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Future Vision: The Next Revolution in Production Operations

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Abstract

In recent years there has been a proliferation of onshore control centres and advanced collaborative environments supporting the digitization of offshore oil and gas production. Information and communications technologies have facilitated this 'digital' evolution. To-date the results have been impressive, improved productivity and economics, together with health, safety and environmental benefits have been demonstrated. New advances in digital technologies are now poised to revolutionize how engineers and oil and gas professionals collate, visualize and interact with complex information, from real-time sensor data through to 'fuzzy, asynchronous chat' from instant messaging and other internet based communications tools.

This paper presents a review of how the next generation information and communication technologies are impacting complex, virtualized operations in industries such as the military. Case studies and lessons learned are presented together with insights and experience on how these findings can be applied to offshore production operations.

Introduction

Sometime in the near future …

Mike swiveled in his chair, he had just heard his jPhone 6th edition ping. It was his maintenance schedule for the day. He leaned back in his chair and waved through the window to his kids as they left for school in Sugar Land. Sitting in his home office he thought about his day. As a virtual maintenance engineer, this was the first time he had worked for VirtuOil.

Today Mike was to maintain a pump on the Bull Frog platform, a deep-water facility 300 miles off of the coast of Nigeria. He was scheduled to carry out planned maintenance at 2.00 pm Houston time. That gave him 4 hours to familiarize himself with the facility and the pump. Putting on his 3-D 'mini cave' headset, with built in neural controller, he found himself in VirtuOil's 5th life environment. The automatic retina scan had verified his security clearance, and he was immediately given access to the virtual platform.

He moved his avatar through to the pump location and carried out a visual inspection, noting the condition and checking the pump history with the integrity management database. It appeared that the corrosion levels were worse than expected by the semantic corrosion feedback system. He needed a corrosion subject matter expert to advise him on the situation. He spoke "corrosion, pump L24, Bullfrog" and was immediately connected to Henning Hoert, a virtual corrosion expert based in Tromso, Norway. Using the iRoom immersive collaborative environment, Mike and Henning simulated a number of maintenance and repair scenarios and decided on a clear course of action, which required a few minor changes to other virtual workflows in the same area as the pump. The business workflow engine had already logged their 'chat' and was updating the schedules for those virtual workers who had concurrent tasks. Thanking Henning, Mike completed his simulated run-through and got up to find some lunch.

At 2:00 pm Mike again donned his mini cave headset together with his haptic maintenance gloves and proceeded, virtually, to the pump. His discussions with Henning had prepared him for the stiffness of the valve wheel, feeling the resistance through his gloves, there were still some activities that required 'the human touch.' Gently he closed the value and carried out his maintenance tasks. Completing his tasks in the two hour 'slot' agreed, he sent the video of the activity to the VirtuOil maintenance supervisor and logged off. Now that VirtuOil only had 20 full time staff to manage the 7 million b/d production, virtual employees such as Mike were at a premium. Tomorrow, he was scheduled to maintain one of the 'old style' downhole separation units for RealOil. He sat back thinking about how the virtualized oil and gas industry allowed him to 'work from home', benefiting his two daughters and dramatically reducing the carbon footprint from oil and gas exploration and extraction activities.

In Mike's view, the future certainly was bright….

This scenario asks two questions. What are the technologies that support the business capabilities and how far away is the oil & gas industry from adopting and utilizing these technologies?

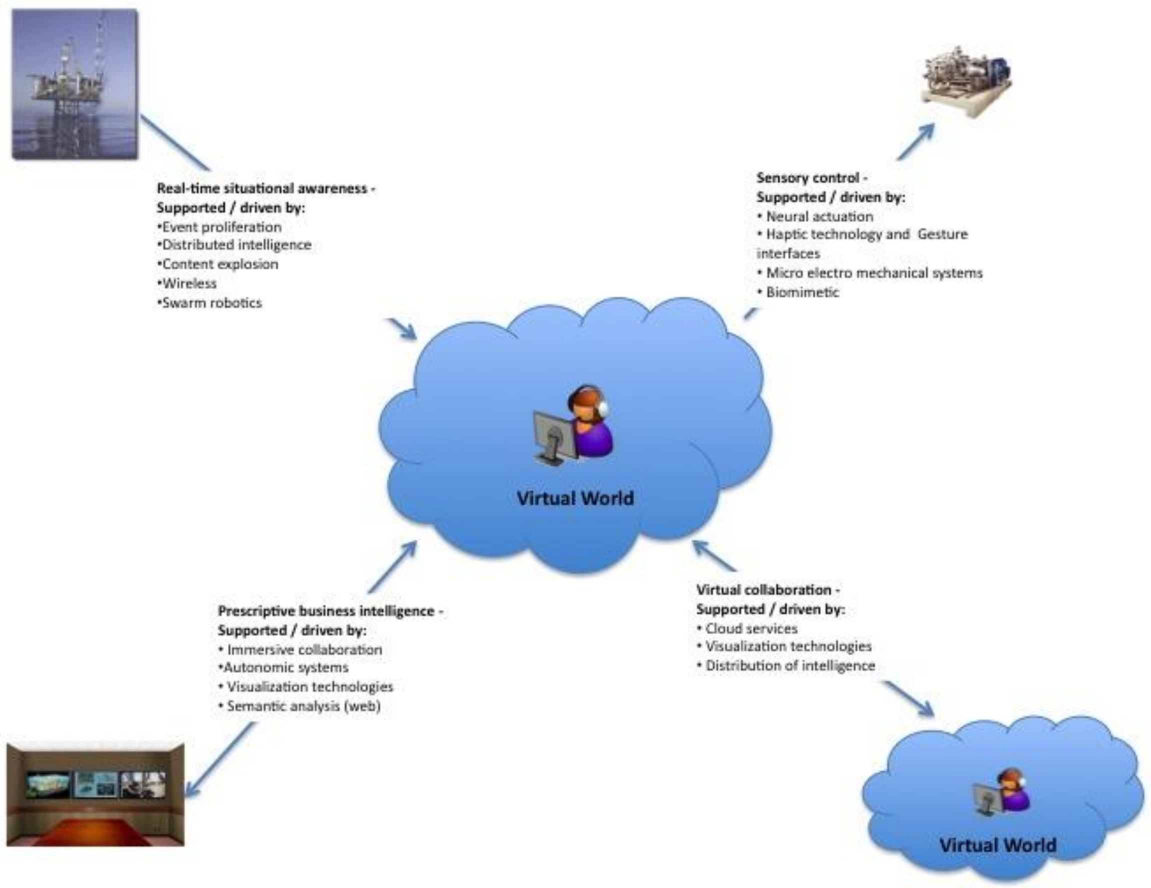
What are the Key Emerging Technologies?

The technologies implicit in the scenario can be thought of as supporting the following business capabilities:

- Real-time Situational Awareness
- Prescriptive Business Intelligence
- Virtual Collaboration
- Sensory Control

Figure 1 details the key information and communication technologies (ICT) that facilitate these business capabilities.

Figure 1



These emerging technologies which facilitate the four business capabilities offer the potential for the oil and gas industry to fundamentally change the way the next generation workforce finds, produces and delivers hydrocarbons around the world.

Real-Time Situational Awareness

Firstly Mike is relying on real-time situational awareness. The proliferation of sensors and the number and type of measurable data has facilitated an increase in the granularity and frequency of measurement. 'Disposable' motes and swarm robotics have allowed transient processes such as fluid flow through the well bore, temperatures, pressures, etc. to be measured in real-time. Similarly the ability to give devices, motes, people and equipment individual IP addresses has lead to an information rich environment. In respect of measurable data, event proliferation and content explosion has occurred and Mike and his fellow virtual workers rely on distributed intelligence in the system, supported by sophisticated semantic analysis to filter and present the relevant information for action.

Prescriptive Business Intelligence

In assessing the situation and maintenance requirements on the 'Bull Frog' facility, and based on the vast quantities of data coming from the sensors and corporate maintenance databases, Mike requires both real-time and right-time intelligence. Not just to filter and present a concise set of information to him, but also to understand the appropriate workflows and personnel that may be impacted by Mike's analysis and conclusions. As is illustrated in the introductory scenario, linguistic and semantic intelligence is required to allow Mike to quickly find and interact with subject matter experts, in this instance the corrosion expert Henning.

Virtual Collaboration

As is evident in the scenario, virtual collaboration is the cornerstone to Mike successfully completing his activities in a safe and efficient manner. Mike is able to participate fully in virtual teams and projects of his choosing through virtual environments which automatically adapt to Mike's situation whether he is sitting in a large scale collaboration center or simply connected from his home or field location. By subscribing to his project and expertise teams, Mike is able to collaborate on key activities and projects as needed with people from around the globe spanning cultures, company boundaries and time zones with relative ease to accomplish his objectives. The virtual environment knows Mike and how he prefers to interact. It can also transform quickly to connect the relevant group and topic complete with provisioning the latest real-time information and meeting history context.

Sensory Control

Finally, Mike needs to interact physically with the pump he has been contracted to service. Sensory control technologies such as neural actuation devices, haptic and gesture interface technologies, supported by micro electro mechanical devices allow Mike to experience the turning of the valve wheel, and hence get a 'feel' for the status of the pump and the maintenance requirements. Consequently, Mike's tacit knowledge and expertise are readily utilized. Additionally, the rich media recording of Mike's interaction with the pump allow the transfer of some of his tacit knowledge to virtual apprentices and trainees.

Table 1 summarizes the current status of these emerging ICT technologies.

Table 1

	ICT Technology	**Description**	**Current Status and Examples**
Real-time situational awareness	Distributed Intelligence	The ability to distribute processing and storage capacity optimally throughout event processing systems will increase dramatically as the network becomes the platform and sensor devices become significantly more intelligent.	• Reva systems • 1 mm^3 mote could have the processing power and memory of a 1998 desktop server, with integrated power supply and transmitter, within 10 years.
	Swarm Robotics	This approach to the coordination of multi-robot systems emerged from the field of artificial swarm intelligence, as well as the biological study of insects.	• Self assembly • Collective intelligence • Solar powered wireless insects for expendable surveillance
Prescriptive Business Intelligence and Virtual Collaboration	Immersive Collaboration	The ability to experience a teaming environment virtually will enable individuals and organizations to span culture, distance and time while reducing travel time, inconvenience, risk, expense and emissions.	• Next generation collaborative environments • Enhanced TelePresence • Second Life type applications
	Autonomic Systems	Advances in available information and computing power and efficiency, coupled with advances in event processing, modelling and artificial intelligence algorithms, will make autonomic systems not only feasible but robust and cost-effective. The movement is likely to occur in two phases: automated information aggregation and reporting; and then with automated response and control.	• Trading systems • Closed loop process control • Robotics
	Semantic Analysis	Advances in semantic analysis and other aspects of AI enabling systems to understand, learn and adapt to changing conditions will make Business Activity Monitoring (BAM) increasingly predictive, prescriptive and proactive.	• WiseWindow • Progress Apama
	Visualization Technologies	Progress in the ability to extend human visualization capabilities in terms of distance, magnification, multi-channel, history and pattern matching is already opening a range of new and intriguing possibilities in oil & gas and elsewhere.	• Remote visualization compression algorithms • TelePresence life like remote human interaction • Casino camera intelligence

Table 1 continued

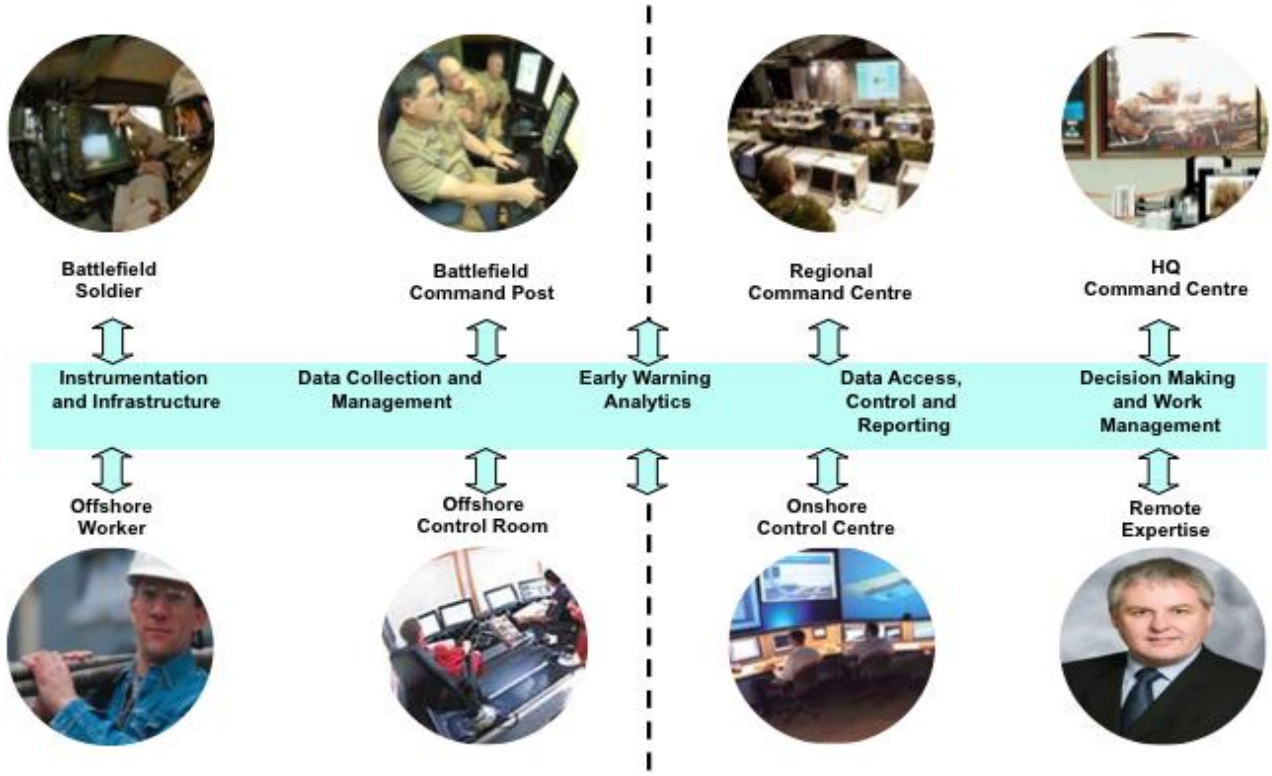
	ICT Technology	Description	Current Status and Examples
Sensory Control	Haptic Technologies	Advances in imitating the sense of touch by applying forces, vibrations and / or motions to the user promise to have wide-reaching applications.	• Maintenance engineering • Underwater exploration • Simulation / training • Gaming
	Neural Actuation	This revolution builds upon the Defense Advanced Research Projects Agency (DARPA) investments in neuroscience, robotics, sensors, power systems, and actuation. The study of Human Assisted Neural Devices has decoded the brain's motor signals such that motor movements of a robotic arm can now be achieved entirely by direct brain control.	• Super human prosthetics • Smart skin for aircraft • Bipedal locomotion
	Micro Electro-mechanical Devices	Nano-technology; the convergence of molecular level construction and micro-electronics will allow fully functioning, independent sensors and devices such as mote sensor arrays, not only shrink radically but also exist in harsh environments.	• ETH nanobot research • MIT: mems vibration harvesting for wireless sensors • COLIBRYS: MEMS for oil and gas
	Biomimetics	The imitation of life is an exciting new set of scientific disciplines which are now rapidly pushing the envelope in terms of physicality, sensing and intelligence.	• Harsh environment robotics • Human strength enhancement • Hazardous duty surveillance

It is interesting to note that most of these technologies appear to be driven by requirements from other industries, or perhaps more pervasively by consumer technologies and gaming.

Are Other Industries Paving the Way?

In adopting and deploying the previously highlighted business capabilities, the authors believe that other industries such as the military have experiences and learning, that are applicable and of relevance to the oil and gas industry. Technologies that they are using to both integrate collaboration across and along the value chain and at the same time optimize processes and resources. As is illustrated in Figure 2, the military is a particularly good analogue as they share many of the same challenges for the deployment of sense and respond capabilities in hostile and often remote locations where communication infrastructures and expertise may be lacking.

Figure 2



With the desired 'business' capabilities of situational awareness, speed of command, total asset visibility, adaptive planning, streamlined operations and risk management, the requirements and challenges the military faces in the 21st century have lead to substantial investment in research, development and deployment of the previously identified enabling technologies (see Table 2).

Table 2

Requirements	**Challenges**
Sense and Respond • **"**Battlesphere" movement, identification, information • Faster decision making by Commanders based on content, quality, relevance and timeliness of information	**Collaborative Command Centres** • Centres used for immersive decision environments vs. station oriented single purpose computing sections
Seamless Integration • Shared situational awareness across joint operation environments • Application and data services with policy enforcement and reporting provide more organizational alignment	**Human and Machine Collaboration** • Nodes on the network provision services to other nodes, allowing for planned and/or impromptu collaboration
Connectivity • Continuous, ad hoc, and or isolated – dynamic auto adjust services to available service needs. Network enables mobility and agility	**Decision Support** • Stationary command centres with support tools and services • Mobile command services, those are very mobile whether vehicle, airplanes, ships, suitcases, etc

So where is the military in their development and deployment of these capabilities and supporting technologies today? And what learning can be transferred to offshore oil and gas?

Real-time Situational Awareness

The military, particularly in the US, is investing a great deal of research effort into building 'knowledge environments' that enhance situational awareness, including the use of service orientated architectures, the semantic web, ontology’s and intelligent agents. There is also research, development and deployment of the underlying infrastructure technologies that allow effective communication and collaboration in remote, hostile (both militarily and environmentally) locations. Key to the deployment of these infrastructure technologies is the use of COTS, commercial off the shelf components.

Specific areas of research and deployment include:

- Psychologically inspired object recognition systems, which give robots and visual sensing devices the ability to see objects in the way humans do, and to make reasonable judgments based on those sights.
- Scalable networks; through initiatives such WAND, the Wireless Adaptive Network Development project, which using COTS technology looks to keep soldiers linked with each other on the battlefield through 'ad-hoc' networks that can shift frequencies and side-step interference, thus making communications more pervasive and reliable.
- Real-time 3-D maps, employing, LIDAR (light detection and ranging), thermal imaging and x-ray back-scattering to not only display buildings and streets, but objects and people inside as well. The technology promises millimeter accuracy in measuring static features such as doors and windows.

Prescriptive Business Intelligence

“Agility is the gold standard for Information Age militaries. Facing uncertain futures and new sets of threats in a complex, dynamic, and challenging security environment, militaries around the world are transforming themselves, becoming more information-enabled and network-centric.” (1)

The majority of the world’s military organizations are looking to ‘implement’ network-centric operations (NCO) and effects based organizations with the goal of become more agile. In support of these long-term goals a great deal of effort is being directed towards tools and technologies that enhance operational (business) intelligence. Examples of ongoing research and development that are in the public domain include:

- “Collaborative Technologies for Network-Centric Operations: A U.S. naval research programme is developing a networked collaborative intelligence tool called JIGSAW (Joint Intelligence Graphical Situation Awareness Web) which is a shared graphical workspace for intelligence analysts to share their assessments of real-time situations and facilitate joint collaboration.” (2)
- “The Norwegian Defence Research Establishment (FFI) is studying semantic technologies in order to evaluate how they can be utilized in military applications.” (3)
- “In the Czech Republic they are investigating virtual reality devices that support C2 (command and control) systems. Currently, improvements in the virtual reality presentation layer, using COTS technology, are being investigated.” (4)
- Semantic Machine Understanding: Using text mining and meaning clusters to extract knowledge patterns that can be applied to predict future data. Supported by the ability to incorporate humans and machines to form a collaborative network these tools are seen as providing a foundation for automatic sense and decision-making.
- A Service Orientated Architecture has been designed and built that combines swarming technologies and active metadata to distribute information and services across a swarm network.
- Utilizing Web 2.0 technologies such as Yahoo Pipes, Open Kapow Robots, Flikr and YouTube in ‘mash-ups’ for convoy route planning and Improvised Explosive Device forensic analysis. Web 2.0 tools and mash-ups provided faster collection of data and resulting correlation of information than the legacy systems offered. This provides for a faster OODA Loop (Observe, Orient, Decide and Act) and an increased overall battle rhythm. This increased battle rhythm results in more concurrent operations or operations that can be planned (and executed) faster than current systems allow.

For the military, the holy grail of NCO is self-synchronization. It rests firmly on the proposition that subordinates have superior local knowledge. If they understand the goals (commander’s intent), principles (rules of engagement), and plans (orders) of an operation, they can produce results superior to centrally controlled organizations. In addition to researching and deploying tools and technologies, much of military research is focused on organizational and cultural issues that enhance or inhibit adoption and effectiveness of these technologies, particularly in virtual environments.

Virtual Collaboration

Virtual collaboration through augmented reality (the merging of real and virtual information) is seen as a tool to achieve a common ground for network based operations. Multi-user augmented reality applications have been piloted to aid-cross cultural communication in networked operations. Optic see-through and video see-through systems have been investigated. The goal of this research is to allow the commanders (from different countries or cultures) to interact without spending effort on negotiating what things are, or mean. This for example can be achieved by 'translation' of map symbols so that one commander sees one type representation of an object, while another commander in the same situation sees another representation that is meaningful to him/her.

Other areas of technology deployment include:

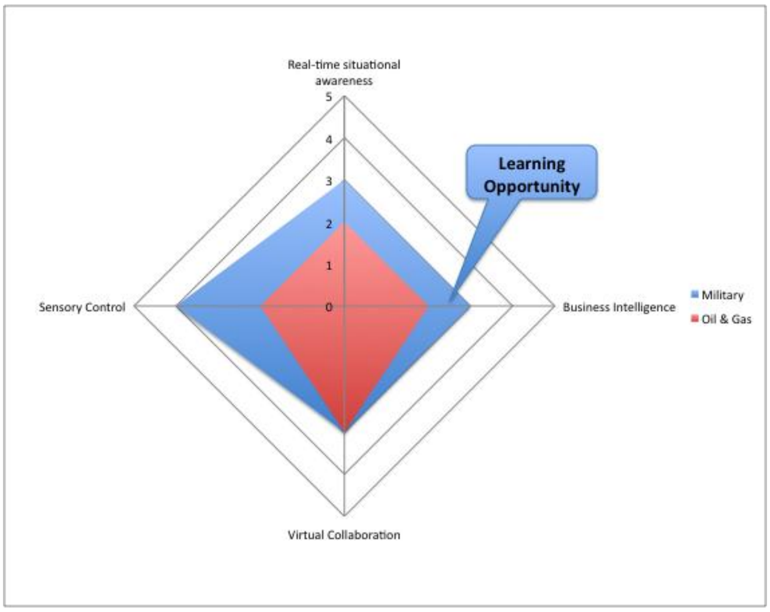
- Collaborative Working and Visualization Environments that use common operational pictures to support collaborative military planning in joint command and control situations.
- Flexible OLED displays for wearable information displays

Sensory Control

The US Army has recently awarded a $4 million contract to a coalition of scientists, all of which will soon start developing a "thought helmet" to enable voiceless, secure communication between field personnel. In theory, at least, the helmet will boast a litany of sensors that will hopefully "lead to direct mental control of military systems by thought alone. "Also in the US, DARPA, through its Nano Air Vehicle program, is looking for ultra-lightweight devices that could theoretically perform indoor and outdoor military missions." [(5)] More specifically, it's looking for something less than 7.5-centimeters and under 10-grams, and the overriding goal is to "explore novel, bio-inspired, conventional and unconventional configurations to provide the war-fighter with unprecedented capability for urban mission operations."

It is evident that the military industry is investing a lot of time and effort in technologies and processes that could readily be adapted and adopted in the offshore oil and gas environment. Consider the maturity assessment of the military industry versus oil and gas as illustrated in figure 3. Based on this qualitative assessment of public domain information, the authors believe that the military industry is generally ahead of the oil and gas industry in at least three of the four emerging technology clusters addressed in this paper. If 'non public' domain information were considered we would expect to see the military industry even further ahead. The implementation environments in the military are also remarkably similar to many oil and gas environments, so the opportunity for oil and gas companies to use the military as analog would seem well worth investigating.

Figure 3



Adopting Emerging Technologies - Where the Oil and Gas Industry could be within a Decade

Clearly, the worldwide oil and gas industry is at an inflection point. It is evident that the industry must find ways to make existing structures and boundaries more flexible to accommodate the dynamics of 21st century energy supply. Responding to these challenges, IOCs and service and supply companies increasingly will need to virtualize their capabilities, acquire and manage the critical knowledge workers they require, and interact more effectively with ecosystem players and stakeholders. IT and communications infrastructure will play a critical role in providing the collaboration and communication tools required for virtualization, while supporting the necessary organizational transformation.

As a consequence of these transformational forces, the authors believe that oil and gas companies will necessarily become more 'virtual.' The virtual oil company minimizes or eliminates obstacles created by location, distance and time. The example of Mike in the near future becomes a distinct reality.

The enabler of the virtual oil company is the information and communications network that supports the knowledge worker. The network links all the disparate elements of the organization, no matter how remote, providing real-time access to people, data, and processes around the world. The boundary, or "edge," of the organization becomes the down-hole sensor or the mobile maintenance worker, not the regional office or offshore platform. The development of "edge organizations" that support worldwide oil and gas activities will require robust, scalable, collaborative environments supported by seamless networks that integrate all communication modes, including voice, data, and video.

Through the adoption and deployment of the emerging technologies described in the previous sections, and by taking on-board key learning's from other industries such as the military, it is believed that the oil and gas industry can implement the desired capabilities and deliver the core competencies, as illustrated in Figure 4, that the authors believe will be required by the oil company of the future.

Figure 4

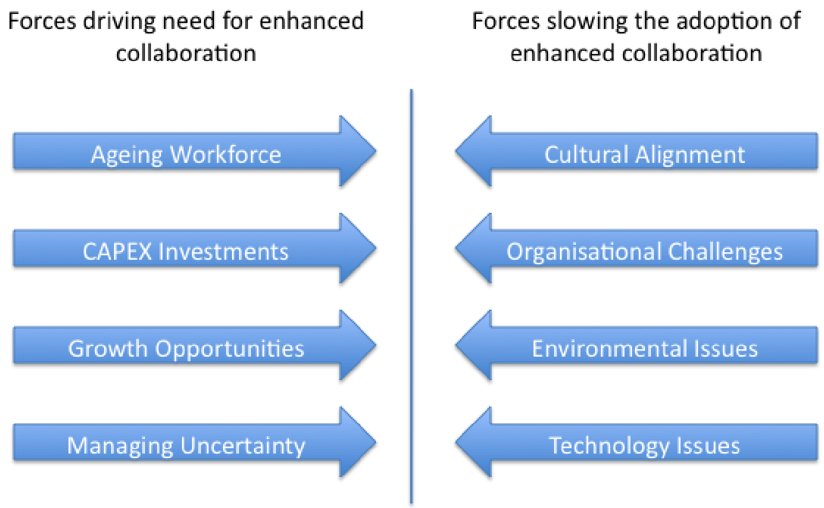
Forces likely to Impact Speed of Adoption

Demand requirements make it essential to maximize production from both existing and new oil and gas fields. Given that the oil and gas industry is one of the most knowledge-intensive industries, and given that the interpretive capabilities of industry professionals will be needed to deliver against this requirement, the oil and gas industry's demand for these specialized skills is already outstripping supply. Compounding the problem, in traditional oil and gas locations such as Houston, Aberdeen, and Calgary, where a significant proportion of the industry skills are located, individuals with the needed expertise are aging. As these people leave the workforce, there are not enough skilled workers to replace them. Fewer young people are choosing to pursue careers in engineering or science (specifically in oil and gas) leaving a serious gap between the industry's need for skilled people and the available worldwide supply. Additionally, there is a mismatch in the location of industry skills as, spurred by economic aspirations, "emerging" countries such as China, India, and Venezuela produce a surplus of oil and gas professionals. These skill requirements present a major challenge to the oil and gas industry (and, specifically, to IOCs and service and supply companies) as industry executives recognize that outward-facing, complex, knowledge-based roles will be required to sustain and grow their businesses for the next 15 years.

One of the consequences of this restructuring of the industry, together with the location of oil and gas reserves, has been a shift in the balance of power toward the NOC's. In this highly demand-driven environment, traditional reasons for partnering with IOCs (access to capital, technology, and markets) continue to diminish. NOC's have developed in-house expertise and have access to technology through the service and supply companies, who are paid in cash rather than reserves. NOC's also are expanding along the value chain into downstream activities, such as refining, to ensure access to markets. Consequently, IOCs increasingly face the prospect of being offered access to high-cost or environmentally challenging (or both) reserves. As a result, IOCs are experiencing static or minimal increases in reserve/production ratios (currently 10 to 15 years for most IOCs), together with steady increases in finding and lifting costs.

Figure 5 summarizes the key forces which are likely to impact speed of adoption. Historically, oil & gas has been considered to be among the slowest industries in terms of speed of innovation, but today there is ample reason to expect that things may all be about to change.

Figure 5



Conclusion

The dynamics of energy supply are changing rapidly as old business models quickly become obsolete. Oil and gas companies that cannot adapt to the exigencies of ever-more-difficult extraction of hydrocarbons, the pressure to operate globally, and the increased scarcity of the industry's professional expertise will have a hard time surviving. Oil and gas companies need to map how they will evolve to the next step, using the network as a platform for virtual, agile operations that respond quickly to global changes. Using learning from other industries such as the military, the authors are confident that the oil and gas industry can transform itself for success in the remainder of the 21st century.

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