

## INTEGRATED OPERATIONS: VALUE AND APPROACH IN THE OIL INDUSTRY

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### Abstract

Today's society is increasingly susceptible to global economic crisis. The energy is still extremely dependent on oil, whose extraction scenarios usually have great complexity. The technology in the oil industry has undergone a vertiginous development in recent times. Advances in information, data and telecommunications have been reflected in the connectivity of systems and people with tremendous impacts on improvements of operational and business decisions. In this context, came to light an important movement of Integrated Operations (IO), which has systematized the implementation of this concept in the oil and gas operators and service providers. Each company has created its program, with peculiarities and challenges. This paper, including an intensive literature search, analyzed the objectives, concepts and architectures of Integrated Operations deployments in five major operators. Through a reference framework, the differences and similarities of these models were discussed. There was also an analysis in recent bibliography in order to better understand the value for Integrated Operations.

**Keywords:** Integrated Operations, Smart Fields, Digital Fields, Value

### 1. INTRODUCTION

Oil today remains the main source of primary energy, which accounts for over 30% of world energy. Today, oil is usually regarded as a product that plays a key role in the global economy. Despite the scale of the oil trading as a raw material, recently it has increased its value of a financial asset. Eventually, oil prices were characterized by a very high volatility in both the short and the long-term intervals. High uncertainty in oil prices is becoming a very significant problem for oil and gas companies (Kolbikov, 2014). Another aspect is related to complexity of the new proven oil reserves. They will demand not only investments, new technologies, but also process redesign and optimization.

One of the chief challenges facing the EP industry is to increase the recovery of hydrocarbons from the existing asset base. With access to new resources getting more difficult and production declines facing several major mature provinces, the awareness that is needed to manage assets differently is growing. Recovery optimization is therefore a growing issue with significant future capital, technological and

workforce competence development implications (Potters, 2005). Since the turn of the millennium, most major oil companies and global operating vendor/service companies have increasingly addressed oil exploration and operation enabled by information and communication technology as their future way of doing business. Integrated Operations (IO) is a concept used to describe this new way of doing business (Rosendahl, 2013).

According to Larsen, 2012, Integrated Operations (IO) is the integration of people, work processes and technology to make smarter decisions and better execution. It is enabled by using shared real time information, collaborative technologies and multiple expertises across disciplines, organizations and geographical locations. There is a multiplicity of names for Integrated Operations, coined by oil companies, some of which are: Digital Oil Field, Digital Oil Field of the Future, Smart Fields, Smart Wells, iField, iWells, eField, and Intelligent Field (Cramer, 2012).

In this sense, this work's main objective is to perform a literature review, comparing the several approaches of Integrated Operations in the major oil operators, associating literature cases with value results.

This paper is divided into five parts, starting with the methodology. Following, approaches of five oil operators are presented: Saudi Aramco, Statoil, Shell, British Petroleum and Petrobras. Then, the reference framework is discussed and literature success case studies are analyzed. In the final part, conclusions and references are found.

## 2. METHODOLOGICAL APPROACH

The methodological framework adopted for the development of this research was based on a bibliographic review, by analyzing strategies, approaches, concepts and cases of Integrated Operations initiatives across oil operator majors. The study was carried through the papers presented in the last years. The methodological approach is presented in the Figure 1 below.

Two libraries of technical documents and journal articles were used: OnePetro and Scopus. After the first search, the outcome was refined to come up with the selection of papers. Before the case analysis, the papers were overviewed to select the subjects of interest.

Next, the main implementation aspects of five major oil operators will be discussed.

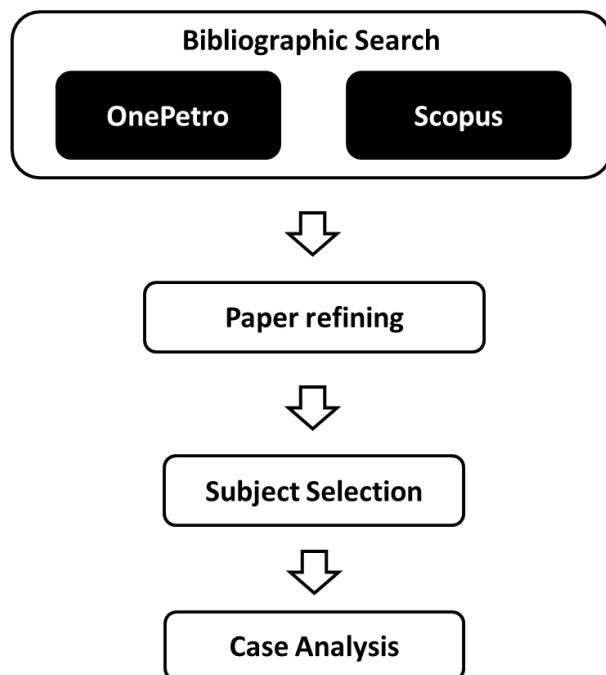


Figure 1. Methodological approach

From: The authors own

## 3. OVERVIEW OF INTEGRATED OPERATIONS ON THE MAJOR OIL OPERATORS

### 3.1 Saudi Aramco

The Intelligent field is the oil industry's new trend that enables continuous monitoring and optimization of individual wells and overall reservoir performance. This is achieved by integrating fields' real time data in the reservoir management business processes. The results from this integration are anticipated to increase production rates, identify opportunities for higher hydrocarbon recoveries and reduce operating costs and future capital expenditures (Al-Dhubaib, 2008). It was explained by AbdulKarim, 2010, that in the industry, integration of the various digital surface and subsurface technologies into E&P business processes has been given different names, such as: Smart fields, Intelligent Field (I-Field), Digital Oil Field of the Future (DOFOF), integrated field (I-field) and Integrated Operations (IO).

The oil industry is implementing largely initiatives in recent years, redesigning processes and workflows in order to maximize hydrocarbon production, recovery, profits, or health, safety and environmental compliance. Saudi Aramco is considered to be a leader in deploying and utilizing the intelligent field technology to maximize the value of hydrocarbon reservoirs (Alhuthali, 2012).

Nasser, 2011, adds that recent Intelligent Field implementations have significantly optimized Saudi Aramco upstream operation with great values captured and reported. Decisions that used to take several months now take few hours by utilizing intelligent field technology. Saudi Aramco internally initiated an assessment to study the current real time management practices in order to tap and leverage on the existing guidelines as well as propose possible enhancements that will add value to the intelligent field implementation.

#### 3.1.1 Intelligent Field Objectives

The overall objective is to optimize business processes as the knowledge and the process improvement gained at any one phase significantly influences the overall process. This, in turn, provides an opportunity to further enhance practices and strategies in the entire field development and management cycles (AbdulKarim, 2010). Al-Dhubaib, 2008, explains that these objectives are connected to the enhancing recoverable oil through in-time intervention and full-field optimization and also improving HSE through remote monitoring and intervention and reducing operation cost by lowering manual supervision and intervention. One

of the major objectives of these projects is to integrate and leverage on multidisciplinary team collaboration and real-time field data through all the phases of field development and management life cycle (AbdulKarim, 2010).

The Digital Field developments and implementations are efforts that integrate people, processes and systems to achieve real-time and/or in-time decision making and optimization in most, if not in all, upstream business processes. (Al-Dhubaib, 2011). According to Barghouty, 2010, the value proposition of the Intelligent Field includes increasing production potential, recovery factor and efficiency with the most safe and environmentally sound practices.

### 3.1.2 Approach

The I-Field initiative is being implemented on two parallel ways. One is based on the installation in new and old fields to evaluate, exploit and drive available intelligent field technologies to address Saudi Aramco objectives. The second path is a structured development approach that captures the challenges, lessons learned and integrates required systems, specifications, processes and procedures for an overall solution that lays out an architecture for large scale implementation and a company-wide role out (Al-Dhubaib, 2008). According to AbdulKarim, 2010, Saudi Aramco has capitalized on digital fields development in the

surface and subsurface well technologies to optimize fields development and operation strategies, through projects that were able to provide significant and immediate benefits such as cost saving and optimized plans as well as optimize intra-and inter-business processes.

### 3.1.3 Concept

Figure 2 shows Saudi Aramco implementation approach. It consists of four major layers, namely: Surveillance, Integration, Optimization and Innovation. The surveillance layer provides continuous monitoring and applies data management tools and processes to ensure usefulness of the data. The integration layer interrogates real time data on a continuous basis to detect behavior trends and anomalies. Engineers are alerted to such anomalies for further analysis and resolution. (AbdulKarim, 2010). Alhuthali, 2012, explains that the optimization layer provides a comprehensive optimization system that covers the entire production system with various processes, assets and recourses. The last layer is the innovation where maximum advantage of the intelligent field can be realized through efficient transformation of data to knowledge and informed decisions. It provides the proper environment to capture experience and motivate cross-functional dialogue and thinking to introduce innovative solutions and maximize the value of intelligent field technology.

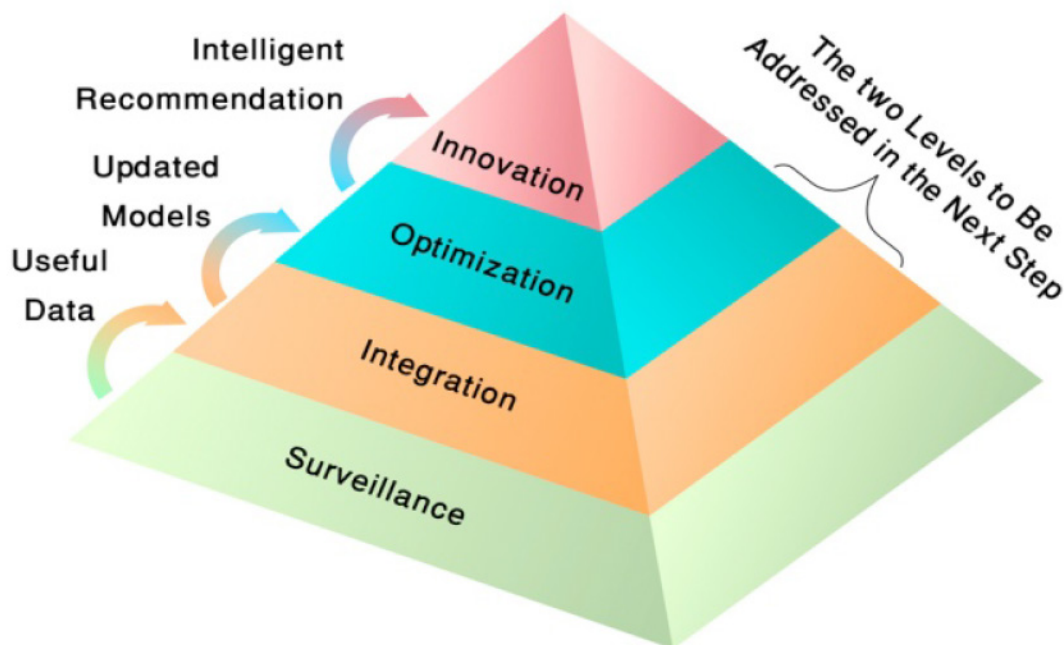


Figure 2. Implementation architecture

From: AbdulKarim (2010)

### 3.2 Statoil

In Statoil, Integrated Operations (IO) is defined as the integration of people, process, and technology to make and execute better decisions quicker. IO is enabled by the use of real time data, collaborative technologies, and multidiscipline workflows (ways of working) in work processes (Halland, 2013). According to Henriquez, 2008, Statoil defines the term as collaboration across disciplines, companies and organizational and geographical boundaries based on the use of modern information and communication technology in order to ensure safer, better and more rapid decisions.

Statoil's IO Corporate Initiative was established in response to this with responsibility for supporting and coordinating the company's IO projects across business units and with R&D (Lilleng, 2010). Henriquez, 2008, explains that a phase of experimentation, including R&D activities, pilots and wide deployment, was identified as necessary [in Statoil] for the understanding of the challenges ahead to mature.

#### 3.2.1 Integrated Operations Objectives

A fundamental premise underlying the industry's focus on integrated operations is that IO will improve decision-making. Improved decisions should in turn lead to safer and more efficient operations (...) Efforts to maintain, or create a new, equilibrium between people, technology and organization are fundamental in achieving IO's goal: better decisions (Ringstad, 2007).

The definition of IO constitutes the basis for Statoil's IO stack model that consists of seven interdependent success criteria representing the necessary and sufficient conditions for value creation by means of IO. (...) Together, they create capabilities for faster and better decisions and execution that add significant value to the business (Larsen, 2012).

#### 3.2.2 Approach

The ambition could be higher if a concrete vision/objective was established: to strengthen decision-making onshore and strengthen execution offshore (Henriquez, 2008). Lilleng, 2010, states that the common operation model for Statoil's operations incorporates IO as a key enabler and is based on the principle that all work tasks which can be done onshore shall be done onshore implying that most administrative tasks are removed from offshore allowing increased focus on the installations on operations and safety issues, the effects of which are reflected in improved operational efficiency and reduced costs.

Lilleng, 2012, demonstrates that the process mapping is important to the identification and documentation of good practices with respect to IO providing the basis for experience transfer and organizational learning across assets. The objectives of the IO assessments are to enable

the business units to identify potential areas for operational improvements; enable the relevant process owners and the IO corporate initiative to identify best practices that can be used to improve ways of working and the standardized work processes; enable Statoil to compare performance and steer resources in a more optimal manner in order to achieve a consistent performance level throughout the company, and enable Statoil's top management to assess the level of IO adaption (Lilleng, 2010). In addition, according to the author, other key elements, beyond the processes, make up an MTO (Man, Technology, and Organization) perspective of enabling factors. To have a capability to improve business value, it is necessary to have [these] four key elements in place (Larsen, 2012).

#### 3.2.3 Concept

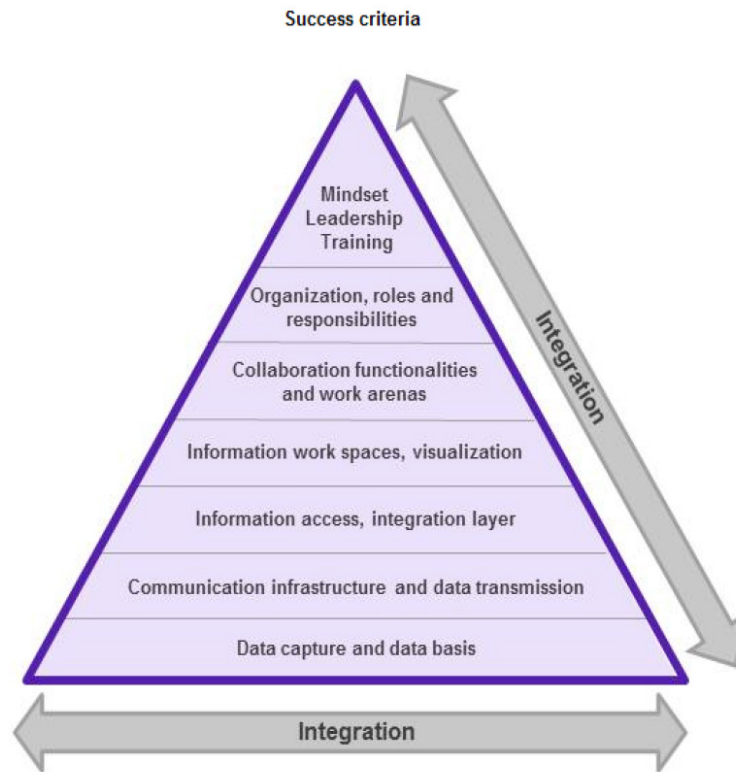
The criteria in the IO stack model are shown in the Figure 02, including the decision and execution layer at the very top. The ability to achieve faster and better decision-making and execution depends on the layers below. In other words, what one is able to achieve at the different layers depends on the layers below, pointing to an interdependency, or interconnectedness, between the different layers. The different layers can be seen as the resources that an organization can use and combine to achieve its goals. Thus, how well a company is equipped at the different layers will determine its ability to achieve its goals, e.g., through faster and better decisions and execution (Larsen, 2012). Lilleng, 2010, remembers that the double-headed arrows illustrate that integration of elements are required within and across layers of the model (see Figure 3). All layers need to be coherently integrated for a successful IO implementation.

### 3.3 Shell

Shell's version of the digital-oilfield process is called Smart Fields. SmartFields began with the installation and monitoring of control systems in wells. This has expanded to cover field management and has been formulated as a value loop (Udofia, 2014). According to Perrons, 2010, Smart Fields is not a standalone technology that has been developed by a single team; rather, it is based on the integration of dozens of tools, skills, and workflows to improve the performance of core Shell EP assets in a structural and sustainable way.

#### 3.3.1 Value Loop Objectives

Smart Fields aims to provide an operating field with the capabilities to optimize production in the short term and maximize lifecycle value in the long term (Udofia, 2014). Potters, 2005, adds that it targets five core processes: Operations, Production Optimization, Reservoir Surveillance, Field Development Planning and Well Execution.



**Figure 3.** Stack model

Source: Adapted from Lilleng (2012)

The first decade of Smart Fields in Shell focused on the new technologies, making business cases and implementing the technologies as widely as feasible. This has led to major contributions to the bottom line, as shown in the Smart Fields Value Assessment. Entering the second decade, the focus of the Smart Fields programme is on accelerating the implementation of new technologies across assets in a way that value generation is sustained (de Best, 2012). According to Udofia, 2014, Smart Fields aims for continuous production optimization of an asset or group of assets through the integration of people, tools and processes. Smart Fields solutions purpose to provide an operating field the capabilities to optimize production in the short term and maximize lifecycle value in the long term.

### 3.3.2 Approach

To understand the key drivers and pitfalls in global implementation of technologies, a 'Sustain' methodology was developed, which provided insight in where these successes and improvement areas are. Building on the results from the 'Sustain' assessments, the approach and focus of the roadmap 'from technology to commodity' was adjusted to deliver robust and sustainable deployment and

continued value creation of Smart Fields technologies (de Best, 2012). Bogaert, 2004, explains that the Smart Fields methodology considers new and existing smart technology, work processes and skills required to create value. The implementation of identified smart opportunities is always subject to a sound business case, the definition of functional requirements, and subsequently the selection of adequate smart solutions.

### 3.3.3 Concept

Analyzing the various case studies and projects where smartness was applied, it became clear that the Smart Fields concept involves a lot more than just the installation of smart equipment. The increased functionality of smartness will only create value when it forms part of a so-called Value Loop (see Figure 4, Bogaert, 2004). According to de Best, 2012, the Value Loop describes how technology components are linked to the people and processes to enable the value of the technology to materialize. Captured in this concept, is the integration of the various technology components. As important is the integration of the multiple disciplines involved and workflows within the organization.



The value loop octagon is at the centre of the Smart Fields methodology. Crucial to the generation of asset value from the introduction of smartness is to close the Value Loop. The octagon illustrates the definition of the asset boundaries, data acquisition and interpretation, calibration of relevant models, the generation of options using the virtual asset models and the selection of the most attractive alternatives, which are then planned for execution. Unless a value loop containing measurement, interpretation and action,

is properly closed it does not generate value (Bogaert, 2004). In the same direction, Potters, 2005, states that the implications of this model are simple: individual activities do not add value unless we effectively connect and integrate them and 'close the loop'. Each activity must be supported with the right skills and workflows. The performance of the total loop determines the quality of our decision-making and the efficiency and effectiveness of the asset management process.

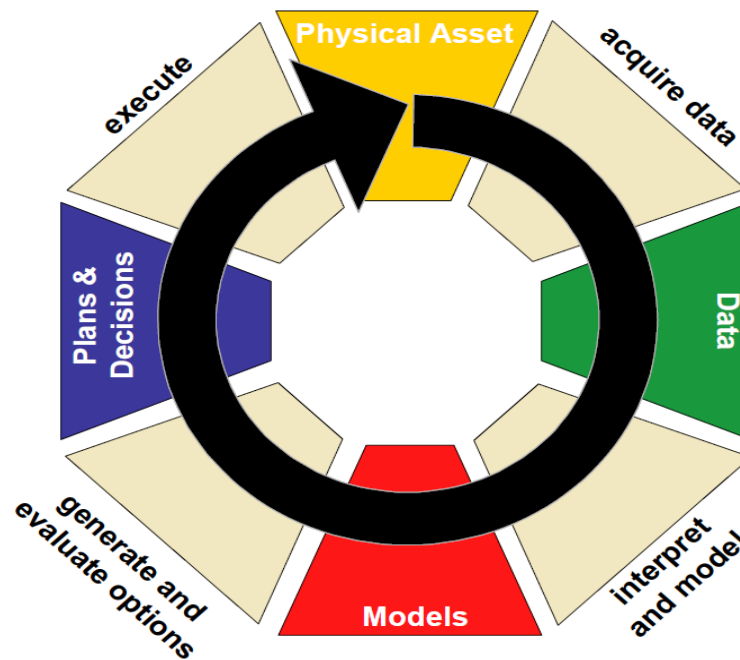


Figure 4. Value loop (octagon)

Source: Bogaert (2004)

### 3.4 British Petroleum

The BP initiative to implement a digital oilfield is called the FIELD OF THE FUTURE programme. Tools and processes developed as part of this programme have been successfully deployed in a number of existing assets, demonstrating and returning real value to BP (Thomson, 2008). Stenhouse, 2008, adds that recent successes, at a number of BP assets, has shown that there is a huge potential for increased production from using the predictive capability of existing models in daily operations, once these models have been combined with real-time data and delivered in a form that actively supports the production optimization process. The ability to replicate this success across the whole of BP's upstream operations represents the focus of the short-loop optimization capability of the FIELD OF THE FUTURE programme which aims to bring the use of BP's modelling software to the forefront of daily operational decision making.

BP's FIELD OF THE FUTURE program has evolved from a collection of related activities to a fully integrated program that is delivering real results in terms of production and recovery benefits. Along the way, the program has had to overcome a number of challenges - around the intent of the program, its value, and how this value will be delivered. The enduring theme of the program is one of integration of activities that relate to real time data, whether reservoir or wells, operations or facilities, technical or digital, development or deployment, central team or asset team (Reddick, 2008).

#### 3.4.1 Field of the future Objectives

Past experience in BP, with modelling and optimization technologies, has shown that there is a huge potential for increased production from the use of models in support of daily operations, once the quality of these models has been

assured (Stenhouse, 2008). BP wants to maximize the value by exploiting the technologies available, including those from the FIELD OF THE FUTURE programme (Thomson, 2008).

### 3.4.2 Approach

BP's FIELD OF THE FUTURE program was established with an initial focus on engagement and deployment, the objective being to deploy core technologies in a limited number of assets in order to build a track record, to re-affirm the prize and to build a technical and architectural foundation for subsequent 'bigger moves' (Reddick, 2008). According to Otto, 2008, having a holistic approach to Digital Infrastructure and IT Architecture has enabled the FIELD OF THE FUTURE programme to achieve an integrated solution and go beyond what would otherwise be a set of smart but isolated point answers.

Within the FIELD OF THE FUTURE business transformation program, adoption success is based on the consistent application of tools to assure: stakeholder identification and engagement, clarity of expectations of staff during and after the implementation project, deep understanding

of how work will change through process walkthroughs to clarify roles and their interactions, identification of risks to adoption, and potential mitigations, understanding between concurrent initiatives that will impact the same team members, clarity of a specific team's readiness for change (Reddick, 2008).

### 3.4.3 Concept

Optimization comprises the pinnacle of the FIELD OF THE FUTURE capability pyramid shown schematically in Figure 5. This simple diagram explicitly recognizes that a robust and sustainable optimization capability can only be delivered on a platform provided by a reliable asset infrastructure together with an advanced level of remote performance management. Delivering the robust platform for optimization is the focus of a number of the FIELD OF THE FUTURE technology programmes (Stenhouse, 2008). Dickens, 2010, adds that the three-tier model developed at the inception of the formal programme has proved robust (Figure 4). The core of the BP Program is aimed at the concept of improved decision support (better decisions faster) through application of real-time data capabilities in production and reservoir activities.

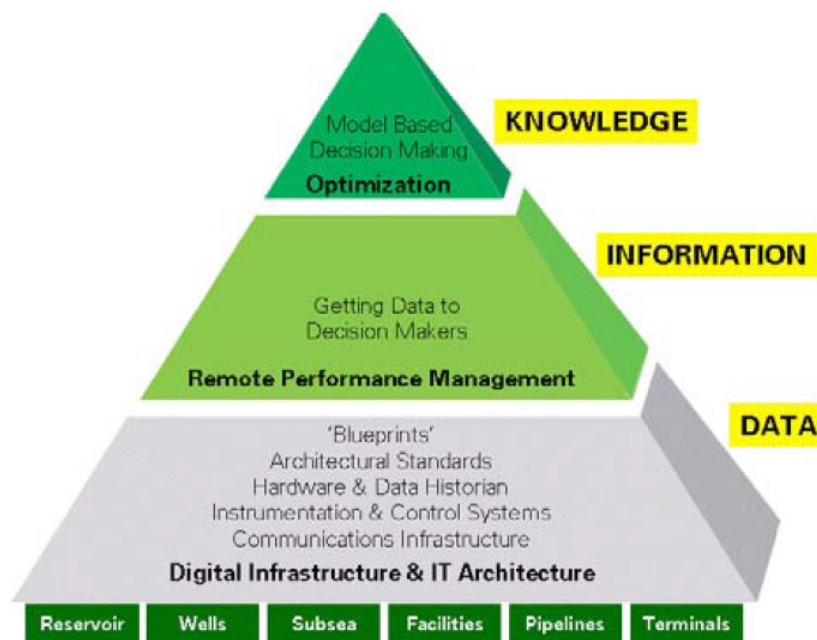


Figure 5. Field of the future knowledge management framework

Source: Dickens (2010)

### 3.5 Petrobras

Petrobras has been developing a pilot strategy based on multiple scenarios to evaluate the technology level of digital oilfields. Six assets were chosen, taking into account

the diversity of production processes (heavy oil, offshore, onshore, brown, and green fields) found all over the Brazilian fields (Moisés, 2008). This first step of implementation was called GeDlg (acronym of Integrated and Digital

Management – in Portuguese). According to Petrobras' vision, GeDIg consists of a new working concept based on real time data availability associated with a new integrated management model, including not only the development of new technologies, but also the implementation of new processes and structured change management efforts, allowing a better collaboration culture better incorporation by the involved people. This new integrated vision is considered a competitive advantage as the decision-making process become faster and more effective, leading to production optimization, cost reduction, reservoir recovery factor increasing and/or safer operations (Vinturini, 2008).

Considering the lessons learned with the GeDIg pilots, Petrobras is implementing a second initiative called GIOp (Integrated Operations Management, in Portuguese) in its E&P Segment. GIOp consists of the integration of technical disciplines, service providers, and support activities involved in production, executed by data made available in right time and new workflows, in order to perform decision making faster and with better quality and process efficiency, considering collaborative environments (Siqueira, 2012).

### 3.5.1 GeDIg/GIOp Objectives

GIOp will allow a systemic view of operations in order to enhance of production and operational efficiency and lower CAPEX and OPEX (Rosendahl, 2013). According to Russo, 2010, the expected benefits were grouped into two categories: Quantifiable benefits (Production increase; Costs reduction; Recovery factor increase and Intangible benefits (Better access to operational data; Security; Environment).

### 3.5.2 Approach

Pilots of Integrated Operations were setup in Petrobras, addressing different scenarios of production in Brazil. Thus, many lessons learned came up for future initiatives (Rosendahl, 2013). After the pilots operation, lessons learned were gathered to guide the expansion of the digital oilfield concept for other Petrobras assets (Moisés, 2008).

### 3.5.3 Concept

To completely integrate production chain, data needs to flow bottom-up in the asset pyramid structure as shown in Figure 6. The pyramid base contains all monitoring variables and in its way up, after signal processing and simulator coupling, data becomes more valuable for decision makers. In different levels, information is used to interfere in the process by adjusting control variables to keep the indicators in a range around its set point or goal. The responsibility increases as the decisions are taken from higher levels and tends to affect more processes. Usually, data is restricted to knowledge islands and the interaction and communication among these islands is noisy and intermittent. To avoid flaws and misunderstanding between production actors, it is necessary to integrate data and people to increase operational efficiency and to create synergy bounds between them and aggregate value to information as it flows from the base to the top of production process pyramid (Moisés, 2008). According to Rosendahl, 2013, regarding people, it is expected to enhance the collaborative way of working that eliminates barriers and interferences across the employees. Whenever it is possible, GIOp will redesign and simplify processes, integrate disciplines, plan onshore and take like a priority the predictive maintenance. The main focus will be on solutions increasingly intelligent and innovative, with preference to existing technologies.

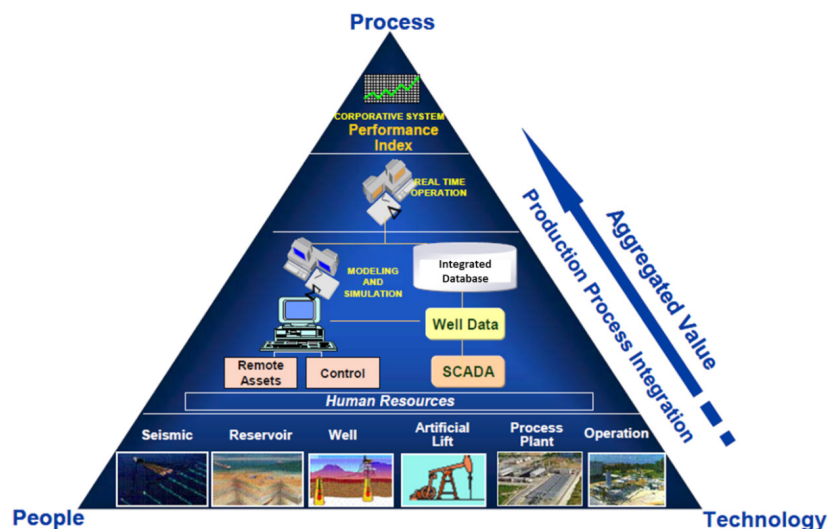


Figure 6. Petrobras aggregated value pyramid

Source: Adapted from Moisés (2008)



#### 4. REFERENCE FRAMEWORK

The oil production scenario is quite challenging. This is because of the complexity involved or due the economic importance for the humankind. Companies in this industry have looked for alternatives to the production processes optimization and have, in the recent past, implemented

Integrated Operations initiatives, each one in their own way. This is due to the diversity of situations and scenarios. Deployment pillars are people, process, technology and organization. In Table 1, below, it is presented a comparative analysis of five major oil operators Integrated Operations initiatives.

Table 1. Reference framework

People	Saudi Aramco	Two main types of collaboration were identified for the IFC environment. The first one involves people and the process to allow for professionals to gather and exchange ideas and discuss coming up with proper actions to solve potential problems. The second type of collaboration is provided by the people and technological interaction to exchange models, data, experiences, best practices and more. (Barghouty, 2010)
	Statoil	An operational decision arena will typically be both physical and virtual. Statoil has established advanced collaboration rooms/arenas for all operating units on the NCS offshore and onshore. However, not all experts onshore will be physically co-located requiring dispersed collaboration tools and flexible desktop solutions to be included in the collaboration set-up making it possible to efficiently include all relevant experts and expert groups into the same virtual decision arena and creating a common situational awareness. (Lilleng, 2010)
	Shell	By gathering more and better data from our EP assets, it is possible to offload many offshore/on-location operations tasks to a remote location where these functions can be handled more efficiently and safely. Remote assisted operations (RAO) achieves this objective by having an office-based operator working with the asset operations team to provide immediate situational awareness of field operations, and to reduce the amount of time required for making decisions. (Perrons, 2010)
	BP	Real-Time data and its benefits will be fully exploited only if we adapt the way we work and can make decision in real time. The aim of Advanced Collaborative Environments (ACE's) is to enable our decision makers to take important decisions in real time. (Reddick, 2008)
	Petrobras	Collaborative rooms encourage cooperation, integration of teams in real time, more intense flow of information and knowledge within the Asset, leading to a new organizational culture. This new culture stimulates more optimized and structured issues analysis, evaluation of scenarios and definition of action plans, supporting the decision making process. (Vinturini, 2008)
Process	Saudi Aramco	Workflow implementations offer great opportunities in automating or semi-automating mundane and complex processes and tasks. Workflows are defined end-to-end. (...) As the workflows proceed through the process of collecting, integrating the data, carrying the analysis, presenting analysis and recommending remedial actions, tacit knowledge can be captured along the way for future knowledge management applications. (Al-Dhubaib, 2011)
	Statoil	The key aspects represent success critical elements (activities or best practice) of the work processes with respect to value creation and business objective. (Lilleng, 2010) A number of organizational changes have been introduced as a part of the implementation of IO. New work processes has been described, tasks have been moved from offshore to onshore facilities and from local organizational units to units serving more than one installation, work tasks have been changed for some positions, and interfaces and communication lines between professional groups have been altered. (Ringstad, 2007)
	Shell	Individual activities do not add value unless effectively connected and integrated ('close the loop'). Each activity must be supported with the right skills and workflows. The performance of the total loop determines the quality of the decision-making and the efficiency and effectiveness of the asset management process. (Potters, 2005)
	BP	Optimization technology should be introduced gradually, starting simple and adding complexity as required with a value-driven approach. There are a limited number of optimization workflows that are common to many upstream operations. A toolkit designed to support these workflows can be rapidly reconfigured and re-deployed. (Stenhouse, 2008)
	Petrobras	To design new workflows more efficiently, it is necessary to have a complete understanding of the asset business processes. The AS IS process mapping combined with asset technology availability and critical analysis helps the TO BE workflow design that pursues cost reduction, recovery factor augmentation and operational efficiency improvement. The process mapping allows the benefits and impacts evaluation and guides the change management action plan. (Moisés, 2008)

Technology	Saudi Aramco	The tasks should be automated to the maximum possible extent. Data quality control and validation should also be automated to allow the engineers to focus more on analysis and decision-making. (...) It is necessary to provide systems that allow seamless integration of data to workflows, easy integration of applications to workflows, easy integration and interaction of the user with the workflow process, and integration of separate disciplines by related workflows. (Barghouty, 2010)
	Statoil	IO technology comprises both tools (e.g. software and equipment for audiovisual communication) and facilities (e.g. collaboration rooms). (Ringstad, 2007) Topsides and processing plants are increasingly instrumented and automated making total systems optimization a realistic opportunity for many green and brown field installations. (...)The increasing data volumes put stronger requirements on communication and data transmission networks both locally and regionally. (Lilleng, 2010)
	Shell	Smart Fields is not a standalone technology that has been developed by a single team; rather, it is based on the integration of dozens of tools, skills, and workflows to improve the performance of core Shell EP assets in a structural and sustainable way. (Perrons, 2010)
	BP	The following technology themes form the core of BP's FIELD OF THE FUTURE Programme: real-time reservoir management, production optimization, remote performance monitoring and collaboration, advanced collaborative environments and connecting global know-how and expertise. (Reddick, 2008)
	Petrobras	GeDIg is not only a technology project: For the GeDIg deployment to be a success the project team focused on improving the work-processes and decision-making. A common risk is that the concept can be used to promote particular pet technologies as opposed to the integration of technology pieces. By concentrating on workflows, the focus will be on Asset decision-making and how decisions can be improved. Shortly, the GeDIg is not a technology project, but a substantial element of technology needed to achieve operational transformation. (Vinturini, 2008)
Organization	Saudi Aramco	The systems to be integrated are diverse and span various technologies from measurement, data acquisition, control, communication, data management and applications to visualization systems and collaboration environments. In the vast scale of Saudi Aramco operations, these systems are being managed and supported by different organizations. Each organization has its own business set skills, business mandate, business processes and business priorities. (Al-Dhubaib, 2008)
	Statoil	Networking of people and defining who to involve in each part of the work processes and with which competencies, mandates and decision authorities is the next key success factor. Statoil has established harmonized work process for all key work processes along the value chain documented in Statoil's business process model (BPM). The Statoil BPM is based on standardized notations defining roles and responsibilities, and links requirements, best practices, information needs including modelling (geo-, reservoir-, pipe/flow-, process-) inputs etc. to the tasks defined for each work process participant. (Lilleng, 2010)
	Shell	Smart Fields design principles have been deployed in several assets around the world, and one major trend has become apparent throughout this global deployment process: for these technologies to deliver maximum value, the participating teams need to believe in the value of these design requirements. (Perrons, 2010)
	BP	Core to the engagement and support element is the need to understand the impact of the new capability on the business processes and workflows, and the change management consequences of this for the roles, accountabilities and behaviors of people in the organization. Often, the determinant of success is in matching the support offer to the particular business challenges and change support needs of a specific customer. (Dickens, 2010)
	Petrobras	The GIOp implementation objectives are, surely, focused on the improvement of operational and economic results of Petrobras E&P activities. Therefore, it must be highlighted it handles a new matricial management structure implementation for an organization based on a functional management philosophy. Thus, GIOp must implement a new management philosophy, where operational integration must connect to the existing matricial structure. (Siqueira, 2012)

Source: The authors own

Despite all the differences in the implementation approaches, Integrated Operations creates a considerable convergence in expectations of results and benefits across the oil companies, providing better decisions, process

optimization and innovation of work processes. The most important consequence is to enhance safety and improve the business value. Figure 7 below illustrates the value creation with Integrated Operations.

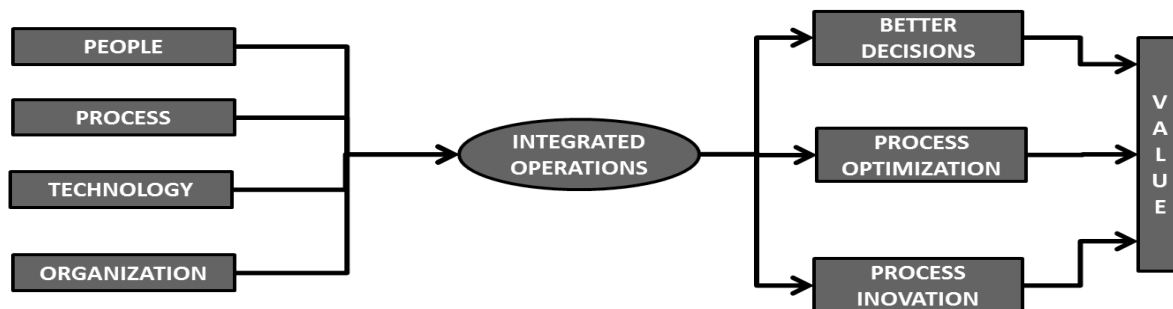


Figure 7. Integrated Operations and Value Criation

Source: The authors own

Following, some related applications of the Integrated Operations, which resulted in quantified benefits, are presented.

## 5. SUCCESS CASES OF INTEGRATED OPERATIONS

An important reference of value was given by Kapteijn (2002), who estimated that the potential value of Integrated Operations in the Shell Operation Units may represent an improvement by more than 10% in production from existing and new fields and that the recovery from greenfields may be increased by at least 5%. Bogaert (2004) described smart technologies successfully applied in Shell. Smart well completion technology and intelligent gas lift optimization have been integrated, incorporating remote data acquisition, real-time flow estimation and remote process control. The overall benefits equate to about 10% production gains and approximately 2% additional reserves.

Also according to Bogaert (2004), an average production gain of 6-7% from intelligent gas lift optimization on its own has been measured. Other benefits pointed by this author are 3% gains by the reduced backpressure with the multi-phase flowmeter, reduced lost time in wire-line operations and the ability to close off gassed-out and/or water flooded intervals.

Henderson (2005) adds that internal and external evaluation of the business impact of “smartness” have demonstrated that the following mix of benefits can be achieved in projects which fully implement Smart Fields technologies and systems: 5 - 10% recovery improvements, 10% production increases, 20% OPEX reduction, significant development planning cycle time reduction and reduced development risks and uncertainties.

Brulé (2008), in a case study review, addressed the issue of reducing the decision time, showing that data integration deficiencies can slow decision-making, with significant economic impact. In his work, he pointed out cases of data

integration and accessibility of water injection in the oil reservoir (Spraberry Driver Unit, West Texas), with benefits estimated at 6 million USD/month.

ExxonMobil implemented a production and optimization surveillance. An assessment with engineers and technicians was held. This case was reported by Crawford (2008), where the survey results indicated that on average 44% of the time was presently spent gathering and accessing data and generating plots and reports. The efficiency gains were sufficient to justify the surveillance initiative and it was not necessary to include production volumes or reserves increases (effectiveness gains).

Chevron reported considerable gains with the implementation of an Integrated Operations Centre in the steam generation facilities of San Joaquin Valley Business Unit. Oran (2008) pointed to benefits that include: 12% improvement in generator capacity utilization, capital avoidance for emission upgrades with fewer generators needed, 1% improvement in generator efficiencies and reliability improvements with predictive response to generator problems.

In 2009, Thorogood presented a paper that quantified value in a North Sea case. Proactive engagement of the service supplier during initial testing and well commissioning phases ensured that an optimum waste disposal solution was attained despite initial setbacks. An integrated services approach was initiated based on cooperation between the operator and service provider. The process continued through drilling operations, reducing the operator environmental liability and obtaining major drilling cost savings. The value-added by drilling waste injection operations in this field was estimated at US \$2 million.

Edwards (2010) added important references of success in the application of Integrated Operations, considering that the addition of the typical 0.5-2.0% production improvement gain as reported by CERA can deliver a huge business benefits. Moore-Cernoch (2010) pointed out

several practical results of collaborative environments and operating centers (British Petroleum). For example, in Gulf of Mexico, it was reported an increase of seven thousand boepd in avoided losses. The author also presented many losses avoided by minimizing shutdowns in North Sea and Gulf of Mexico. The article pointed a result of Lejon (2010), which reported an interesting case in a gas field of Statoil. By monitoring the well production with a dedicated group of experts, in an Integrated Operations center, it was possible to manage the sand production, without compromising safety, resulting in increased production of gas and condensate, in a sustainable manner, by about 20%.

Dickens (2010) reported important benefits of BP. In the subsurface and wells area, the impact of applying the well monitoring capabilities has been substantial and delivered a production impact of typically 1-2% of the original base production. Improvements in staff efficiency – up to 25% were observed. The work projected results of Integrated Operations like the delivery of significant production (100mboed BPnet) and reserve (1bnbbbl) targets by 2017.

Amin (2010) described another interesting case, by redesigning the production planning process and optimization (in an offshore Gulf field), from reactive to proactive, integrating different components of the production optimization process and increasing communication across the stakeholders. With the system, still in an early stage of deployment, it was possible to report an increase of around 3% in the operational efficiency.

Another interesting case was reported by Sankaran (2011) that presented results in Agbami (Chevron field in Nigeria). The Integrated Operations benefits in quantitative terms through a case study over a year of operation are described. Gains have been reported with the optimization of the wells in the order of fifty thousand bpd.

An interesting case was mentioned by Alhuthali (2012), who described the experience of Saudi Aramco with Integrated Operations in the Khurais Field. During a maintenance shutdown, it was possible to collect the necessary information for determining the static pressure of the reservoir, productivity rates and injectivity over one hundred wells, enough for the monitoring of the entire reservoir in twenty-one days against four hundred fifty-five days estimated without the use of Integrated Operations.

The above-related cases took place in several oil operators and in different parts of the world. They illustrate the full potential of Integrated Operations. Thus, the value generation and the benefits associated with such projects could be considered in a high level of importance.

## 6. CONCLUSION

The technology of the oil industry context has evolved vastly. In that way, the potential to redesign and optimize the work processes has become huge. Today, the information is available in a way never imagined before. Thus, decisions can be much better and proper, resulting in many benefits, adding safety and business value.

The companies in the sector, especially operators, aware of this, are looking for to translate this potential to practical value. With independent initiatives, in diverse scenarios and with a wide variety of challenges, these companies are deploying the Integrated Operations their own way. Recently, there has been a clear evolution in the systematization of these initiatives, with more structured review of work processes in the organizations.

Quantifying the gain of Integrated Operations is a huge challenge. However, new scientific literature indicates numerous benefits and a tremendous value for these initiatives. Companies are already getting a way to parameterize the benefits in numbers, which unquestionably points out to the importance of Integrated Operations in the oil production of the current complex scenario.

## 7. REFERENCES

- AbdulKarim, A., AL-Dhubaib, T., Elrafie, E. and Alamoudi, M. O. (2010), "Overview of Saudi Aramco's Intelligent Field Program", SPE129706, paper presented at the SPE Intelligent Energy Conference and Exhibition held in Utrecht, The Netherlands, 23–25 March 2010.
- Al-Dhubaib, T. A., Issaka, M. B., Barghouty, M. F., Mubarak, S., Dowais, A. H., Shenqiti, M. S. and Ansari, N. H. (2008), "Saudi Aramco Intelligent Field Development Approach: Building the Surveillance Layer", SPE 112106, paper presented at the 2008 SPE Intelligent Energy Conference and Exhibition held in Amsterdam, The Netherlands, 25–27 February 2008.
- Al-Dhubaib, T. A. (2011), "Intelligent Fields: Industry's Frontier & Opportunities", SPE 141874, paper presented at the SPE Middle East Oil and Gas Show and Conference held in Manama, Bahrain, 25–28 September 2011.
- Alhuthali, A. H., Al-Ajmi, F. A., Shamrani, S. S. and Abitrabi Ballan, A. N (2012)., "Maximizing the Value of the Intelligent Field: Experience and Prospective", SPE 150116, paper presented at the SPE Intelligent Energy International held in Utrecht, The Netherlands, 27–29 March 2012.
- Amin, A. A. K. *et al.* (2010), "Maximizing Value of a Giant Offshore Asset through Proper Production Planning, Optimization and Capacity Management", SPE 137978, paper presented at the Abu Dhabi International Petroleum



Exhibition & Conference held in Abu Dhabi, UAE, 1–4 November 2010.

Barghouty, M. F. Al Dhubaib, T. A., Jama, A. A. and Jaimes, O. (2010), “Intelligent Field Centers (IFCs): Integrating People, Processes and Technologies to Optimally Manage Giant Fields”, SPE 128469, paper presented at the SPE Intelligent Energy Conference and Exhibition held in Utrecht, The Netherlands, 23–25 March 2010.

Bogaert, P.M., Yang, W., Meijers, H.C., van Dongen, J.C.M and Konopczynski, M. (2004), “Improving Oil Production Using Smart Fields Technology in the SF30 Satellite Oil Development Offshore Malaysia”, OTC 16162, paper presented at the Offshore Technology Conference held in Houston, Texas, U.S.A., 3–6 May 2004.

Brulé, M. *et al.* (2008), “Bridging the Gap Between Real Time Optimization and Information Based Technologies”, SPE 116758, paper presented at the SPE Annual Technical Conference and Exhibition, Denver, Colorado, USA, 2008.

Cramer, R. *et al.* (2012), “A Measure of the Digital Oil Field Status - Is It The End of The Beginning?” SPE 149957, paper presented at the SPE Intelligent Energy International held in Utrecht, The Netherlands, 27–29 March 2012.

Crawford, M. L., Hoefner, M. L. and Oakes, J. E. (2008), “A Standard Solution for Upstream Oil and Gas Surveillance”, SPE 112152, paper presented at the Intelligent Energy Conference and Exhibition. Amsterdam, The Netherlands: Society of Petroleum Engineers 2008.

de Best, L. and van den Berg, F. (2012), “Smart Fields - Sustaining and Accelerating Benefits from Intelligent Fields”, SPE 150407, paper presented at the SPE Intelligent Energy International held in Utrecht, The Netherlands, 27–29 March 2012.

Dickens, J., Latin, D., Verra, G., Blosser, W., Edmonds, G. and Grimshaw, G. (2010), “The BP FIELD OF THE FUTURE Programme: The Continuing Mission To Deliver Value”, SPE 128672, paper presented at the SPE Intelligent Energy Conference and Exhibition held in Utrecht, The Netherlands, 23–25 March 2010.

Edwards, T.; Mydland, Ø.; Henriquez, A. (2010), “The Art of Intelligent Energy(IE) - Insights and Lessons Learned from the application of IE”, SPE 128669, paper presented at the SPE Intelligent Energy Conference and Exhibition. Utrecht, The Netherlands: Society of Petroleum Engineers 2010.

Halland, T., Jensen, L. K., Eike, M. and Solnørdaal, D. (2013), “Implementing Intelligent Energy - Change Management Experiences and Recommendations”, SPE 167451, paper presented at the at the SPE Middle East Intelligent Energy Conference and Exhibition held in Dubai, UAE, 28–30 October 2013.

Henderson, G. (2005), “The Impact of Digital Technologies on the Global Shell EP Business”, OTC 17727, paper presented at the Offshore Technology Conference Houston, Texas 2005.

Henriquez, A., Fjærtøft, I., Johnsen, C., Yttredal, O. and Gabrielsen, T. (2008), “Enablers for the Successful Implementation of Intelligent Energy: The Statoil Case”, SPE 111470, paper presented at the 2008 SPE Intelligent Energy Conference and Exhibition held in Amsterdam, The Netherlands, 25–27 February 2008.

Kapteijn, P. K. A., “Smart Fields: How to Generate More Value from Hydrocarbon Resources”, WPC 32149, paper presented at the 17th World Petroleum Congress, Rio de Janeiro, Brazil: World Petroleum Congress, 2002.

Kolbikov, S., Kolbikova E. and Sholudko, A. (2002), “Risk Evaluation of Investment Decision During Low Oil Prices”, SPE-171158-MS, paper presented at the SPE Russian Oil and Gas Exploration and Production Technical Conference and Exhibition held in Moscow, Russia, 14–16 October 2014.

Larsen, S., Bjørkevoll, K. S., Gibson, A. K., Gunnerud, V., Lien, D. O., Thorvik, K., Nystad, A. N. (2012), “A Stack Model and Capabilities Approach to Investigate Integrated Operations Across Different Industrial Sectors - O&G Industry versus Aviation, Military and Medicine”, SPE 150431, paper presented at the SPE Intelligent Energy International held in Utrecht, The Netherlands, 27–29 March 2012.

Lejon, K.; Hersvik, K. J.; Bøe, A. (2010), “Multi-asset production support centre-generating values”, SPE 127730, paper presented at the SPE Intelligent Energy Conference and Exhibition held in Utrecht, The Netherlands, 23–25 March 2010.

Lilleng, T. and Sagatun, S. I. (2010), “Integrated Operations Methodology and Value Proposition”, SPE 128576, paper presented at the SPE Intelligent Energy Conference and Exhibition held in Utrecht, The Netherlands, 23–25 March 2010.

Lilleng, T., Øyen, M., Farestvedt, U., Engelsen, H., Nordbø, H., Vennes, B., Revheim, A., Seim, O. and Halvorsen, T. (2012), “Integrated Operations in Statoil – from Ambition to Action”, SPE 150418, paper presented at the SPE Intelligent Energy International held in Utrecht, The Netherlands, 27–29 March 2012.

Moisés, G.V., Rolim, T. A. and Formigli, J.M. (2008), “GeDIg: Petrobras Corporate Program for Digital Integrated Field Management”, SPE 112153, paper presented at the 2008 SPE Intelligent Energy Conference and Exhibition held in Amsterdam, The Netherlands, 25–27 February 2008.

Moore-Cernoch, K. (2010), “Advanced Collaborative Environments Stay the Course, Transform the Business”, SPE 138595, paper presented at the Abu Dhabi International



Petroleum Exhibition & Conference held in Abu Dhabi, UAE, 1–4 November 2010.

Nasser, N. A. and Awaji M. A. (2011), “Intelligent Field Data management: Case Study”, SPE 149040, paper presented at the SPE/DGS Saudi Arabia Section Technical Symposium and Exhibition held in Al-Khobar, Saudi Arabia, 15–18 May 2011.

Oran, K.; Brink, J.; Ouimette, J. (2008), “Implementation Results for Chevron’s i-field in San Joaquin Valley”, California, SPE 112260, paper presented at the Intelligent Energy Conference and Exhibition. Amsterdam, The Netherlands 2008.

Otto, G., Foreman, R. and Verra, G. (2008), “FIELD OF THE FUTURE Digital Infrastructure and IT Architecture”, SPE 112149, paper presented at the 2008 SPE Intelligent Energy Conference and Exhibition held in Amsterdam, The Netherlands, 25–27 February 2008.

Perrons, R. K. (2010), “Perdido: The First Smart Field in the Western Hemisphere”, SPE 127858, paper presented at the SPE Intelligent Energy Conference and Exhibition held in Utrecht, The Netherlands, 23–25 March 2010.

Potters H. and Kapteijn, P. (2005), “Reservoir Surveillance and Smart Fields”, IPTC 11039, paper presented at the International Petroleum Technology Conference held in Doha, Qatar, 21–23, November, 2005.

Reddick, C., Castro, A., Pannett, I., Perry, J., Dickens, J., Sisk, C., Verra, G. and Shirzadi, S. (2008), “BP’s FIELD OF THE FUTURE Program: Delivering Success”, SPE 112194, paper presented at the 2008 SPE Intelligent Energy Conference and Exhibition held in Amsterdam, The Netherlands, 25–27 February 2008.

Ringstad, A. J. and Andersen, K. (2007), “Integrated Operations and the Need for a Balanced Development of People, Technology and Organisation”, IPTC 11668, paper presented at the International Petroleum Technology Conference held in Dubai, U.A.E., 4–6 December 2007.

Rosendahl, T. and Hepsø, V. (2013), “Integrated Operations in the Oil and Gas Industry: Sustainability and Capability Development”, 1ª Edição. Hershey, EUA: Business Science Reference (an imprint of IGI Global).

Russo, E. E. R., Amoroso, J. C. and Rolim, T. A. (2010), “Benefits Quantification and Change Management in Petrobras Corporate Program for Digital Integrated Field Management (GeDig)”, SPE 128675, paper presented at the 2010 SPE Intelligent Energy Conference and Exhibition held in Jaarbeurs, Utrecht, The Netherlands, 23-25 March 2010.

Sankaran, S. *et al.* (2011), “Realizing Value From Implementing i-field™ in Agbami - A Deepwater Greenfield in an Offshore Nigeria Development”, SPE Economics & Management, v. 3, n. 1, p. 31-44, January 2011.

Siqueira, C. A. M., da Cunha, V. N., Meneghelli, R. B., Barreto, F. A. P., Sesma E. J. and Simões R. C. S. (2012), “Challenges in Managing People to Implement an Integrated Operations Systems: A Petrobras Case Study in An Operational Unit of Exploration and Production”, SPE 150233, paper presented at the SPE Intelligent Energy International held in Utrecht, The Netherlands, 27–29 March 2012.

Stenhouse, B. (2008), “Modelling and Optimisation in BP Exploration and Production; Case Studies and Learnings”, SPE 112148 paper presented at the 2008 SPE Intelligent Energy Conference and Exhibition held in Amsterdam, The Netherlands, 25–27 February 2008.

Thomson, A. (2008), “Deploying FIELD OF THE FUTURE on Major Projects”, SPE 112117, paper presented at the 2008 SPE Intelligent Energy Conference and Exhibition held in Amsterdam, The Netherlands, 25–27 February 2008.

Thorogood, M. *et al.* (2009), “The Right People, Process and Technology: A Formula to Value-Added”, OMC 2009-084, paper presented at the Offshore Mediterranean Conference and Exhibition, Ravenna, Italy 2009.

Udofia, E. E., Oni, O., Oghedegbe, O. and Chaker, A. S. (2014), “Smart Fields Management in Deepwater Field: Experience and Perspectives”, OTC 24078, Journal of Petroleum Technology, September, 2014 (pp. 97-99)

Vinturini, W.L., de Castro, G.B. Crespo, J.H.S., Albernaz, J.R., Lopes, M.A.S. and Valadares, A. (2008), “The Fazenda Alegre Journey into Intelligent Energy—Lessons Learned From a Successful Holistic Approach of People, Process, and Technology Aligned to Business Strategy and Results”, SPE 112160, paper presented at the SPE Intelligent Energy Conference and Exhibition held in Amsterdam, The Netherlands, 25–27 February 2008.