronized releases, effectively slowing the rate of development. A further disadvantage is that niche players may lack the opportunity or means of marketing their products because they do not have access to, or cannot afford the interfaces to plug-in their software.

Expert Systems

Demographic changes in our industry are also encouraging companies to consider how to retain expertise and to revisit their stance on knowledge management. Training, data management and artificial intelligence all have a role to play. There was a flurry of activity developing expert systems in drilling and completions during the early 1990s, covering a wide range of topics[20-32] which include stuck pipe, gas lift, rod pumping, and corrosion and material selection, fluid analysis, fracturing, acidising, pressure analysis, directional drilling, fishing operations, well control, cement slurry design, casing design, MWD interpretation and bit selection. Reviewing the literature, few of these seem to have matured into products that are now in every day use. An exception is the bit selection system [30,31].

In their review of oilfield expert systems[32], MacAllister, Day and McCormack defined AI as the capacity of a machine to imitate intelligent human behaviour in a limited domain. The restriction of a limited domain was added to a dictionary definition by the authors to avoid failures associated with attempts to capture expertise in a knowledge domain that was too large. They also identified the pitfall of using AI techniques when conventional techniques will solve the problem. These pitfalls may account for the apparent lack of wide-spread progress.

One of the most successful expert systems available today is Mathematica, a mathematical tool that is capable of symbolic manipulation and solution of a wide range of mathematical equations. The capabilities of its rule based engine now exceed that of a human in many areas to the extent that it has delivered mathematical relationships that were previously unknown, emphasizing its projective contribution. Perhaps more importantly, it is linked to some highly flexible tools to both input the data and communicate the results[33] and can even describe how it reached its conclusion.

Expert systems have also enjoyed success in the medical field and it seems from the literature, in reservoir engineering. It is likely that mathematics, medicine and reservoir engineering are a more harmonious fit with expert systems because the underlying rule base is either naturally or more rigorously defined or that more effort has been expended in making it so. Comparatively little effort has been expended in drilling and completions to understand and document our work flows and this lack of attention at a systems level may be hampering progress.

Finding Giant's Shoulders to Stand On

The expertise and knowledge of many individuals from multiple organisations must be brought together to successfully deliver a well. Pre-spud meetings are held to share this expertise, build teams and establish common goals. During the course of drilling a well the team members meet to review progress or address problems and to plan the next stage. At each stage information is being exchanged but unless teams have a well developed and executed knowledge management plan, this information might only be stored in meeting notes and these are usually restricted to the core team members drilling the well. What discipline or tools might help make better use of this data, increasing perception by alerting individuals or teams to earlier problems and solutions? Even slight improvements could confer major benefits.

Search Capability Search engines have greatly enhanced perception, and through integration have improved comprehension too. In the medical world, two doctors tested Google's ability to diagnose medical cases by entering details from 26 cases in a medical journal[34]. Google's answer matched the diagnosis in the journal in 58% of the cases. Wikipedia[35], has shown that large populations of like-minded individuals can successfully pool information and synthesise knowledge, modifying the contributions as new information comes to light. This ability to build on earlier knowledge is a foundation of engineering excellence and though a system that is open to the public is susceptible to abuse, for a system that is confined to a company where all employees have been vetted and are supervised, the risk for uncontrolled information is very low.

Intelligently linking non-productive time (NPT) and lessons learned information would help to quantify both risks and the chance of successful recovery for the various contingencies.

Games are an interesting source of ideas, both technically and behaviourally. When you watch a child playing a video game, especially first person shooters, they are constantly going over the same section striving for improvement. If only this was an approach we could take with our own software. Johnson[36] stated "Video games know more about getting people to use stuff than enterprise software does. The secret sauce is mastery and pleasure". Even medium fidelity simulators, which are much of what we have today, would enable logistics and procedures to be explored in this way. High fidelity simulation would permit plans and designs to be scrutinized at a detailed engineering level. Operationally, we could imagine drillers re-playing their shift on software, trying different approaches, learning, striving for improvement and then preparing for next shift.

As systems become more connected and our ability to manipulate virtual objects increases, so other opportunities emerge.

Integrated Systems Links between technical and commercial systems would enable drilling engineers to pass equipment design requirements to the vendor as part of a request for information. The technical specifications, including assurance details could then be transferred back to the purchaser. In this way, each of the dimensions, strengths and metallurgy could become part of the envelope. Exchange of codes, identifying the equipment and its subcomponents would enable the equipment to be tracked using radio frequency identification (RFID) tags or character recognition software, ensuring that the correct equipment is shipped and put down hole. Automated operations reporting would tally the total hours downhole helping billing, and the down-hole operating conditions could be reported and drilling parameters changed, helping eliminate downhole failures. Within BP's operations, downhole equipment failure remains one of the top four NPT categories. Currently, confirmation that the tool's operating envelope has been exceeded may not be identified until tear-down has been completed back in town.

Fig. 3 World of Warcraft – can online games help us understand the way we work?

The Internet has had a profound impact on business models, improving accessibility to data and improving efficiency by cutting out middle-men. Second Life[37] is a virtual world, accessible via the internet, where virtual real-estate and goods are sold and people are making real money. For some companies it is a way of accessing customer preferences and provides market research at an attractive price. For others it also provides a means of communicating with their employees, adding a little fun, the pleasure referred to by Johnson. To our knowledge, drilling and completions does not yet appear in this world, but technical issues aside, could we not use it to illustrate to prospective employees what a drilling engineer does, showcase our achievements or demonstrate the lengths we go to protect the environment? There are social aspects too, and for some people whom are technically strong but otherwise socially awkward, slowing social interactions down gives control[38].

With relatively few users, identifying workflows and optimizing our software for ease of use is a challenge. In August 2007 a software error in an online game, **Fig. 3** provided a ready made laboratory for studying the effects of an epidemic[39]. The authors were able to track the error, the spread of which was influenced by behaviours, attitudes and the natural resilience of some of the players. Could communication of ideas and technology transfer be investigated in a similar way, by monitoring usage patterns at a screen level or equipment component level, rather than at the application level?

The Impact of Web 2.0 on Applications

The managers of digital technology in most large organisations favour web based applications. These can be deployed and managed far more easily than client installs and there is certainty that all users will be working on the same release of software. With the advent of Web 2.0, which facilitates collaborative working and information sharing, we have seen a number of popular client orientated applications ported to the web with the same degree of functional performance but with far greater information retrieval capability.

Unfortunately terminology like “Web 2.0” is not meaningful to the average drilling engineer. It is regarded as something to occupy the minds of “IT geeks”. It is, in fact, an example of a transformational technology that has gone unnoticed because the accelerated development of digital products and the internet is something we all now take for granted. A characteristic of Web 1.0 applications was that the total solution came out of the box but Web 2.0 applications exhibit learning characteristics. O’Reilly[40] describes a key Web 2.0 principle as “the service automatically gets better the more people use it”. Google and e-Bay are great examples. Both provide a framework web service that draws on information supplied by end users and quickly the power of the whole becomes much greater than the sum of its components. The phrase “harnessing collective intelligence” is very pertinent.

So how will Web 2.0 technology influence oil and gas applications over the next few years? The answer is not clear at present as a number of transformational steps must be taken for Web 2.0 oriented oil and gas applications to enjoy widespread uptake:-

- Energy companies must become much more willing to share information for the common good. Taking the view that a 10% performance improvement by all industry players is better than a 5% improvement for those that compete most effectively is the basis for Web 2.0 success.
- Energy market vendors must focus on technical excellence in defined sectors rather than attempting to provide a total solution. In a free market nobody buys everything from one supplier – they shop around to find the best deal based on their metrics for price, quality, performance and time.
- Vendors must be willing to share knowledge and experience with their competitors and derive market leadership from superior service rather than through the withholding of information.

As the oil and gas business has a common focus of maximising volume production at the cheapest price with minimum health, safety and environmental impact there is the basis for effective collaboration which could be enhanced by Web 2.0 applications. Information learning and sharing could be at a discipline, corporate or industry level but successful Web 2.0 applications have demonstrated categorically that the greatest returns will be derived from industry-wide collaboration. The sharing of best practices is more effective if there are more best-practice cases to share. Taking drilling applications as an example, high quality casing design, fracture gradient and pore pressure calculations are required in all operations and the combined knowledge for a particular region from all operators and service companies will provide the most efficient and safe operation for the next well delivery. In the long term this enhances the reputation and profitability of all market players.

What will feel different to the user of an oil and gas Web 2.0 application? The most likely answer in that it will be much more statistical in nature, taking greater account of the uncertainties in our data.

WITSML and SOA

There are several published articles on the value propositions of the Transfer Standard Markup Language (WITSML)[41] standard and Service Oriented Architecture (SOA)[42]. Within the drilling and completions disciplines WITSML and SOA are a perfect match to deliver an optimised architecture for both real-time and historical data processing. As an analogy, think about the required processes to convene a remote meeting. You need to draw upon a set of common services such as audio and video conferencing, network connections between the locations, a security model so that uninvited guests cannot listen in to the content and some form of integrated scheduling so that participants turn up at the same time. All of this is analogous to the integration of web services that is afforded by SOA but think how pointless this would all be if you subsequently found that your participants could not speak the same language – this is where WITSML delivers value in this analogy.

Working together, SOA and WITSML are going to have a profound effect on drilling and completions applications. As shown in **Fig. 4,** SOA will encourage the development of applications around a common set of web (business) services which will be re-usable. This is a big step away from autonomous applications which have been the normal design and are still commonly used today. This will produce much tighter linkage between software functionality and business processes and will speed up the development time of new applications. Revisions to existing applications, which are usually driven by changing business requirements, will also be much easier as only the specific processes will need to be updated rather than a significant re-design of the whole application. This will inevitably lead to improved reliability of new products as much of the composite SOA applications should be proven already at a software code level.

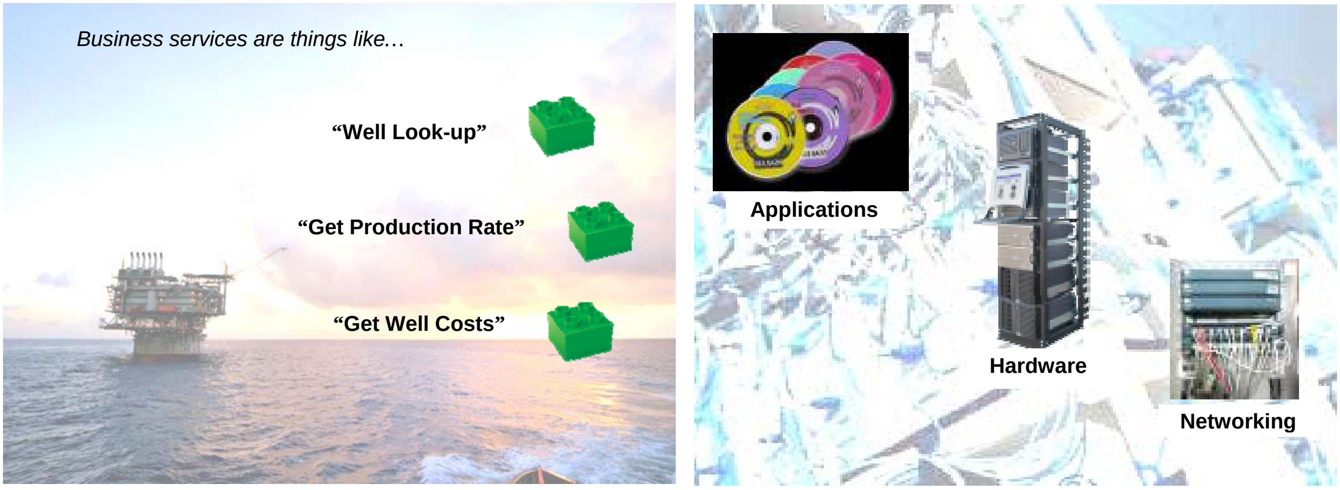

Fig. 4 With service oriented architecture building blocks for IT are business services, without service oriented architecture IT is organized by infrastructure components

Perhaps the most significant change that WITSML and SOA together will bring to drilling and completions is information integration. **Fig. 5** shows the flow of wellsite information to a master well data store. From here, information such as operator, location, well type, well status and real-time operational information is transmitted to regional centres where it is accessible by local web services and applications. Similar access will be possible to financial and other non-discipline specific information. This will allow a new type of operational applications to link performance directly to cost and demand. At the human interface end, new services will be developed to deliver a much more powerful visualisation experience for the engineer or manager. These could range from composite drilling logs and real-time displays through to performance metrics and forecasting.

Fig. 5 Wellsite information flows to a master well data store and is then distributed at both global and local levels

Hardware

Situation awareness can be enhanced by the appropriate selection and use of hardware. Indeed, new working practices demand a change in our approach. The move into BP's new Aberdeen office is reducing the physical space available for storage, and material that has traditionally been held in paper form is being scanned to improve accessibility and reduce, but not eliminate the physical volume. Plans are in place to issue dual screens to all operations drilling engineers to compensate for this loss of physical space. In this way, product catalogues, offset well information and real time data can be kept in view on one screen whilst the active documents are held on the other.

Greater use of graphics and visualization[43,44] has resulted in a steady increase in the demand for higher specification machines for engineers. Game consoles are attractive in terms of price-performance and they are already influencing thinking on subsurface processing and interpretation tools[45]. Hardware may have a direct influence on behaviours too. During discussions on the elements of a risk matrix, two engineers were struggling to agree the terminology for mitigation and the mouse was eventually physically passed from one engineer to the other. Observing the exchange, it would have been simpler and more efficient had it been possible to use two mice simultaneously using verbal communication and well developed social protocols to temporarily transfer control.

Realistic, medium fidelity simulators have been used for many years for well control training. More recently, life-sized rig simulators have been constructed to help train crews and to step through complex operational procedures. For some teams, exercises involving the operator, contractor and service companies are now standard. With collaborative environments now being common-place, Sawaryn *et. al*. suggested that they could be linked to these simulators, closely representing real operational conditions[46]. Such an environment could provide an excellent testing and proving ground for new R&D software and control systems, in some cases running behind standard configurations before exposure to higher cost field operations. In the aviation industry, high fidelity simulators have been available for some time to train and certify pilots to the point that they can fly fare paying passengers after certification without ever leaving the ground. The question is how far are we away from being able to do something similar, ultimately drilling a well before it is spudded?

Conclusions

- Situation awareness is a useful framework in which to assess the suitability of current drilling and completions applications and future needs.
- Gaps and opportunities for improvement exist in all three areas of perception, comprehension and projection. However, the rapid growth of data and slow rate of integration of both software and hardware components seems to be limiting perceptive capability. This restricts our ability to achieve the higher comprehension and projection goals.
- Business value is achieved through the elements of projection, decision making and then action. In comparison with other businesses, relatively little effort has been expended in drilling and completions to understand and document our work flows and this lack of attention at a systems level may be hampering progress.
- A better understanding of workflows and what influences them will also help to ensure the appropriate solution methods are applied to a problem.
- The assumptions under which earlier applications were constructed and used have changed.
- New applications are needed for this new era. In some cases we should expect them to bear more resemblance to gaming software than raw calculating engines.
- Within drilling and completions the combination of WITSML and SOA offers an optimised architecture for both real-time and historical data processing.

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