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Technology Shaking Up Land Seismic

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Technology developments in land seismic instrumentation–both evolutionary and revolutionary–promise oil and gas operators greater clarity in subsurface imaging through greater sample density. Picture it as affordable Lasik surgery for land seismic consumers.

To understand why such change is significant, consider that onshore seismic is chronically undersampled for a variety of technological, cultural and economic factors. On a practical basis, traditional seismic systems are people and equipment intensive, and involve laying arrays of inline vertical motion analog geophones as single-component sensors along a stake and flag grid. With cultural and physical issues constraining ideal sensor deployment, costs rise quickly when it comes to onshore data acquisition, and the tradeoff has been surveys that produce low sample density with modest subsurface resolution. For operators experiencing a near doubling in land seismic acquisition costs over the past two years, interest is high for any solution that improves sample density and reduces seismic acquisition cost.

At the same time, new developments in seismic instrumentation are encouraging geophysicists to consider wide-azimuth/multiazimuth or multicomponent data as a method for improving subsurface resolution, whether a survey is acquired using cabled or cableless recording systems. Improvements in subsurface resolution portend game-changing implications for an industry seeking improved technologies to locate hydrocarbons left behind in mature basins, or contained in complex lithologies, smaller reservoirs, deeper horizons and unconventional geology.

"Our thesis is that existing land 3-D seismic technology is insufficient in many cases to fully image prospects. What you see going on now is a perfect storm–in a good way–in which new technologies are hitting the market at a time when oil and gas companies are feeling pressure to add reserves. They can do this through exploration, but in an increasing number of instances, the operators are going back to known basins and looking for more subtle, more challenging prospects," explains Chris Friedemann, I/O's senior vice president of corporate marketing.

Mark Farine, vice president of sales for the western hemisphere at Sercel, which manufactures seismic systems as a division of CGGVeritas, agrees. "Everything being done today is about getting more receivers in the field, " he says. "You are starting to see in-line sensor spacing come down. An oil company has done a multicomponent survey with sensors spaced at 2.7 meters, which was unheard of only a few years ago."

Higher Channel Counts

Farine notes that five years ago most land seismic design was based on multiple channels in a box. "You had cables and multiple geophone takeouts per box, and you had one battery per box. Most of the systems were quite heavy and power consuming. The average number of channels deployed five years ago was in the range of a couple thousand. Some 3-D surveys got as large as 4,000 channels, but you still had a lot of 2-D activity, which brought that average down," Farine recalls. "Today, systems are able to handle thousands and thousands of channels. The transverse data rate on our advanced commercial systems is 100 megabytes/second, and it is really there to facilitate 30,000, 40,000 or even 50,000 channel counts."

Larry Denver, chairman and CEO of cableless seismic equipment manufacturer Ascend Geo, is witnessing the same thing. "Going back to the late 1970s, you started with a few hundred channels. Simply getting to 1,000 channels seemed a bit unlikely, let alone 10,000 channels. If you look onshore or offshore, channel counts continue to climb, and we are at a point now where we are going to see them climb at an accelerated pace."

A brave new future in land seismic technology is being defined largely by evolutionary developments involving size reductions in single-sensor, multicomponent digital units. Micro-electric-mechanical (MEMS) sensors capture a wider frequency spectrum of subsurface data than analog coiled spring geophones, which allows geophysicists to develop higher-resolution images of the subsurface.

Increasing channel counts are not only boosting data resolution, but also the quantity of data that must be handled "downstream" in processing. When the acquisition happens with multicomponent sensors, the volume of data acquired further jumps by a factor of three, Friedemann notes. To take full advantage of the technological advancements and unlock complex geologies, including unconventional oil or gas, the seismic industry must be prepared for a step-change increase in the amount of data that will need to be processed and quality-controlled throughout the entire imaging process, he says.

The physical ability exists to capture the data operators want, in the volume operators need. In fact, today's technology provides data gathering capabilities

I/O's FireFly® cableless system was used in a 10,000-station deployment to collect and process wide-azimuth, high-density 3-D data over a 28 square-mile area at BP's Wamsutter Field in Wyoming earlier this year. The system has since undergone a second field trial for Apache Corporation in East Texas, where data acquisition was completed in June.

that have jumped ahead of the industry's ability to effectively process and interpret denser information sets, according to Farine. "A lot of times, people recording multicomponent data are only using part of the data because the processing side of converted-wave seismic is well behind the acquisition side. The interpreters have not quite figured out what it all means," he relates. "Within the next five years, processing and interpretation will improve and we will see a broader use of multicomponent sensors in much denser configurations, which means total channels and data volumes will continue to increase."

A Revitalized Business

Revitalization of the land seismic industry has come quickly. The industry was at rock bottom only four years ago as operators avoided the exploration side of the exploration, production and drilling equation. Operators active in growth-through-the-bit programs focused primarily on scale-oriented resource plays. But that has changed, and garnered notice outside the industry.

"Seismic contractors are in the process of expanding their fleets and crews, and also retrofitting older equipment," Lehman Brothers' oil services analyst James West observed in a May 2007 report. In the United States, land crew counts have nearly doubled since 2003, and worldwide land seismic crew counts have increased from 500 in 2005 to closer to 625 today. On the marine side, Lehman Brothers predicts the size of the worldwide seismic vessel fleet will expand from 96 in 2005 to 120 by 2008.

These trends suggest that the industry has returned to an exploration and development model, instead of the other way around. Exploration as a percentage of total upstream spending dropped from more than 25 percent in 1998 to less than 20 percent in 2004, according to West. Seismic contractors saw an abrupt decline in crew counts, and oil reserve replacement rates for a sampling of 200 publicly held companies plummeted from nearly 150 percent in 1999 to 50 percent by 2004. But that has changed. Operators are going back to work and exploration–particularly onshore–is entering a growth era. Seismic contractors have returned to profitability, and seismic equipment manufacturers cite growing order backlogs in a market estimated at $1.6 billion annually, and as participants point out, growing at a rate of 10-15 percent annually.

"We have 14 manufacturing facilities in 10 countries. We keep increasing capacity, but it does not seem like we are ever able to increase it enough," says Farine. "Construction of marine seismic vessels is driving business. On the land side, new companies certainly create a tremendous opportunity, along with the expansion of existing crews. You talk to some of the guys who operate in North and South America and they say they have to add another 20 percent to their channel pools, not to expand the number of crews, but to provide the number of channels per crew clients are asking for."

According to Friedemann, advancements in data storage and communications are also enabling the industry to envision a new future in land seismic. Imagine a field of iPods™, collecting and storing high-density, multichannel seismic data that can be processed by high-capacity, "superalgorithms" to produce subsurface images with far greater clarity. While the seismic industry is not there yet, he says it is no longer farfetched to argue a convergence of digital technology–including multicomponent digital sensors and flash memory storage–are being integrated with expanded computer processing capabilities and improved telemetry such as BlueTooth™, broadband or wireless broadband to create a technological trifecta providing oil and gas operators greater subsurface resolution, reduced exploration risk, and lower seismic acquisition costs.

Although the iPod metaphor may be a bit overly simplistic, this vision of the future is not Buck Rogers stuff either. Industry reports show that field trials are under way–or have already been completed–in Wyoming, Texas, Canada, Hungary, Russia and Belize involving some aspect of cableless seismic or multicomponent sampling. The buzz, particularly at seismic trade shows, focuses on land-based cableless seismography, where the ability to eliminate cables and increase station count (and gather more data at each station) has far-reaching consequences on the cost/benefit side for operators.

Looking at the more revolutionary changes taking place in land seismic equipment capabilities, Friedemann says cableless seismography promises a world where surveying operations will blend unobtrusively into urban zones, co-exist in delicate environmental settings, and be easily deployed in rugged terrain with lower data acquisition costs, shorter cycle times, and improved imaging density and clarity.

Cableless Multiazimuth Survey

And that has amplified interest in the first deployment of cableless seismic in a multiazimuth application at the Wamsutter Field in the environmentally sensitive Red Desert area in south-central Wyoming. BP finished its first high-density, cableless land seismic field trial in early 2007, reports Craig Cooper, BP's seismic project coordinator for North America.

Wamsutter features complex natural fracture systems that can be conduits for both hydrocarbons and water, and determining fracture trends and orientation is significant in deciding whether to drill in a particular location, Cooper explains. "For us, this is about the pursuit of tight reservoirs, or what we call challenging gas reservoirs," he says. "Traditional seismic will not meet our needs in terms of allowing us to extract the kinds of information we need to do an intelligent job in drilling these challenging gas reservoirs. We had to do a better job of resolving and characterizing our target reservoirs."

BP's 1,700 square-mile holdings in Wamsutter represent the company's largest block of contiguously operated acreage in the United States. The field produces 135 million cubic feet of gas a day from 1,100 wells. BP plans a $1 billion, 2,000-well infill and step-out drilling program in a region where complex tight sand geology impacts production from newly drilled wells and creates subsurface conditions that obfuscate image quality. Furthermore, there are substantial surface environmental regulations involved in operating in the region, which features a corrugated terrain that entails safety considerations for seismic crews, Cooper points out.

The field trial involved I/O's FireFly® cableless system in a 10,000-station deployment to collect and process wide-azimuth data over a 28 square-mile area. Each FireFly field station incorporates a field station unit (FSU) that has a built-in microprocessor, global positioning, power supply, and data storage system connected to a VectorSeis® sensor, which records full-wave multicomponent data. The FSU is connected by standard VHF radio to a central control facility. Cooper says the BP field trial employed light detection and ranging (LiDAR) and GPS technology to test the concept of stakeless station locations for placing the sensors in a flexible seismic survey design.

BP geophysicists are intrigued with the potential for cableless seismic acquisition systems in North America for a suite of reasons that include increased flexibility in seismic design, HS&E considerations and general logistics, according to Cooper. "We are certainly putting emphasis on acquiring pro--prietary seismic data because effective drilling of these tight reservoirs requires much better seismic quality, and the best way to achieve that is to control the design, acquisition, processing, and interpretation of the data," he says.

The data acquisition phase finished at Wamsutter last January. BP geophysicists got an early look at minimally processed data in February, and expect to have a final volume from I/O's GX Technology processing subsidiary in August. "We are encouraged with what we have seen so far, and we have high expectations for what we will see in the fully migrated volume," Cooper comments.

Lower Acquisition Costs

According to Friedemann, cableless technology lowers acquisition costs compared to conventional recording systems by reducing crew sizes and cycle times. The largest time savings in the Wamsutter field trial came through a 40-day reduction in the shooting process, he says, although incremental time savings were also gained in layout, pickup and preprocessing. Friedemann adds that while achieving data quality of 400-fold or higher during the Wamsutter field trial versus 20-40 fold for a conventional survey, FireFly reduced the total amount of equipment deployed by roughly 60 percent.

"The way it was deployed in terms of handheld navigation tools generally seemed to work well," Cooper observes. "The other thing that worked well was during shooting (with dynamite), the automated control system was very efficient. We had approximately a six-hour day for shooting and achieved a peak production of 1,001 shots. Extrapolate a shooting rate of 200-300 shots per hour to a typical survey and you can see the flashes of potential for acquiring data using a system like FireFly."

Cost reductions will not be completely understood until the full data suite is completed, Cooper says. "What you start doing is thinking of things you typically would not use because of the increased flexibility you get with a cableless system," Cooper explains. "You lay out a denser blanket of receivers, which you may not have done with a cable system. So you start to do things that will potentially add to cost and add to the amount of time it takes to work your operations. One of the big challenges is to focus on the logistics of just how you implement this kind of seismic in a way that does not drive up costs or extend the amount of time spent acquiring data."

The FireFly system has undergone a second field trial for Apache Corporation in East Texas. Heavy rains slowed deployment during the spring, but the data acquisition phase was completed in June 2007, Friedemann reports.

"There are certain factors that will drive the adoption of full-wave cableless seismic in the U.S. land market. First, there are more environmental and access challenges here, especially on federal lands, so cableless systems offer a relative advantage," Friedemann explains. "Often, you are going to be trying the technology a little closer to home, and North America is home to many of the equipment manufacturers. Having said

Sercel's fifth-generation digital recording system is designed to accommodate high channel counts and greater layout flexibility in either a single-component or multicomponent configuration. With a capacity of 100,000 channels, the system provides accuracy, speed and ease of use in even the largest survey.

that, full-wave technology itself has been embraced robustly in other parts of the world. For instance, Russia is a big adopter. Canada has been as well. And we are seeing tremendous interest from operators in North Africa and in parts of the Middle East."

Cableless 3-D Solutions

Equipment manufacturers have created several solutions for cableless seismic systems. Sercel markets cableless seismic through its UnITe™ system, which the company acquired in the September 2006 purchase of Scotland-based VibTech. The systems use analog sensors, but Farine says Sercel will integrate UnITe into the company's latest generation product line, which works with analog or digital sensors and can be deployed by way of cable, cell phone, or wirelessly.

"The cableless system integrates cellular telephone technology with 3-D repeaters to transfer data in real time through broadband, although the system can be used for autonomous recording with the data stored inside each receiver," Farine details.

Ascend Geo began marketing analog cableless equipment two years ago with deployments in Central America and North Texas. Denver says the company is a subsidiary of Aspect Energy LLC, an oil and gas operator that established Ascend Geo in 2001 in response to rising seismic acquisition costs.

"What drove it for our company was our desire to drop the cost of shooting 3-D," recalls Denver. "If you are going to be aggressive chasing large blocks, and you are shooting thousands of squares, any operational savings you can find are material. Aspect Energy has more than 5 million acres in Hungary. Dropping 20-40 percent on operational costs for a 3-D seismic shoot is enormous. That is the primary driver."

The company markets a cableless system under the Ultra™ trade name. "Our philosophy is centered on a very flexible, simple, passive recorder. We designed a system capable of supporting virtually any form of array-based or multicomponent acquisition for standard or time-lapse imaging. As part of our passive recorder design, we can also expand the channels of any cable-based crew because we are not required to integrate to their centrals to integrate the data. This will be critical to contractors as they add cable-free channels to their existing cabled crews," Denver says.

"Acquisition systems can be simplified substantially when cables are eliminated from the design," he continues. "We believe it will serve to shorten development cycle times and manufacturing timelines, and require fewer in-house developments. All of it points to lowering the overall cost of seismic and increasing channel counts."

The Ultra system is based on stations that can be deployed simply in applications ranging from megachannel surveys to small, high-density acquisitions in urban areas, Denver details. "Weight, flexibility, and environmental footprint are the primary concerns for the 2-D/3-D surveys we have been shooting with Ultra in the jungles of Belize over the past year," he states.

"The real issue, if you look at cable in general, is that you are going to be out there with literally tons of copper," Denver goes on. "That is what it takes to hook up a typical crew. And you are going to spend a good part of the day repairing those cables or connectors to get that data back in real time. If you can store the data locally in a reliable electronic device and pick it up when you are ready, you can eliminate an enormous amount of cost in laying out the cables, picking them up, and maintaining and repairing them."

Recent applications of the Ultra system involve high-density "surgical" 3-D surveys of only a few hundred acres in urban environments in Fort Worth, where it is difficult to deploy large channel count and spatially broad grids of cables and equipment, according to Denver.

"Surgical 3-D programs can be turned quickly and generate subsurface images that allow operators to avoid karst zones, discern fractures, and optimize bore hole placement in small leaseholds in plays such as the Barnett Shale," he elaborates.

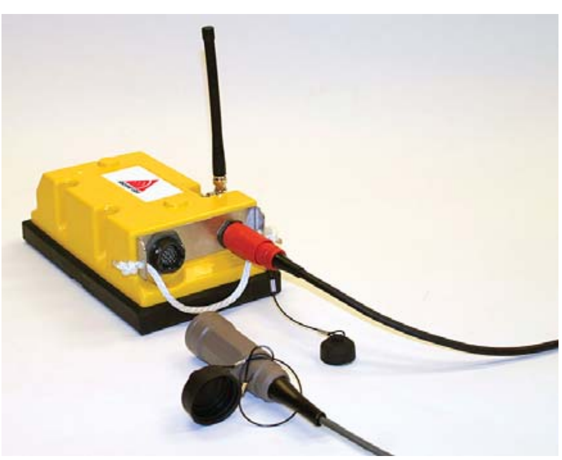
To push the concept even further, Denver reports that the company has completed a 9-C acquisition with three-component phones and a shear-wave vibe, and is now preparing for a passive 2-D survey along a North Texas train track where the train will be the energy source.

Early Stage Of Deployment

Although cableless seismic surveying is proving its value in initial applications in various types of plays, the technology is still in an early stage of deployment. And Farine points out, there is still plenty of room in the market for conventional geophone arrays coupled to cabled recording systems.

"More than 90 percent of seismic acquisition in the United States and Canada is still done with geophone arrays and cabled systems," Farine states. "There are technical reasons why a accelerometer cannot be used for every job. It depends on target depth, and ground roll, ground noise and source-generated noise are issues. An array of geophones will suppress that noise better than a single sensor will. There are 17 million cabled analog geophones in existence, and there are good reasons why cable analog input systems are still very important for seismic contractors to have in their portfolios."

In fact, industry experts note that when it comes to achieving high numbers of channels, cabled systems can still be the best option in terms of volume, weight, and cost/price. Still, there is no doubt that digital systems capable of recording higher-channel count, multicomponent and multiazimuth data with-



Ascend Geo's Ultra™ G5 recorder with battery and geophone connectors is shown here. Scalable up to 50,000 channels, the cableless system has been used in both large mega-channel surveys and surgical, high-density surveys ranging from Central American jungle terrain to urban areas in the Barnett Shale play.

out the constraints of cables represent a welcomed step change in land surveying capability, Lehman's West observes.

"We believe the seismic industry is in the early stages of a major transition from 3-D seismic to full-wave seismic," he remarks. "The main benefits for full-wave imaging include improved subsurface resolution, the ability to differentiate lithologies, and the ability to track fluid movements in the reservoir. Full-wave also allows geophysicists to deal with abrupt, near-surface velocity changes in Arctic or desert environments, account for anisotropy in the subsurface, map fracture networks in reservoirs, and acquire seismic data in environments where noise from drilling rigs or production equipment impedes seismic imaging."

The big driver, again, is the ability to achieve higher channel counts, which enables the recording of higher-density, higher-resolution and higher-fold surveys, as well as multicomponent data, Farine comments, noting that Sercel began marketing its fifth-generation recording system in November 2005. "We have seen channel counts grow over the past 30 years from a few hundred with our first-generation system in 1977 to tens of thousands today," he says. "Each generation of instrumentation has significantly increased channel counts, even as the equipment itself has gotten smaller, lighter and more efficient."

And there is no reason to think that trend will slow anytime soon, particularly given the synergies between full-wave digital recording systems and advanced techniques, such as time-lapse 4-D seismic and microseismic, that use the earth's energy as the source, points out Friedemann. Ultimately, he says the trend toward cableless systems with multicomponent sensors is building toward a future where 3-D seismic is as much a part of everyday production operations as it is an exploration tool.

"We think 4-D applications will emerge in a big way in the land market to optimize reservoir development, exploitation drilling programs, and field production. Cableless systems recording multicomponent data will be the main enablers of that," Friedemann concludes. "A cableless, full-wave platform could be an ideal way to implement 4-D. You could permanently install multicomponent sensors beneath the weathering layer at depths of 75-100 feet where noise and seasonal variations are low to capture improved data and enhance survey-to-survey repeatability. The service contractor would simply come through at regular intervals to take measurements by connecting a cableless box to the sensors. You would be able to detect how the reservoir is changing as the field is produced so that everything from reservoir management schemes to infill drilling locations could be optimized. That is the future." ❐