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Remote Real Time Operations Centers for Geologically Optimized Productivity

Properly designing a well's drilling plan can be one of the most demanding engineering challenges. World-class wells should simultaneously meet cost, life-cycle productivity, safety, environmental and time constraints. Because of the complexity and ambiguity of such operations, real-time decision making can play an important role in the construction and maintenance of any hydrocarbon producing well.

This paper discusses the current state of the art for the use of Real Time Operations (RTO) within the industry. An overview is given of the use of real-time updating of geological information and models to optimize well bore placement, production and ultimate recovery. The use of RTO and the development of RTO Centers for Drilling and Completions and Production Optimization are discussed in the context of geologically optimized productivity.

Introduction

Well construction and maintenance expenditures represent at least 50% of any field exploitation capital and operating expenses (Saputelli, 1999). In addition, planned expenditures and execution times often deviate from actual ones because of (a) poor characterization of reservoir rock and fluids, and (b) poor anticipation and management of abnormal operational situations. Because of such inherent uncertainties on reservoir geology and operations, live decision-making (while drilling, workover or production) has traditionally played a crucial role in the construction and maintenance of any well. Improvising at the rig site has been the mainstay of the past; the results have not always been optimal.

Lately, there has been an increased use of sensors at the well site. However, current methods for data interpretation and decision making cannot easily cope with the rapidly increasing amounts of real-time data collected while drilling or production (Saputelli *et al*, 2003). Such decision-making process usually consumes daily rig-time or defers production and may use the experience and knowledge available from a limited team.

Additionally, there is a limited supply of the experienced drilling and production personnel who are key assets for the success of any operation. Traditional operating modes where these living assets are deployed to the well site can limit the impact that they can make on other well locations, as well as increase the number of these premium assets required. Continuing the traditional well-site-deployment practice exacerbates the problem of our industry's trend of an aging, decreasing work force.

The understanding of the above indicates that there are many opportunities for improving the decision-making process in the oilfield in the context of Real-time Asset Management.

Real Time Operations Centers (RTOCs) are a new technique being used to deal with these problems. They represent the congregation of knowledge and technology required to support operations from drilling operations such as geosteering through to production and completion operations such as well stimulation. RTOCs are being used to increase the collaborative input to drilling, completion and intervention decision making. Done correctly, collaboration from an RTOC improves the decisions put in action at the well site.

Many operators have assembled drilling and production teams to manage critical operations from RTOCs. Using remote monitoring and remote control technology these teams work from centralized facilities. From here they have visibility of and contact with multiple remote drilling and production operations. Processes and work systems are designed to enable collaborative input while also managing the people issues, which can potentially defeat such an initiative, especially if "Big Brother" issues are ignored (Kaminski *et al.*, 2002; Womer *et al.*, 2003; Ursem *et al.*, 2003; Herbert *et al.*, 2003). New technologies allow integrated reservoir study teams to assess vast amounts of information, including drilling performance, in order to decide "at the last minute" about the well path and completion architecture. Experience shows that an enhanced and defined decision-making process reduces non productive rig-time. Further benefits are provided by a streamlined combination of reservoir characterization, drilling and production operations, which we summarize in this paper.

Background

The Oilfield Information Management Challenge

Reservoir management is the recurring process in which an oil-field operator uses data and expertise to optimize the reservoir profitability or some other stated objective about the oilfield's performance. A common list of objectives of reservoir management may include mitigation of risk and uncertainty, increasing oil and gas production, increasing oil and gas reserves, maximizing recovery and profitability, and minimizing capital expenditures and operating costs.

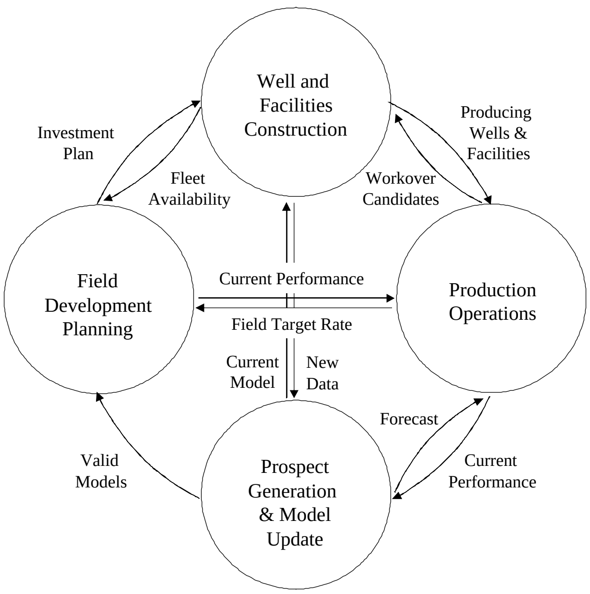

Figure 1 – Four Workflows Addressing Oilfield Management

In managing reservoirs, operators are concerned about the surrounding environment (oil price, market access, and available capital), the limitations of the current infrastructure and physical properties of the subsurface-surface system, the confidence in the reservoir model upon which decisions are to be based and the intrinsic risks of the operations.

However, the acquisition of knowledge about an oilfield can be a lengthy, painstaking and often unstructured activity, which can not be easily undertaken on a continuous basis. In addition, because of the complexity and magnitude of the all-encompassing optimization problem, decisions are made in a fragmented way for various pieces of an oilfield.

In managing oilfields, it is paramount to understand the decision making process and time scales involved. Figure 1 shows four operating company macro-processes, in which available technologies for the digital oilfield can make major contributions. One needs to understand the challenges of such interaction and how major decisions are made.

- During *Prospect Generation and Model Update*, the life cycle may take from 2 to 30 years and the decision loop frequency may be from months to years. Workflow may encompass dynamic data acquisition, capture and management for seismic processing, structural framework and property modeling, geological model validation, visual interpretation, dynamic flow simulation and history matching. Here decisions are made on: acquiring seismic and leases, drilling exploration wells, making reserves commercial, reducing subsurface model uncertainty and production forecasting.

- During *Field Development Planning*, the life cycle may take from 1 to 30 years, and the decision loop frequency may be from days, months or to years. Workflow may encompass data management, scenario modeling, field target planning, facilities modeling, risk and economics analyses, and creating, optimizing and updating exploitation plan portfolios. Decisions are made on well locations and numbers, field target rates, infill drilling opportunities, well intervention plans, and optimization of the portfolio and resources.

- During *Wells and Facilities Construction*, the life cycle may take from 1 month up to 1 year; however the decision loop frequency may take from minutes, days, weeks or to months. Workflow includes dynamic and static data management for well target planning, project costing, engineering, well-site operations, operations monitoring, on-time reporting, project plan adjustments and hazard exposure minimization. Decisions are made on activities for constructing wells and facilities while optimizing project execution time and cost, reducing overruns and non-productive-time, and increasing project effectiveness.

- During *Production Operations*, the life cycle may take from 1 to 30 years and decision loop frequency may be from seconds, days or to months. Workflow may encompass dynamic data capture and management for field surveillance, daily economics, facilities operations and maintenance, well intervention design, remote control and actuation, and abnormal situation management. Decisions are made on delivering integral value from separators, pipelines, compressors, reservoir and wells by continuously maintaining an optimum field operating point, by implementing well productivity enhancement practices, by minimizing maintenance scheduling impact and plant failures, and by maximizing plant capacity availability. Production operations is a key step in collecting and distributing field data to other workflows, and responsible for closing the gap between forecast and actual performance.

Disciplines for Real Time Asset Management

Within the oil industry, three primary disciplines stand out as those that most readily address the concept of the *Digital Oilfield*. These are: (1) Real-time drilling and completions, (2) Real-time production optimization and (3) Integrated asset performance management. Together, these elements comprise the overall disciplines of Real Time Asset Management.

Real Time Drilling and Completions (RTDC) – When considering the scope of Real Time Drilling and Completions, the main focus is on new or mature asset development and all of the activities that surround the drilling and completion of new or existing wells. This discipline best serves the asset manager who has both funding and a clearly developed plan to drill and complete wells. *RTD&C* covers both the workflows of *Well Construction* and *Model Update* of Figure 1.

Real Time Production Optimization (RTPO) – This discipline best addresses the asset manager who already has his infrastructure built — complete with existing wells, production facilities, and the required connectivity between the two. This discipline primarily focuses on optimizing existing production within that infrastructure. *RTPO* covers both the workflows of Production Operations and Prospect Generation and Model Update in Figure 1.

Integrated Asset Performance Management (IAPM) **-** The third discipline's scope encompasses all the activities that managers have to deal with in order to digitally integrate information, plans, activities, and performance measurements. These are common activities, from the early planning phases of an asset through to its maturity. *IAPM* could encompass all the four workflows of Figure 1.

Real Time Drilling and Completions

Real time operations centers for use during drilling and completions operations are burgeoning throughout the industry (Figure 2). Although original pioneers tended to be in high cost, difficult environment sectors, the current trend is towards wide adaptation. Each implementation is different as the drivers for success, or pain points that require alleviation vary from operator to operator and from asset to asset within companies (Womer *et al.*, 2003).

A typical implementation comprises many components. At the rigsite the various surface and downhole sensors feed data to a central data collection and management system (Kaminski *et al.*, 2002; Ursem *et al.*, 2003; Herbert *et al.*, 2003). Microwave, satellite or even fiber optics are used to transmit the data from the remote site to the office environment. Often multiple office sites are provided with feeds of the data once the data has landed into the central network. The internet can be used to provide data access to users who are outside the office/network environment.

In the office, a central monitoring room is established that is staffed 24/7 (Figure 2 a, c). Besides the basic function of maintaining data integrity, the staff in this room is typically expert in the primary driver for the RTOC success. RTOC's focusing on mitigating drilling hazards and preventing NPT (non productive time) will be experts on pore pressure prediction, drilling hydraulics and hole cleaning, bottom hole assembly performance and vibration, torque, drag and stick-slip analysis and prevention. RTOC's with a geosteering focus will be staffed with experts in directional drilling, formation evaluation, geology and LWD sensor analysis and modeling (Figure 4). Key asset team decision makers may not physically work in the monitoring room, but must be available 24/7 and have full connectivity and access to the data in order to provide input and decision making at critical junctures.

The real-time monitoring staff is often supported by a team of planning/modeling experts (Figure 2 b, d). Drilling and completion plans are run through mathematical models to support the expected operation. The model responses are compared with actual measurements in real-time and act as a road map for the operations team. If the actual and model agree – all is well. If the actual and model disagree – there is a need for analysis and response.

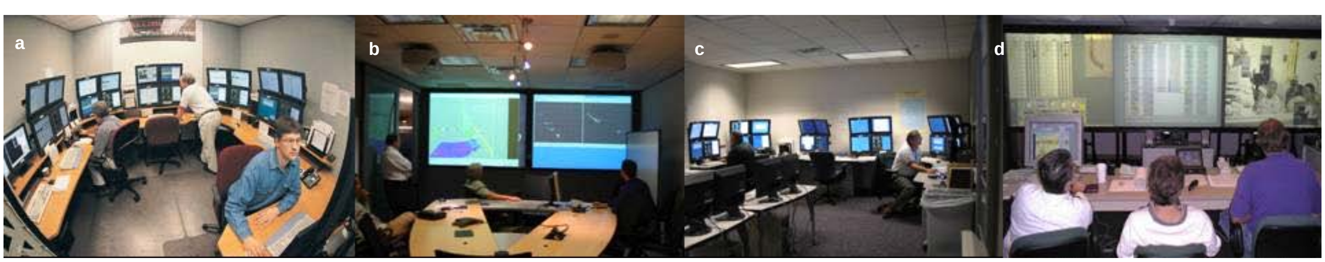

Figure 2 - Real Time Operations Centers – Examples of 24/7 monitoring rooms (a,c) and real-time breakout/"war" rooms (b,d).

Updating Sub-Surface Models and Drilling Plan with Real-time Information to Optimize Ultimate Recovery

Several cases have been documented in the industry describing technologies, applied methods and value delivered through optimization of borehole positioning with directional drilling using real-time data updating the sub-surface model while drilling (Branch et al., 2001; Balke and Rosauer, 2002; Gipson et al., 2002; Nicholson et al., 2002). In these cases the application of such optimization methods result in wells positioned optimally with respect of pay-zone boundaries, (maximizing pay - cut), while satisfying mechanical and operational drilling constrains.

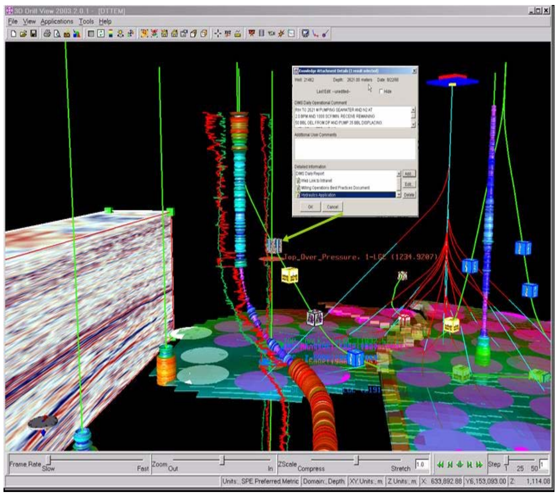

Figure 3 - Multiple Knowledge Integration (Landmark, 2003)

Real Time Reservoir Evaluation (RTRE) integrates fit-for-purpose surface and downhole equipment with dynamic data management, analysis techniques, wellbore and reservoir modeling and simulators which allow near wellbore reservoir characterization while drilling [Hyden and Shayegi, 2004].

A dynamic data management platform [Landmark, 2003] provides the software tool required having a continuous stream of real-time drilling data from both surface and downhole tools and sensors integrate with the subsurface model and data (Figure 3). The formation properties interpretation provided by RTRE constitutes essentially a continuous "testing-while-drilling" capability that is novel in the industry. It may revolutionize the well delivery process by enabling both well testing and reservoir evaluation to be carried out during the drilling phase, as opposed to after reaching total depth or after completion.

One key example is under-balanced drilling (UB), in which RTO has resulted in speeding initiation of production while boosting production rates, prolonging production and maximizing ultimate recovery as compared with traditional methods (Figure 4). In these cases, the pressure in the wellbore—the primary pressure-control mechanism in a conventionally drilled well— is maintained at less than the pore pressures of formations being penetrated. To achieve this, the drilling process, the drilling fluid properties and the wellhead pressure are controlled in such a manner as to maintain a targeted bottom-hole pressure. Downhole pressure is continuously measured while drilling with PWD (pressure while drilling) tools and monitored in real-time at the surface. Techniques for operations such as connections are optimized resulting in a continuous production stream maintained while drilling across the pay zone(s) which minimizes damage to the reservoir.

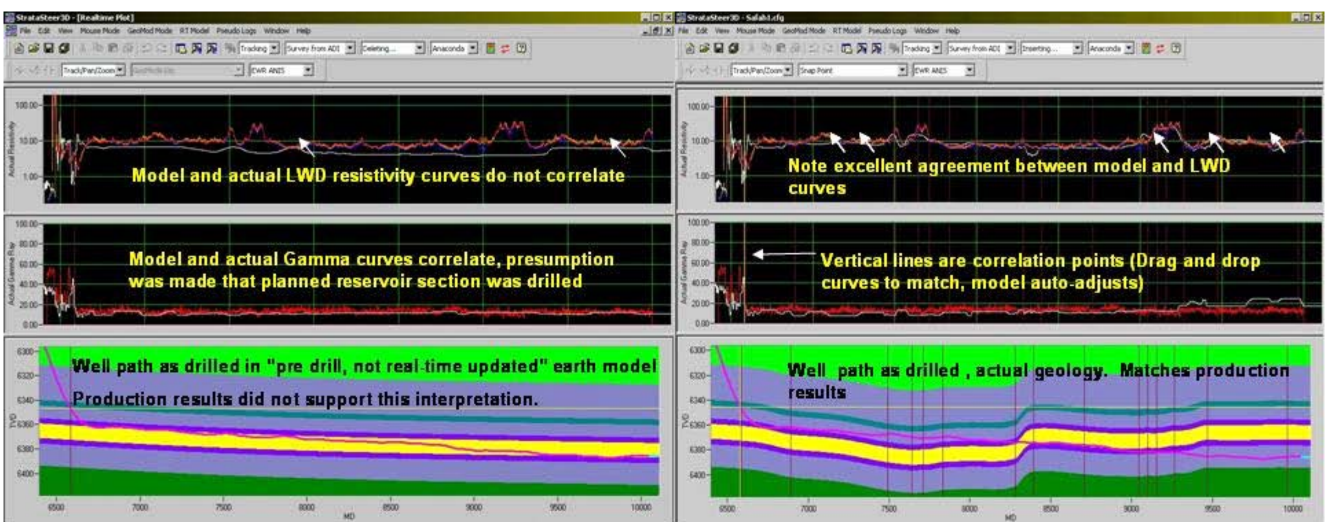

Figure 4 - Real Time Geosteering software integrates the field geological model, planned well path, and LWD sensor tool response models. The left side is what the perceived penetration of the reservoir (yellow formation) was when the well was drilled. The right side shows the actual penetration when "minimal production" forced analysis and review of the well path. Geosteering software is routinely used in RTOC's; close collaboration between the drilling and subsurface teams is required. Data can be analyzed and interpreted in real-time at the well site, or transmitted from the well site in real-time through a Remote Area Network with satellite link to be replicated in one or more RTOC's. From there the data can be used by support engineers and geologists who can visualize the data in various contexts, apply lessons learned from other areas, perform various engineering analyses and recommend new operating parameters to those in charge of the drilling, all while the operation is ongoing.

Real Time Production Optimization

Real-time production optimization (RTPO) is a process of measure-calculate-control cycle at a frequency, which maintains the system's optimal operating conditions within the time-constant constraints of the system (Saputelli *et al.*, 2003).

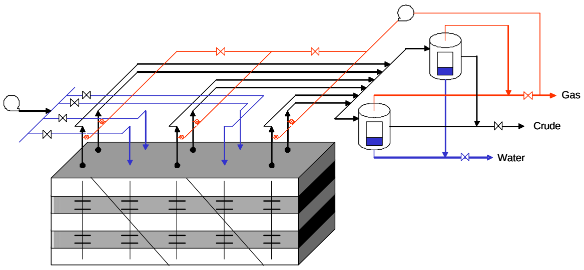

Figure 5 – Schematic of An Integrated Hydrocarbon Production System (from the reservoir to the separator output)

The exploitation and production of hydrocarbons involves a complex interaction of many variables from reservoir and wells to product conditioning and transport (Figure 5). In this system, we can only realistically discuss optimization within the concept of a mathematical model that describes and models all or part of the entire process. We need to think of this as maximizing profit where we carefully define profit for the specific problem; for example profit could refer to the economic value of the entire life of field, or net income derivable over the next three months. Clearly, these two profit motives may be incompatible and may not be achieved simultaneously, but these are real life challenges that face us on a daily basis.

There are many exciting opportunities for Real-time production optimization during oilfield exploitation, including (a) financial and technical resource allocation; (b) secondary and enhanced oil recovery schema, (c) portfolio optimization and resource base planning, (d) total fluid handling capacity and target plateau, (e) hydrocarbon sales, transportation & fluid disposal, (f) infill well location, scheduling, spacing and number, (g) well completion, lift strategy and operation, (h) well stimulation and intervention design, (i) surface facilities capacity and bottlenecking, (j) pipeline scheduling availability and (k) plant and equipment overhaul schedules.

Each of those optimization opportunities represents a challenge of different type and complexity level. The value of RTPO has been extensively reported (Saputelli et al., 2003; Mochizuki *et al.*, 2004).

As reservoir complexity increases with time, and operations move into higher risk and more costly environments, it is imperative that oil and gas producers look for ways to optimize productivity and increase profitability from both new and existing fields. However, reservoir complexity and matureness is usually related to vast amounts of poor quality data and disconnected processes, disciplines and applications. Industry overcomes these problems by adopting a common application environment and integrated data management system solely dedicated to improving decision support for drilling and production operations and engineering (Landmark, 2004). The foundation has one common set of entity definitions, to span the life of a well from its initial design inception throughout its entire producing period. This has been defined for sites, wells, wellbores, physical completions, accounting completions and producing horizons. Through the shared data model, all the engineering applications share universal well identifiers and apply them as appropriate to their diverse functionalities. The result is a streamlined process that integrates multiple vendor applications across several disciplines and organizations.

Another key component in RTPO is the use of collaborative web portals, which ease the interaction of teams which are not co-located, and facilitate the decisions made by field operations teams; this applies for example to development and communication of fit for purpose operational procedures and documents for all parties in the project. The decisions are usually associated with actions that need to be taken in response to an equipment failure or aspect of equipment under performance. The emphasis is therefore on the provision of "real time" information that promotes the right decisions and value-based actions of corresponding functional support teams. Each functional group that supports an operating asset, well-site or plant is represented in the portal and visible to the whole organization in the business model. Presented in this fashion, it demonstrates to an organization that several functional groups are required to support the operation and each has defined roles to play in its performance.

RTPO is successful when applied in the context of the interconnected workflows addressing the oilfield management (Figure 1); this is, maintaining system optimal condition subject to the reservoir and surface facility model and physical constraints, and repeating it continuously, within the time-constraints of the system, i.e. in real-time. Field production operations are usually supported with a plan, which is based on the available reservoir geological realization, surface network models and selection of an optimum exploitation scenario. As new production data becomes available and translated into valuable information, reservoir and pipelines models are tuned constantly to match calculated with measured data. The new tuned model leads to the establishment of a new baseline which allows further iterations to calculate a new optimum exploitation plan or "what-if" scenarios.

People and Process Aspects of Real Time Operations

In adopting any new technology, there are three major factors: people, processes, and technology (Mochizuki *et al*., 2004;

Ursem *et al*., 2003, Womer *et al*., 2003,). A new RTOC system can contribute to achieving benefits we seek, but it is not possible without corresponding changes in the way we train ourselves and learn to work with others. Real Time Operations will involve changes in the processes and workflows in which we perform tasks. This is common to the implementation of any new technology. We tend to emphasize the technology aspect, but the people and process aspects are equally important. A lack of training and workflow modification is guaranteed to result in unsustainable efforts and ultimately wasting the investment.

Summary

We have briefly described in this paper that oilfield management is about orchestrating four different but interrelated workflows: (1) prospect generation and model update, (2) field development planning, (3) well and facilities construction, and (4) production operations. Present challenges of such interactions have severe implications in delivering world class wells that meet simultaneously optimum cost, life-cycle productivity, safety, environmental and time constraints.

Real Time Operations Centers (RTOC) for use during drilling and completions operations support better decision making and better planning. RTOC contributes to reducing occurrences of major drilling dysfunctions and improving the overall well efficiency by permitting geologically optimized productivity. Real-time reservoir evaluation revolutionizes the well delivery process by enabling both well testing and reservoir evaluation to be carried out during the drilling phase, as opposed to after reaching total depth or after completion.

Real Time Production Optimization (RTPO) focuses on maintaining system optimal conditions subject to the reservoir and surface facility model and physical constraints, and repeating it continuously, within the time-constraints of the system, i.e. in real-time. Continuous data acquisition allows geological model update, and new models may imply revised exploitation plans. Collaborative web portals, integrated engineering and subsurface data models are key components to maintain live the RTPO workflow.

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