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The Next Wave

Kaleidoscope Project Aims To Break The Sound Barrier Of Seismic Imaging

By Paul Wells

**AS DIRECTOR OF GEOPHYSICS FOR** Madrid, Spain-based Repsol YPF and project leader of the company's Kaleidoscope Project that was struck to take seismic imaging technology to new and previously unattainable depths and speeds, Francisco Ortigosa is fond of saying that the impact of the initiative is akin to "breaking the sound barrier" in seismic imaging.

"Seismic imaging is performed by processing seismic sound waves. The target of Kaleidoscope is to accelerate the processing in several orders of magnitude," Ortigosa says. "By speeding up seismic imaging, we foresee a revolution in exploration that will be comparable with the revolution in aeronautics after breaking the sound barrier."

The project -- a unique international partnership of top geophysicists, computer scientists and organizations -- has developed advanced computer-based techniques that usher in the next generation of seismic imaging technology used for oil and gas exploration.

Ortigosa says the new technology reveals oil and gas deposits buried deep in the earth efficiently and cost-effectively that had been previously undetectable through traditional imaging techniques.

Specifically, Repsol is hoping Kaleidoscope will help it find and exploit the potentially lucrative but increasingly stubborn unaccounted for reserves in the deep waters of the United States' Gulf of Mexico, where relatively low tax and royalty rates, a stable political regime, abundant infrastructure and massive untapped oil deposits make it a potential bounty worthy of ingenuity and large-scale capital outlay.

Repsol plans to use the new seismic technology to locate hydrocarbons and oil reserves buried some 30,000 feet (10,000 feet of water and then 20,000 more feet of seabed) from the Gulf of Mexico's surface. The U. S. Department of the Interior's Minerals Management Service estimates that the Gulf of Mexico holds approximately 56 billion barrels (bbls) of oil equivalent (oil and natural gas), which, at \$100 per bbl, would be worth nearly \$6 trillion and meet the entire U. S. demand for oil and gas for about five years.

"The hydrocarbon reserves in the Gulf of Mexico are difficult to see because of the interbedded salt bodies in the subsurface, and difficult to reach because of the drilling limitations imposed by water depths and complex structures," Ortigosa explains.

"In order to have easy access to these reserves, the industry is developing seismic imaging technologies and drilling capabilities. The problem is that drilling technology has evolved faster than imaging technology."

Ortigosa notes that exploration and development success ratios in the Gulf of Mexico have decreased

over the last decade due to this fact and, as such, acceleration of the evolution of seismic imaging technology is needed. "This is one of the objectives of the Kaleidoscope Project," he says.

But to do so, the melding of seismic imaging technology and supercomputing would be required. Ortigosa contends that there are three sources of value in seismic imaging: model, algorithm and capacity. He says that, traditionally, imaging algorithms and algorithm implementation have evolved faster than hardware.

"Particularly in the oil industry, algorithm evolution has concentrated on speeding up existing algorithms, trying to optimize the quality/speed tradeoff by making numerous shortcuts, always thinking that someday, who knows when, such tradeoffs will be no longer needed," Ortigosa says.

"This time has arrived as we witness nowadays the crossover of the curves representing evolution speed of hardware and software."

According to Ortigosa, seismic imaging is at least one field hungry for petascale capacity.

"Seismic imaging is definitively a field in our industry where petascale capacity is needed and the Kaleidoscope Project is working simultaneously on hardware and software with this idea in mind. In fact we are writing the first petascale set of seismic imaging applications. The question is not when this capacity will be widely available, but how."

Petascale refers to petaflopscale computing. A petaflop is  $10^{15}$  (i. e. one 1 with 15 zeros) floating-point operations per second.

The collaborative Kaleidoscope Project was established between 3DGeo and Repsol, leveraging the resources of the Barcelona Supercomputing Center (BSC), which houses the MareNostrum supercomputer, and relationships with Stanford University, IBM and the Spanish Research Council.

"Advancing seismic imaging to the next level of precision poses a multi-disciplinary challenge," Ortigosa says. "That is why we have assembled a diverse team of the best minds from industry, government and academia for our Kaleidoscope Project."

Ortigosa says the project now makes possible the full realization of next-generation seismic imaging technology, including a specialized technique called reverse time migration (RTM), that will accelerate and streamline oil and gas exploration by several orders of magnitude compared to current industry standards.

RTM is based on the solution of the two-way acoustic wave-equation. This technique relies on the velocity model to image turning waves. These turning waves are particularly important to unravel subsalt reservoirs and delineate salt flanks, a natural trap for oil and gas. Because it relies on an accurate velocity model, RTM opens new frontiers in designing better velocity estimation algorithms.

RTM has been widely recognized as the next advance in seismic exploration, as it can overcome the limitations of current migration methods in imaging complex geologic structures that exist in the Gulf of Mexico. However, the chief impediment to the large-scale, routine deployment of RTM has been a lack of sufficient computer power. RTM needs 20 times the computing power used in exploration today to be commercially viable and widely usable.

Hence the creation of the Kaleidoscope Project, which unites the necessary components of modelling,

algorithms and the computing power of the MareNostrum supercomputer to realize the potential of RTM.

In fact, to develop the needed petascale application, Ortigosa says there was a need for geophysicists and computer engineers to join forces and work toward the common goal of enhanced seismic imaging capabilities.

"That is the reason why the Kaleidoscope Project brings together a constellation of geophysicists and computer engineers from the academia [BSC] and from the industry with companies like an international oil company [Repsol] and a service company [3DGeo]," he explains.

Uniquely, the Kaleidoscope Project is simultaneously integrating software (algorithms) and hardware (Cell Broadband Engine, or Cell BE, architecture), steps that are traditionally taken sequentially. This unique integration of software and hardware will accelerate seismic imaging by several orders of magnitude compared to conventional solutions running on standard Linux clusters.

"The academia brings into the project the theoretical algorithms and the computing knowledge, while the industry brings into the project the practical application and the business side. The international collaboration guarantees that different points of view and perspectives are considered."

It would appear that the game plan was successful. Through the collaborative project, Ortigosa says Repsol now has exclusive access to the "three key components" of advanced seismic imaging: the RTM codes through Repsol's relationship with the pioneers of the technology; privileged access through BSC to Cell BE-based systems; and exclusive access as well to the MareNostrum supercomputer for use in the oil industry.

IBM developed the Mare- Nostrum supercomputer and co-developed the Cell BE processor. Public benchmarks show that the Cell BE processors perform the computation of algorithms central to seismic imaging, called fast Fourier transforms, 40 times faster than leading brand processors.

Ortigosa says Repsol's integration of the various components that make up the Kaleidoscope Project will ensure that RTM imaging is a routine, cost-effective reality for oil exploration. The company began deploying elements of the new Kaleidoscope RTM technology in the first quarter of 2007 and will soon complete the project.

"We have finished most of the imaging codes and now we have them running on [an] Intel platform. We have almost finished the porting of the codes to the cell processor and we have observed in the kernel a speed increment of 20 times in the RTM when compared to common processors," he says.

"We have already processed several projects and we are using them for our exploration business. We can now see images of the subsalt section not seen before in the industry and we anticipate that this technology will add significant value to ourselves and our potential partners."

With the lion's share of work on the Kaleidoscope Project now completed, Ortigosa says efforts to further refine the technology will be ongoing. "The project finishes at the end of the year but we will continue adding new seismic imaging tools to our Cell BE library of software," he says. "We will also work on the land version of these tools to apply them to complex areas like foothills."

## **CONTACT FOR MORE INFORMATION**

Francisco Ortigosa, Repsol, Tel: (281) 297-1074, E-mail: [fortigosa@repsolypf.com](mailto:fortigosa@repsolypf.com)

[Table of Contents](#)

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