Low-Cost Mobile OSC—An Effective Alternative to Dedicated Drilling Centers

Roger B. Goobie, Robert Clyde, James Brannigan, Goke Akinniranye, Piero Dambrosio, Hesham Elsweisy, Schlumberger Technology Corp; Steve Robinson and Nicholas Lirette, BP America

Abstract

With the global demand for energy at an all time high, drilling operators are paying market premiums as they explore new frontiers in their quest for oil and gas in the deep and ultra-deep horizons. At the same time, drilling in mature reservoirs is growing increasingly complex due to advances in the amount and quality of information available to optimize the reservoir. In these difficult and sometimes harsh environments there is little or no room for error, and the cost of nonproductive time (NPT) related to a poor or less-informed decision can significantly increase the final cost per barrel to the consumer.

In the present drilling environment with the shortage of skilled personnel, most major oil and gas companies are exploring the option of remote dedicated drilling centers to support their real-time exploration and production business processes. A combination of infrastructure, technology, services, and processes are being used to consolidate their expertise in a collaborative environment so that an informed, real-time decision can be made to improve the drilling process and reduce cost.

The economic justification to management and partners for investing and building such drilling centers is clear. However, it is important to be able to scale the effort required and capital expenditure for drilling centers to the specific types of operations. This paper describes the concept and use of a low-cost, remote, mobile operation support center (OSC) that has been used successfully in the Gulf of Mexico (GoM).

For an OSC to be successful, real-time data needs to be quickly turned into information that can be displayed with minimum latency in the right context and in a format that can benefit decision makers. This depends on the skill, experience of the individual engineers, and the software answer products utilized in this surveillance environment. This paper also describes the use of an advanced, real-time software answer product that takes the raw drilling data and filters it into different rig states so that a logical output can be generated automatically.

Introduction

In recent years, the concept of remote drilling centers has been independently developed and implemented by most major oil and gas exploration and production companies, largely in response to a global shortage of expert personnel, and the expense of state-of-the-art analytical tools and infrastructure required by today's complex drilling challenges.

By concentrating these resources in a central location, connected to the field through high-speed data transmission, customers are given access to the very best engineering talent and technologies no matter how remote their location.

The creation of dedicated, real-time monitoring facilities is not always economically feasible. Some operators could benefit from applying these techniques in certain areas where the gains would not justify the cost of such a dedicated full-time facility. To meet this need, the concept of a portable OSC was explored, and recent advances in analytical and communications technologies have now made its implementation possible.

The mobile support center concept includes more than personnel and equipment. It also incorporates a detailed methodology for achieving effective results. These include thorough prejob planning, analysis, and discussion involving not only engineering staff but can also incorporate drilling equipment manufacturers, service suppliers, and other drilling-related personnel. Clearly defined lines of communication are established, responsibilities are defined, and mitigating actions are determined beforehand to ensure prompt and on-target responses when problems do occur.

Background

In the year 2000, a leading oilfield service contractor, with the mission to reduce operational real-time failure, created and staffed a real-time support facility in their Louisiana base. One of the prime tasks that evolved from the internal support center was to help the directional-drilling (DD) and measurement-while-drilling (MWD) rig crew quickly diagnose high-shock and vibration situations so as to effectively mitigate their impact on operations. Service quality was subsequently increased, NPT was reduced, and the value of the internal support center was acknowledged by operators.

The success in dealing with shocks led to the realization of the opportunity to combat other drilling-related problems. This led to the subsequent rollout of an operator office-based mobile OSC.

The GoM drilling environment is diverse, with operations ranging from small drilling barges to deepwater drilling platforms. A single operator often will have responsibilities for operations at both ends of this spectrum. In the more

challenging environment, the implementation of dedicated facilities for real-time monitoring of drilling operations is not new, and the success of this approach is proven and well documented. Nonetheless, many operators believe that their existing approach to more conventional drilling does not require dedicated, real-time monitoring facilities.

The challenge faced was how to address the need for occasional, real-time drilling-optimization support for special projects when the operator felt that building a dedicated, full-scale drilling center could not be justified. The challenge was established to scale down the dedicated-drilling-center concept so it could be quickly mobilized and demobilized to provide the drilling team the vigilance needed to drill a single complex well or section.

The system was designed to deliver

- The correct technical expertise.
- The ability to convert real-time drilling data into information and ensure swift, correct decisions.
- Real-time collaboration and synergy between the operators, rig crew, office staff and relevant contractors.
- Simple mobilization and demobilization by using the right equipment.

The concept was first successfully tested in mid-2005 on a real-time, remote pore pressure project (ref: Case Study #1), with a subsequent unit established later in 2005 for a major deepwater operator in the GoM (ref: Case Study #2).

Connectivity and Transmission

Whether its purpose is for monitoring, data management, decision support, or full remote control; quality connectivity is a necessity for any remote operation. Over the last decade, lower cost, light-weight satellite communication systems have offered sufficient reliability for use throughout most of the world for remote operation's support.

Communications interruptions still do occur regularly, mainly related to poor location setup, system malfunction, and weather. However, with current data communication buffers, short-term outages have much less of an effect on the quality of real-time data transmission.

Another key enabler has been the standardization of data transmission protocols. The Wellsite Information Transfer Standard Markup Language (WITSML) is a recently adopted standard for exchange of drilling data. WITSML was used in all the cases presented, both for transmission of the data and for feeding analysis applications.

Hardware

A typical mobile OSC is depicted in **Fig. 1.** To maximize the benefits, it was necessary to develop an adaptable and scalable hardware setup.

Use of a powerful computer attached to a mobile workdesk with integral monitors enabled the portable workstation to be wheeled during operations between the normal working area and meeting rooms. The integral video switch allows any of

the displays to be redirected to existing computer projectors.

With the addition of an uninterruptible power supply, and wireless network connection, the system is fully mobile without the need to shut down and reboot between short moves.

A key feature of the hardware setup designed for this application is that the mobile OSC can be established within a few hours in an operator's drilling department meeting room. Likewise, at the end of a well, it may be quickly demobilized and redeployed. The hardware was designed with scalability in mind to allow the addition of more mobile support centers in the event that more drilling rigs are required to be monitored in the future.

Co-location

Locating the mobile OSC close to the operations team is critical to ensure best collaboration and communication. Due to the scaled-down nature of this concept, co-location was easily achieved with minimal disruption to the existing office layout. The mobile support center was able to be rolled into the existing meeting rooms to provide updates in real time for team meetings. In addition, when docked in the normal work area, the station served as a focal point for team members to readily check on current well operations. Decisions are improved because the office team could readily access real data as opposed to "gut-feel" decisions made solely from a telephone conversation.

Fig. 1—An operation support center.

People

Selecting the right profile technical expert to man the mobile support center is a key to success. Although many years of drilling optimization experience are preferred, this is not always practical with the current demand for oilfield expertise.

A minimum of five years of wellsite drilling experience was considered sufficient for this role. More importantly, there is a requirement for a "new breed" of expertise—the ability to quickly grasp drilling events through enhanced visualization of remote data and to clearly explain events in a professional,

concise, and credible manner.

In some cases, the office-based mobile support center expert teamed up with a wellsite-based drilling optimization engineer. This further enhanced communication between the wellsite and office-based teams. In these circumstances, a rotation of personnel between the rigsite and the office-based mobile support center enhanced integration between the wellsite and office-based drilling teams.

With time and familiarization by the onshore and offshore drilling teams, the mobile support center could be consulted for an analytical perspective on drilling events and performance enhancement advice.

Software

The main focus of the mobile OSC was for drilling optimization, including real-time shock and vibration mitigation, adequate hole cleaning assurance, and downhole drilling pressure management. A software toolkit was developed to remotely analyze real-time drilling data. The toolkit allows dynamic presentations of the real-time data and calculated values to help understand drilling events quickly and efficiently. The ability to present the real-time data in a graphically compelling fashion provides a clear basis on which optimization decisions can be made.

The main window of the drilling optimization software presents a synchronized real-time display of drilling parameters in depth and in time so that drilling events can be understood from either or both perspectives. The software developed for this application also offers the ability to playback the data and maintain this synchronization.

As depicted in **Fig. 2**, the BHA is scaled to correlate with the depth log. This proved to be a very compelling visualization tool to understand the interaction of the BHA components in real-time with the formations drilled. Drilling parameters could be adjusted to suit the component source of shock and vibration before catastrophic failure occurred. Previously, such events were only diagnosed after the incident had occurred.

Daily drilling performance is easily monitored with the automated time-depth plot, which can visualize time-depth data over the whole well or can be zoomed in to see the time-depth relationship on a 24-hour basis or in smaller time sections (see **Fig. 3**). The time-depth curve is also synchronized with the depth and time log displays in playback mode, which further aids the quick comprehension of drilling progress and events.
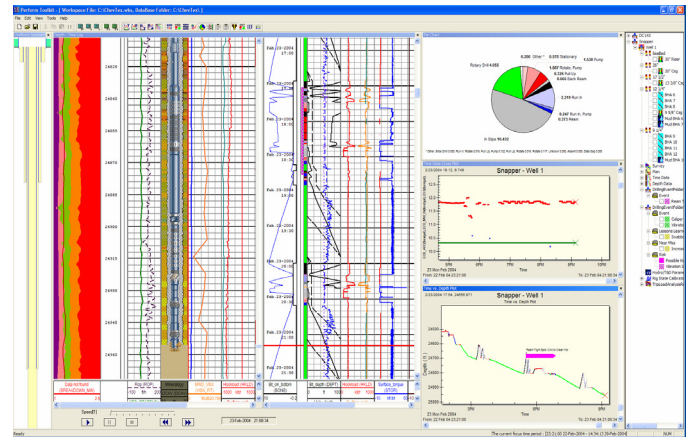
Fig. 2—BHA aligned with depth data and synchronized with time.

Traditionally, accurate rig status time breakdowns were performed with dedicated work study specialists equipped with a stop watch and clipboard. From the dog house the drilling operations would be monitored and logged with an effective time breakdown. The new software substitutes a Bayesian logic network to analyze five main rig surface sensors to automatically interpret the rig status in high resolution. This can be used to automatically generate a rig status breakdown (see **Fig. 4**) depicting how much time is spent on each drilling activity.

Most operators today base their impression of rig efficiency on what is documented on the International Association of Drilling Contractors (IADC) daily drilling report. However the automated rig status breakdown often demonstrated major errors with this method of estimation. On several occasions, the IADC report established that "22 hours drilling" was spent during a 24-hour time period, which the automated software verified to be as low as 8 hours of actual on bottom drilling time. By notifying the rigsite team of the real "on bottom" drilling efficiency, awareness was drawn to previously undocumented idle time, and improvements were made.

Using the rig-state calculations, the software also supports automated real-time torque and drag monitoring to develop trip-in, trip-out, and rotating on- and off-bottom trends. In one example, this feature was used to quickly differentiate between salt creep and tar flow. Whereas salt creep is indicated by an increase in drilling torque, tar additionally presents a high stick/slip value. Salt creep could be managed if detected early in this manner by increasing mud weight. Unfortunately, no effective solution was found for tar flow except for cementing and sidetracking. However, rapid notification of tar flow detection from the mobile OSC helped to avoid a stuck pipe situation.
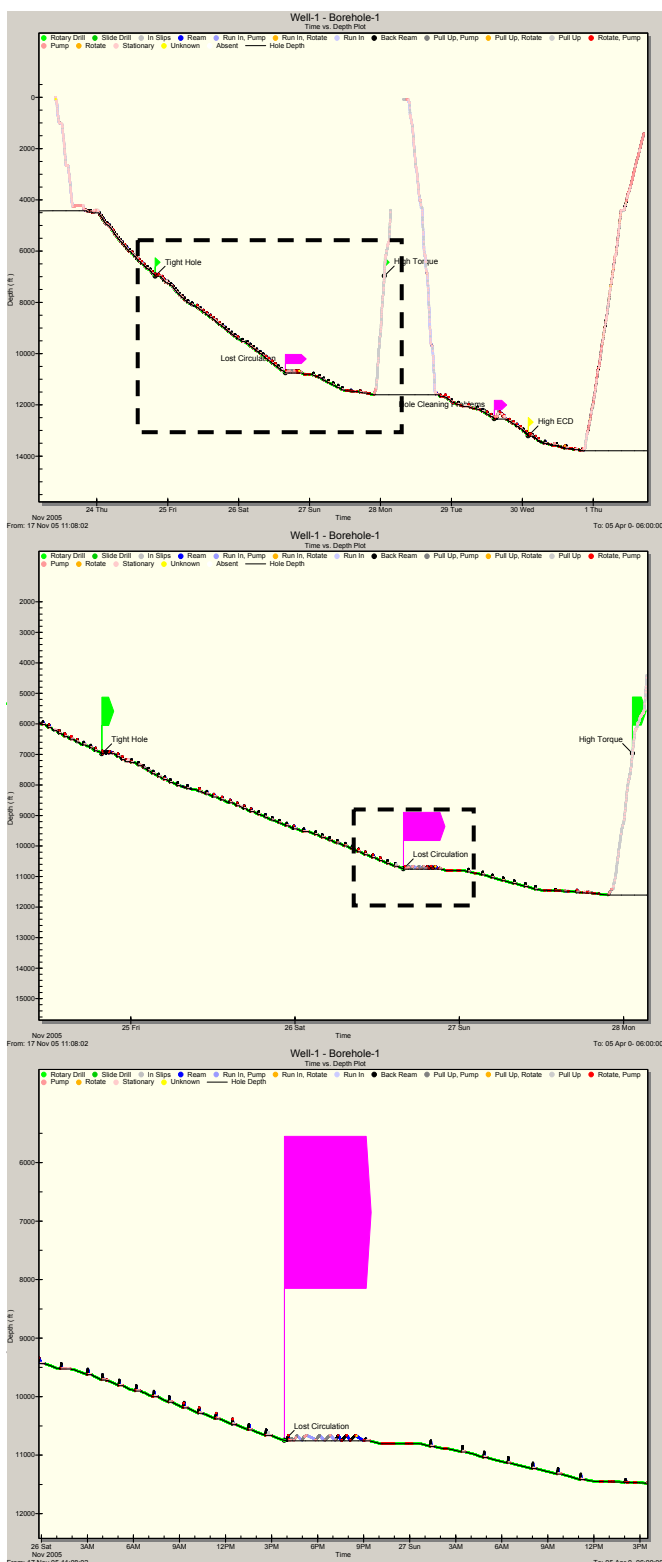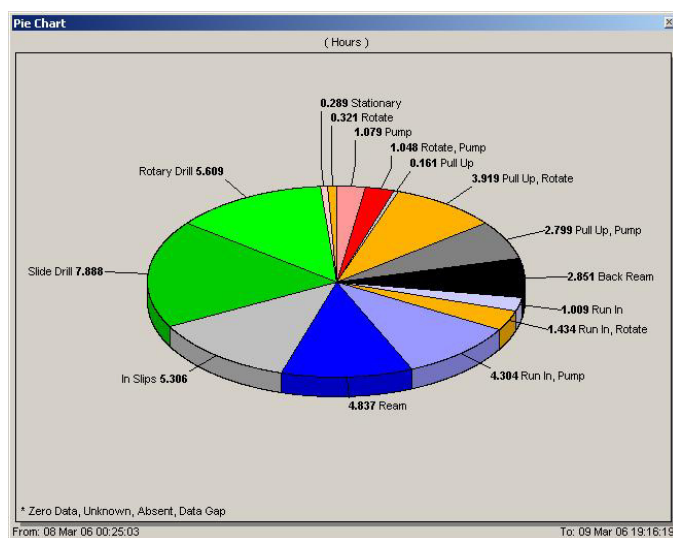
Fig. 3—Time-depth curve colored with rig state.

Fig. 4—Rig status breakdown.

Case Study #1

In mid 2005, the mobile OSC concept was tested successfully on a remote, real-time pore pressure project for a GoM operator.

A team of experts comprised of geoscientists and drilling engineers used the mobile support center to assist an aggressive drilling campaign that eliminated a string of casing.[1]

The field was an extremely difficult drilling environment related to pore pressure uncertainties. Drilling-fluid density often reached as high as 18.0 lbm/gal, creating a high risk of wellbore instability and lost circulation. Six or more casing strings are typically required to reach the target reservoir.

Drilling performance was optimized by using logging-while-drilling (LWD) technologies and sending the real-time streaming data received from the downhole tools through mud-pulse telemetry via satellite to a mobile support center for real-time drilling analysis. A multidisciplinary team monitored and updated the wellbore hydrodynamics and earth model by incorporating observations during drilling **(Fig. 5).** The results, along with mud-weight recommendation, were then sent to the rig, and the appropriate actions were taken to ensure that the surface mud weight, the equivalent circulating density (ECD) and the equivalent static density (ESD) were kept within the limits of the pore pressure and fracture gradient.

By using the technique described above, engineers were successful in extending both the 9 ⅝–in. intermediate casing and 7–in. liner string to sufficient depths and eliminated a string of 5–in. casing common to wells in the area. This avoided additional time and cost associated with slimhole drilling and the completion limitations inherent in small production casing.

The initial mud density program was established from offset well data. These predictions were further refined using a 3D mechanical earth model[2]; real-time LWD formation pressure while drilling (FPWD), sonic data, and other relevant

wellsite information provided confidence in the geopressure predictions.

The initial plan called for the 9 ⅝–in. casing to be set at 6,800 ft true vertical depth subsea (TVDSS) and was constrained by a 13.0-lbm/gal fracture gradient derived from previous experience in the field. However, the calculated fracture gradient derived from the real-time velocities and density measurements indicated that the formation strength was substantially higher. The mud weight was increased and drilling continued under the surveillance of the mobile OSC, thus pushing the 9 ⅝–in. casing safely to 8,187 ft TVDSS.

By pushing the 9 ⅝–in. casing string deeper that planned, the preplanned 5–in. casing string was no longer required. Figure 5 demonstrates the process adopted to reduce the error of uncertainty in this case study.
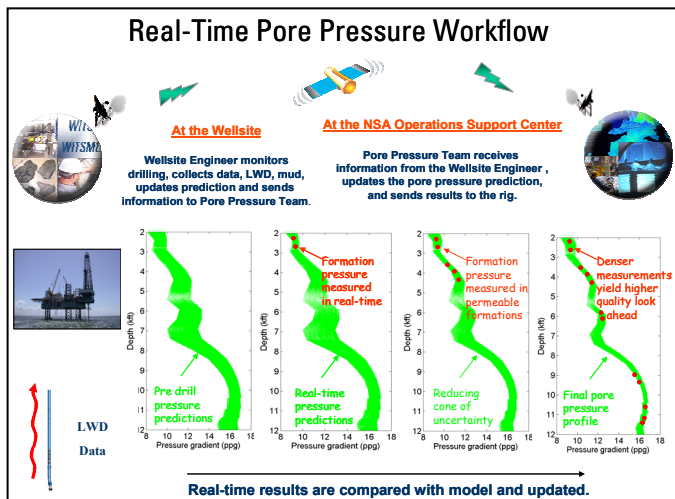

Fig. 5—Real-time pore-pressure workflow.

Case Study #2

In an effort to improve the drilling efficiency in Deepwater GoM and minimize downhole vibrations, an operator's GoM exploration business unit teamed up with an engineering service and a drilling service company to implement a drilling strategy to design the "best BHA". The team successfully mitigated shocks and vibrations by monitoring the BHA's performance via a mobile OSC located inside the operator's Houston office. This resulted in making a recent six-string, sub-salt exploration well one of the top three exploration wells ever drilled in the GoM based on the days/10K metric.

The strategy involved predrill planning to optimize the BHA design and bit selection, using the mobile OSC to monitor the drill string dynamics in real time during the execution phase of the project, and a post-analysis and evaluation phase to capture the lessons learned and to plan for the next section. If the bit selected and BHA is not designed correctly, varying the drilling parameters in real time to mitigate shock-and-vibration-related issues may be futile.

In this prospect, the drilling company's finite element drilling simulator was used to understand the under-reamer placement and design with respect to the bit design and the interaction with the other BHA components and the formation strengths being drilled.

Once the BHA design optimization phase was completed, drilling commenced with continuous real-time monitoring of the drilling process using the engineering service company's mobile OSC, located in the operator's office in Houston, which supported an engineer at the wellsite. The mobile OSC team also provided predrill modeling for the BHA design, real-time updates on wellbore friction factors for torque and drag analysis, and useful plots of all the drilling parameters over time for trending. **Figure 6** shows the stable drilling window and the corresponding changes to the weight on bit (WOB) and revolutions per minute (RPM) that are required in order to stay within this zone and maximize the mechanical specific energy available to the bit once the specific mode of vibration has been identified.
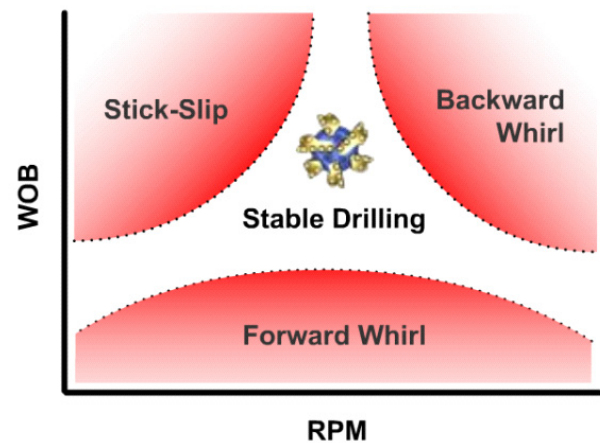

Fig. 6—The stable drilling window.

The biggest concern in this particular exploration well was the vibration issue observed in the past on the 18 ⅛ × 22-in. and the 12 ¼ × 14-in. sections. The challenge in the 18 ⅛ × 22-in. section was to drill through an extended salt section to penetrate at least 600 ft into the top of salt (TOS) before setting the 18-in. liner string. The concentric reamer chosen was specially retrofitted with less aggressive 13-mm cutters and teamed with a bit that had 16-mm face cutters with 13-mm gauge cutters. To maximize stability and reduce vibrations, an eight-bladed partial steering wheel design was chosen. This bit featured ultra wear resistant cutters designed to extend the bit life if vibrations did arise. With careful design and execution, the high level shocks experienced in the past while drilling with a BHA of this nature were not encountered in this hole section.

The challenge in the 12¼ × 14-in. section was the possibility of the bit being in soft formation during the salt exit while the reamer remained in salt, thus creating significant torque differential and damage to the BHA. The bit selected for this section was equipped with 13 mm face and gauge ultra wear resistant cutters. The cutter size on the concentric reamer was also chosen to match that of the bit cutters and was placed approximately 104 ft from the bit with spiral, short blade

stabilizers above and below to improve centralization and reduce vibrations.

An interbedded sand and shale formation was encountered below the salt package in this section, which induced several high vibration levels. However, real-time intervention by the multidisciplinary team in the mobile OSC, using the predetermined mitigation method, proved successful. Again, with careful design and execution, the 12 ¼ × 14-in. BHA worked extremely well while experiencing low levels of vibrations with an average ROP of 50 ft/hr in normal drilling conditions and no damage to the BHA. **Table 1** shows a summary of the hole sections drilled and the vibration levels and ROP observed for the well.

TABLE 1: SUMMARY OF PERFORMANCE FOR EACH SECTION

Section	Vibration Level	Average ROP (ft/hr)
18 ⅛ x 22-in.	Low	55
16 ½ -in.	Low	112
12 ¼ x 14-in.	Medium–High	50
10 ⅝ x 12 ¼-in.	Low	45

The results on this well were well received by the business unit, especially following the experience in the previous exploration well where a twist-off occurred in the same section. This particular exploration well was able to prevent a reduction in drilling efficiency and to eliminate BHA failure by applying all the learning from the past and implementing a new monitoring system. Continuous improvements in BHA design, BHA simulation, and vibration monitoring and identification will surely reduce and mitigate vibration risk in future wells.

Figure 7 shows the BHA and vibration levels experienced in this well and the previous well drilled in the area; the difference is clear and can be attributed to the BHA design, under-reamer design and placement, and the real-time intervention of the engineers manning the mobile OSC.

General Conclusions

The mobile OSC is able to deliver comparative results to its dedicated counterpart, including access to top-flight engineering experience, specialized expertise for unique or unusually challenging problems, and a means for facilitating better collaboration among drilling personnel and suppliers—all resulting in better and more timely decisions.

With its ability to relocate and resume work quickly as operational focus requires, the portable support unit serves as an advanced analytical center for the operational team—within reach no matter how remote their assignment.

Several key requirements identified in this study to ensure the optimum success of this concept include:

- Personnel expertise able to quickly preclude and communicate corrective action for drilling events based on remote data.
- Drilling analysis and visualization software enabling rapid comprehension.
- Team acceptance and integration.

- Adequate prejob planning and postwell evaluation phases integrating the benefits of a mobile support center.
- Flexible standardized hardware allowing easy placement, mobility, and quick expansion.

The mobile support center is not only restricted to the execution phase of a well, but can be used to improve the predrill and postwell evaluation phases through data simulation and replay of previous well events. It is also capable of being used to capture and interpret drilling events, which is an effective aid in documenting lessons learned and best practices.

The ability for a mobile support center to replay data and synchronize across multiple visualization platforms has additionally served as a training resource for drilling team, rig crew and service company personnel.

Future enhancements include an automated mobile phone text-messaging capability to alert drilling team members of preempted drilling events. Acceptance of such a drilling-event notification protocol should be established with the wellsite team beforehand to avoid loss of team collaboration.

This concept has proven its practical value in the field and, as documented in the case studies in this paper, has illustrated the effectiveness of the mobile OSC in a variety of drilling environments.
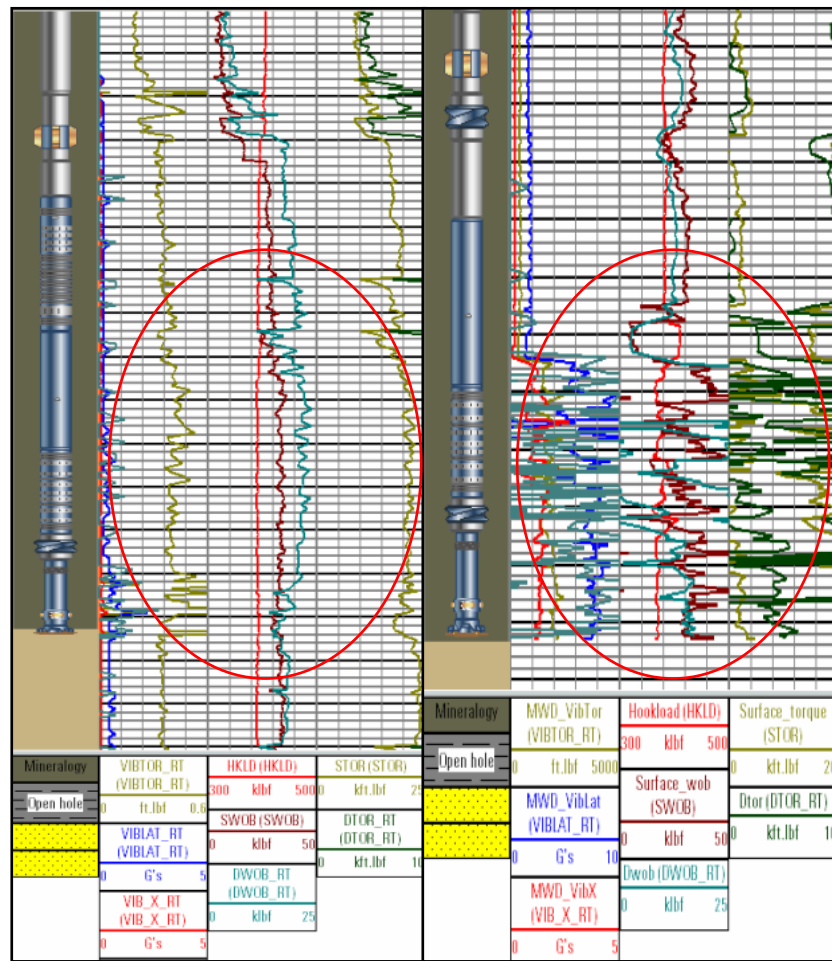
Acknowledgments

References

1. Goobie, R. B. et al.: "Optimize Drilling and Reduce Casing Strings Using Remote Real-Time Well Hydraulic Monitoring Applied Drilling Engineering," paper 103936-PP presented at the 2006 SPE/IADC Drilling Conference and Exhibition, Cancun, August.

2. Sayers, C, den Boer, L., Nagy, Z., Hooyman, P. and Ward, V.: "Pore Pressure in the Gulf of Mexico: Seeing Ahead of the Bit," *World Oil* (December 2005) 55.

SI Metric Conversion Factors

ft	×	3.048*	E-01 = m
in.	×	2.54*	E+00 = cm
lbm/gal	×	1.198	E+02 = kg/m³
lbm/gal	×	1.198	E-01 = kg/L

*Conversion factor is exact.

Mineralogy	VIBTOR_RT (VIBTOR_RT)	HKLD (HKLD)	STOR (STOR)
Open hole	0 ft.lbf 0.8	300 klbf 5000	0 kft.lbf 25
	VIBLAT_RT (VIBLAT_RT)	SWOB (SWOB)	DTOR_RT (DTOR_RT)
	0 G's 5	0 klbf 50	0 kft.lbf 10
	VIB_X_RT (VIB_X_RT)	DWOB_RT (DWOB_RT)	
	0 G's 5	0 klbf 25	

Mineralogy	MWD_VibTor (VIBTOR_RT)	Hookload (HKLD)	Surface_torque (STOR)
Open hole	0 ft.lbf 5000	300 klbf 500	0 kft.lbf 20
	MWD_VibLat (VIBLAT_RT)	Surface_wob (SWOB)	Dtor (DTOR_RT)
	0 G's 10	0 klbf 50	0 kft.lbf 10
	MWD_VibX (VIB_X_RT)	Dwob (DWOB_RT)	
	0 G's 5	0 klbf 25	

Optimized BHA and drilling parameters   Previous well: Problems led to twist-off

Fig. 7—Comparison showing two exploration wells using an 18 ⅛ × 22-in. assembly in salt.