'E-Reservoir' Part Of New World Order

By Chris Usher
Western Geophysical

Editor's Note: To assess what may lie ahead in the realm of geophysics, *The Reporter* asked the author to imagine himself transported several years into the future, and then describe the technologies and processes leveraged during a typical day on the job. As the anointed time traveler, the following represents Chris Usher's journal entry from one day of his imaginary visit to the "downhole factory" command-and-control center of tomorrow.

HOUSTON–The reservoir date of June 12, 2006, flickers in the corner of the giant wraparound three-dimensional immersive screen in the downhole factory control center in Houston. I notice the clock icon register 7:30 a.m. as I take my seat at mission control, the geophysical representative on the electronic reservoir team. The e-team is commencing another exciting phase of a multiyear deepwater reservoir management project offshore.

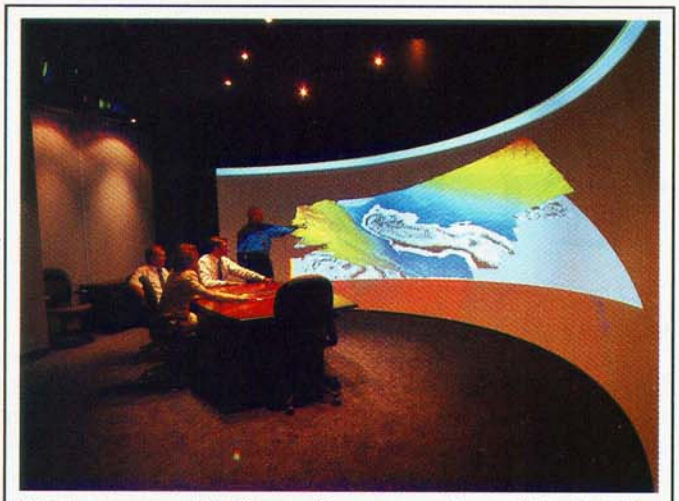
I compare the time shown on the screen with the time indicated on my antique mechanical wristwatch, an inheritance from my grandfather, who worked in the oil field during the last century. It occurs to me that a great deal has changed in oil and gas exploration, drilling and production since the dawn of the new millennium and the "new world order" that has since emerged in the oil and gas business, driven largely by an explosion of internet-driven technologies. Only a few years ago, concepts such as an electronic oil field and continuous real-time reservoir management, with integration of all available data, were merely distant dreams. Today, sitting in the downhole factory control center, it is all right there in front of me.

"This is real-time, interactive processing. The data must be imaged as quickly as possible, because data only have value if they can be used to make timely reservoir management decisions . . . The model is updated in near real-time with expert interaction. Complex "what if" scenarios take only minutes to run, and are validated with a powerful array of applications served up."

Or more precisely, all around me, enveloping me in data.

It took considerable collaborative efforts by the industry to focus technology investment after the 1998-99 downturn to make the e-reservoir a reality. Service contractors forged development alliances with operators, and in some cases, with other service companies to drive complimentary technologies in a fast-forward mode to meet the challenges of the new markets. The result is that the industry in the new millennium delivers better returns to shareholders than ever before, and actively creates new technologies rather than simply reacting to them.

There is no more time for contemplation this morning as the remaining members of the multidisciplinary team enter mission control. They quickly take their seats and begin interacting with Web browser windows on screen. Comprised of geophysicists, geologists and reservoir engineers, the team is reviewing the most recent information through integrated views of the reservoir.



Giant wraparound 3-D immersive screens play a vital role in the downhole factory control center concept, allowing e-team members to interact with reservoir data in a collaborative fashion.

The downhole factory is the product of convergence and integration of technologies such as 4-D seismic, multilateral well bores, downhole processing and intelligent completions.

Seafloor 4-C Surveying *All aboard the super ship*

Today, the 4-C (multicomponent) deepwater crew on board the *Western Nautilus* has returned to Petrobras' deepwater field to harvest yet another pass of time-lapse seismic data. Both the asset manager in Brazil and the crew manager aboard the vessel appear in Netcam windows mounted on the wall. They wish us all a good morning, and then operations begin moving rapidly on the seafloor some 4,000 below surface.

Launched in 2005, the purpose-built seabed 4-C seismic vessel has all of the sensors, sources, cables and handling equipment necessary to autonomously conduct surveys in waters to 8,000 feet deep. The vessel carries three high-powered seismic sources capable of extended bandwidth for enhanced reservoir analysis (compliant with Sec. 308.4 of the Marine Mammal Protection Act of 2002). The continuous recording system, first deployed in the late 1990s, is capable of handling 32,000 sensor channels. Seismic data are archived onto terabyte solid-state "cassettes," and then pumped to an ever-expanding subsea fiber optic network or transmitted by satellite to distant locations.

Quickly, attribute coverage maps now begin to flash on the curved screen. The applications are automatically served up to the team assembled in mission control as well as to the remote Petrobras' team members through the latest Web technology. Some on the team remember a pretty different world in the late 1990s, when baseline surveys were still acquired using conventional surface seismic techniques and 10 solid streamer cables.

Elsewhere in the control room, other team members review the reservoir model using browser links, accessing data from the previous monitor surveys and all other geoscience information from real-time access storage libraries. In fact, tremendous amounts of information stream into the data base daily from drilling activities and other reservoir-focused activities, which collectively make up the downhole factory, including "look-ahead" seismic while drilling and permanently-implanted reservoir sensors, to name only a couple.

This month, however, the asset team in Rio needs more information about fracture orientation in a reservoir zone that was not well sampled by the existing web of well tracks. So shortly after an electronic order for another seabed seismic monitoring phase was selected from the online project catalog, the *Nautilus* is ready to conduct the new multicomponent seismic survey.

Using the rig-mounted Netcam and super-zoom satellite images, team members watch as the shooting vessel traverses rapidly over the producing field with its environmentally friendly seismic source, maneuvering easily around the floating platform. More than 4,000 feet below on the seabed, remotely-operated vehicles have already positioned sensors in the portion of the electronic oil field as specified in the e-order and planned by model-based 4-C illumination analysis.

Data Transfer, Processing *Transcending speed barriers*

Concurrent with the shooting, compressional- and shear-wave signals, received at fiber optic sensors on the sea floor, and those from sensors installed in the bore hole (part of the downhole factory installation at this site) are transmitted over fiber optic links to the central continuous recording management system on the platform. Real-time data is sent in bursts by a high-capacity satellite link to the mission control center in Houston.

Fortunately, bandwidth expansion during the early years of the new millennium facilitated the flow of tremendous quantities of seismic and reservoir data to central computer servers, and provided global access to all necessary applications to extract value from these data, creating entirely new business models for the industry. Watching today's activities unfold on the screen brought that home to me once again, just as it did with every new project phase!

With data collection only now commencing, new seismic data is already being received from Brazil in the huge disk buffers at mission control, automatically triggering quality control runs (observed by the experts in the control rooms and the asset team in Rio via the Web browsers). Simultaneously, the data is loaded into data storage and management data bases, and into preset online processing jobs to run the next cycle of 4-D, 4-C processing on super-clusters of high-speed personal computer processor nodes. The runs begin as quality control is accepted, and proceed uninterrupted unless artificial intelligence software flags

a problem, in which case, the work in progress is suspended by a 4-D, 4-C expert.

This is real-time, interactive processing. The data must be imaged as quickly as possible, because data only have value if they can be used to make timely reservoir management decisions. Since prestack depth imaging became routine a few years ago, images have become extremely reliable. On production projects with existing models, and with today's computing capacity (orders of magnitude more powerful than only five years ago), the model is updated in near real-time with expert interaction. Complex "what if" scenarios take only minutes to run, and are validated with a powerful array of applications served up to collaborating teams.

Reservoir geoscientists work smoothly with client engineers in the shared application environment of the downhole factory control center to integrate the most recent seismic cubes and attribute volumes into the history matching flow. The reservoir model needs updating prior to starting the latest sidetrack well to extract newly identified bypassed oil. As the last patch of data streams through the computers, the fiber cables and sensors from the seabed are recovered. The *Nautilus'* availability is automatically reposted on the e-inventory supply chain management Web page.

The Cyber Wizard *Clicking on world-class expertise*

Suddenly, the 4-D loop icon begins flashing in red on the screen and an alert buzzer simultaneously sounds in the control room. A team member quickly drills down in the browser and discovers that the automated history matching loop has stalled. The system has been unable to rectify differences between the full elastic prestack synthetic data and the newly generated seismic data sets. The team immediately huddles. Perhaps the synthetic generator needs to be modified to incorporate more complex model features to better mimic the seismic response?

During the team's deliberations, I note that several virtual buttons are lit up on the "instant solutions" panel, the virtual yellow pages for a network of worldwide technology solutions. Good news. It appears that res-solutions.com is still logged on in New York City. Res-solutions.com was born as the industry regrouped shortly after the dawn of the new millennium, and as research efforts took on new forms. This entrepreneurial venture was spun off with some of the industry's best intellectual brainpower, including a leading university earth laboratory team

Technology: The Great Enabler

HOUSTON–This view of the geophysical future may appear far fetched at first glance, but it is actually based to a large degree on key enabling technologies that are already beginning to take root in the industry. These next-generation technological components include a comprehensive auto-storage and data management system, an online data processing/quality control system, and Web-enabled data analysis.

The storage system encompasses a full range of auto-storage capabilities. All reservoir data is automatically format-converted on location, and transmitted by any commercially available transmission system to central disk farms for simultaneous archiving, and optional pumping to the customer's processing and analysis system of choice. Application service provision (ASP) links facilitate access to any of the customer's favorite processing or interpretation applications over the user's browser. The system can manage the complete range of seismic, well log, vertical seismic profiling, production data, interpretations, and reservoir models from all phases of reservoir management over the life of a field.

Developed with industry proven geophysical code, the online data processing/quality control system employs the latest Web browser technology. Data are easily accessible from browser windows in the downhole factory immersive environment or from any pervasive computing device–be it a WebTV at the customer's office, or for limited interaction, a handheld device. The system features data-prompted processing. Data is front-end quality controlled during acquisition, formatted on the fly, and pumped to the online system over a global server network.

From preset flows, standard in most reservoir management environments, the data are processed until and unless artificial intelligence routines detect an out-of-specification occurrence. The user is then prompted to select any of several auto-generated quality control attribute cubes, or may view the raw seismic anywhere in the survey. The software also supports Web-enabled, fully flexible job set up for the expert geophysicist, particularly suitable for non-real time investigative studies or research.

The Web-enabled data analysis system was first released in early 2000 (yes, this technology is real). The system was envisioned in the late 1990s as game-changing 4-D analysis software, and was jointly developed by Western Geophysical, Columbia University's Lamont-Doherty Earth Laboratory, and IBM Watson Labs.

As one of the first portal based, Web-enabled analysis systems, it features innovative infrastructure for integrating legacy applications as well as applications coded in the latest Internet-friendly languages. Facilitating complete geo-scientific reservoir analysis and management, the system is the very "soul" of the downhole factory, providing the integration of all necessary reservoir information. It can access historical reservoir data, provide links to online applications, and upscale or downscale results for use in all commercial reservoir simulators. Naturally, the system's portal allows users to choose the seismic interpretation application of their choice. All of these applications can be run on the user's screen through application hosts over the Web.

The system employs the most advanced prestack seismic synthesizer available, as well as completely automated seismic history matching optimization loop scenarios. Results are pumped as they are computed into the system's viewer for visualization in an immersive environment. The system allows expert reservoir management consultants to extract optimum value from the user's assets–with the user's key employees, wherever they may be located, fully integrated within the team. ❐

and key research and development staff from several oil and gas companies.

Within minutes, the R&D liaison at mission control fires up a virtual Internet meeting with res-solutions.com, sharing with them our applications and the current puzzling results. Within two hours, res-solutions.com programmers have modified one of the fully elastic modeling subroutines, facilitating a more complex rendering of the synthetic seismic. We download only the code differences and restart the data processing loop. Within minutes, the history matching process completes successfully.

I glance at the clock icon. The time is a few minutes before noon. It seems the lunch break is about the only thing that has remained unchanged from 1999!

After lunch, the rest of the team will arrive for the geosteering shift in mission control to make use of the morning's acquisition, processing and reservoir characterization efforts and begin the extraction of bypassed hydrocarbons. Delicate tuning of downhole pumps and accurate location of injection wells, based on integrated data in previous monitoring phases, has substantially increased recovery rates–even early on–and added tremendous value for this deepwater field.

Despite all of these advances, however, there is always something new to discover about the reservoir and the earth. Fortunately, highly accurate and maneuverable horizontal drilling technology can target today's newly located bypassed asset in a far corner of the reservoir.

It is just another day's work at the downhole factory. r

***Chris Usher** joined Western Geophysical in 1983 after graduating from Yale University. Through successive positions, he has contributed to the growth and introduction of new technologies in Western Geophysical's data processing business. In 1997 Usher was appointed vice president of data processing, and subsequently, vice president of technology in 1999. Last year, he was appointed to the Baker Hughes Technology Council. Usher is now serving Baker Hughes at the corporate level.*