THE AMERICAN OIL & GAS
REPORTER®
JULY 1998

New Technology

4-D Enabling Command-And-Control

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PALISADES, N.Y.–The exploration and production sector of the oil and gas business is generally behind other complex field-intensive industries in the application of integrated command-and-control practices. In fact, the downstream is very good at computational control of the refining and marketing aspects of its business. All modern refineries are now run by supercomputers, and the gas station without a satellite dish is an anomaly. The refinery command-and-control technologies were developed with massive expenditures for design and software programming in the 1970s, followed by installation and plant conversion in the 1980s.

Similar developments in the E&P business have had to await the emergence of an integrated understanding of the behavior of subsurface reservoirs over the lifetime of fields. Such a unifying theory of how oil and gas drainage really works is a requirement before command-and-control can be properly designed. The realization of 4-D earth models of oil fields in the 1990s has finally provided that foundation–combining geophysical, geological and production engineering views of the subsurface into an integrated model that is needed to move E&P into modern command-and-control business practices in the 21st century.

Command-and-control requires the real-time integration of all incoming data sets required for an accurate visualization of whatever is being controlled, and simultaneous outgoing command over future events. Simulation of many possible future scenarios is a requirement of successful business plan optimization within such control centers. Whether in the air or at sea in one of the U.S. military's combat command centers, in NASA's mission control center (Figure 1), or at the controls of a nuclear reactor, computers fuse the products of monitoring and simulation to visualize the battle field, the space shuttle mission, or the power plant operations in order to optimize outcomes.

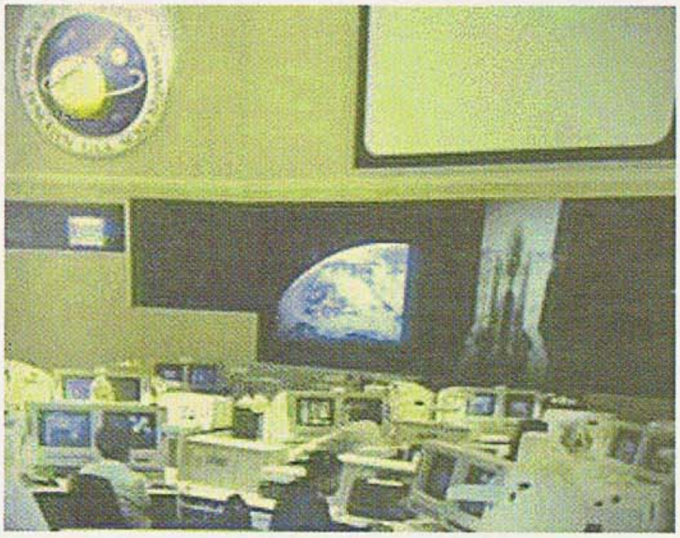
In order for command-and-control to become a reality, data must be continuously collected in real time over packet-switched communication links from sensor networks placed in the field and making relevant measurements of the physical environment to be controlled. Computations must then be distributed across a high-speed information infrastructure–all steered at a visualization and realization nexus by remote personnel who are comparing model simulations of what is expected with observations coming from the field of what is really happening in the subsurface.

Major E&P Changes

There are major changes on the horizon in the way the oil and gas industry approaches its tasks of exploration and production. The integration of discovery, development, and exploitation of new oil fields now shows parallels to the transition that occurred over the last 15 years in the aerospace industry, where engineers transitioned from designing airframes in wind tunnels to entirely computer-aided design. The Boeing 777 went directly from the computer to construction without ever seeing a wind tunnel. Drilling is our industry's "wind tunnel," and in the future, no new well will be drilled until hundreds of possible well path scenarios have been simulated to optimize the business result.

The computational simulations required to go from initial design to scenario playing, to most efficient option selection, and then to drilling have significantly different information infrastructural needs than those present in the industry today. It is important to understand the differences, because the mindset

FIGURE 1



An inside look at the NASA mission control center is shown here.

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change is every bit as all-encompassing and difficult as that experienced by aerospace workers 10 years ago, or by the move to integrated teams in our industry in the early 1990s.

Because of the integrated nature of E&P command-and-control, four-dimensional (time-lapse) seismic monitoring must be coupled with elastic modeling and reservoir simulation to create the computational codes for simulating the most efficient production scenarios of both existing and new fields. The expertise for this incursion of geophysics into what engineers do, and engineering into what geophysicists do, has become more distributed across organizational boundaries, because at the same time, expertise in both disciplines have been downsized.

Personnel Demands

Combine this trend with the coupling between the interpreter and the modeler, and one can see that the E&P command-and-control environment of the future will require newly trained, inter-disciplinary personnel who are one step evolved from today's multi-disciplinary teams. The influx of such cross-disciplinary thinkers will be similar to personnel changes already in place in aerospace, military, and the downstream portions of the energy business.

In turn, the interoperation between geologic, business optimization, and engineering software codes presents needs for delivering data in formats acceptable to the consumers of the data in an automated and seamless manner. These needs often concern regridding to match spatial-temporal resolution and extent of the various data sets. The data services function of the E&P command-and-control center of the future will provide interpolation and extrapolation functions as part of its basic data delivery role for interpreting programs.

This functionality can also be used for coordinate system conversion. The distributed buffering of the underlying networking support can be used for efficient data transport in cases where extrapolation, interpolation, or downsizing are provided by an orchestration layer. For example, data can be downsized at a location close to the data generation site (in terms of network connectivity), whereas it is advantageous to execute data extrapolations closer to the consumer of the integrated data sets. The interpolation of unevenly spaced data to full grids (kriging) is a interesting application of this functionality that has already crept into reservoir characterization applications.

It is interesting to discuss the remaining steps necessary to understand how to intelligently assemble these functions. The most influential force that affects the computer processing methodology behind the command-and-control environment is that drainage monitoring and remediation is an ill-posed inverse problem. The mission of E&P command-and-control is to build a simulator for what is happening "down there" at all spatial and time scales of interest, including seismic, well logs, prior knowledge of geological structure and stratigraphy, etc.

Controlling well production, guided by such models, is like a multi-armed Shiva, with information gathering and control arms working at different time and spatial scales. The challenge is to integrate into a visualization and realization nexus (Figure 2), both the instrumentation of the field (seafloor seismic and bore hole fiber optic sensors, for example) and modeling (high-resolution seismic models that can match well logs and surface seismic images at the same time). The controller's implementation goals are to progressively couple today's seismic scale to tomorrow's reservoir scale.

The 4-D Weapon

True command-and-control technology requires tools to detect problems with drainage and techniques to optimize response to these problems. The development of real-time 4-D seismic monitoring is one of the major weapons that make the environment work. The critical requirement is to deliver data and interpretations that allow solutions to time-dependent observations in time for production decisions. That is, realistic production time-scales drive the ability to visualize 4-D seismic data and its integration with other geological information and seismic/reservoir models.

The requirement is to take production out of the two-and-a-half-dimensional world (2-D bounding horizons, plus production logs in time) into a true 4-D world of observing the remaining volume and volume change of a producing reservoir over time (Figure 3). Where is the oil and gas coming from

FIGURE 2

E&P Command-and-Control Environment Required Computational Synchronization

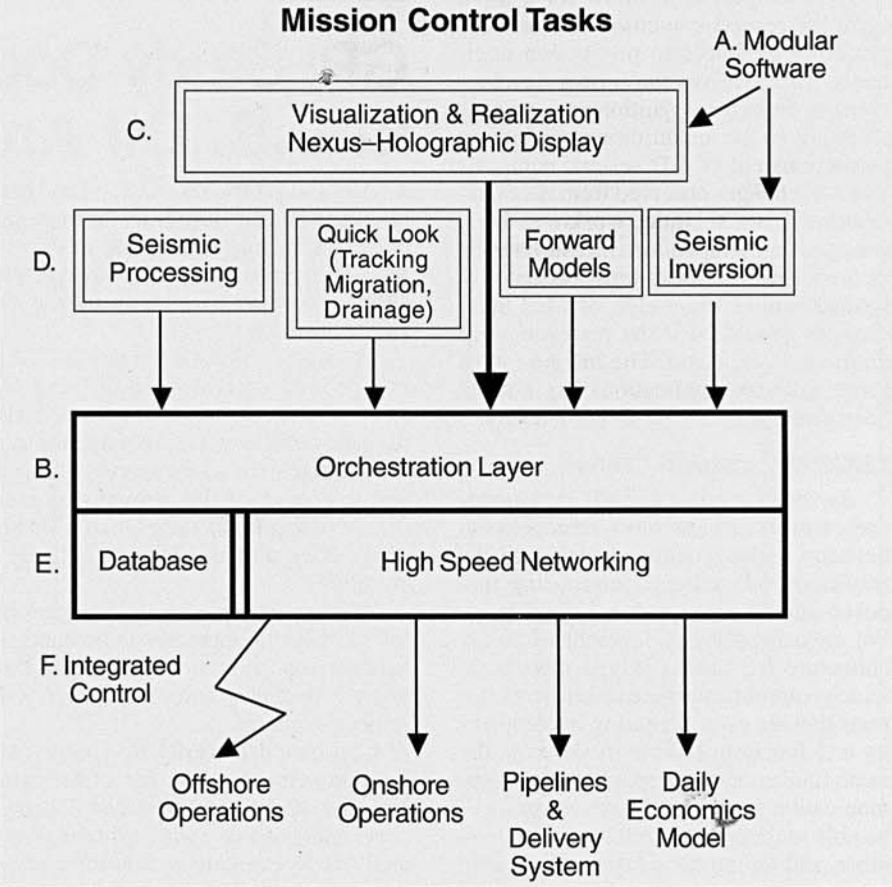
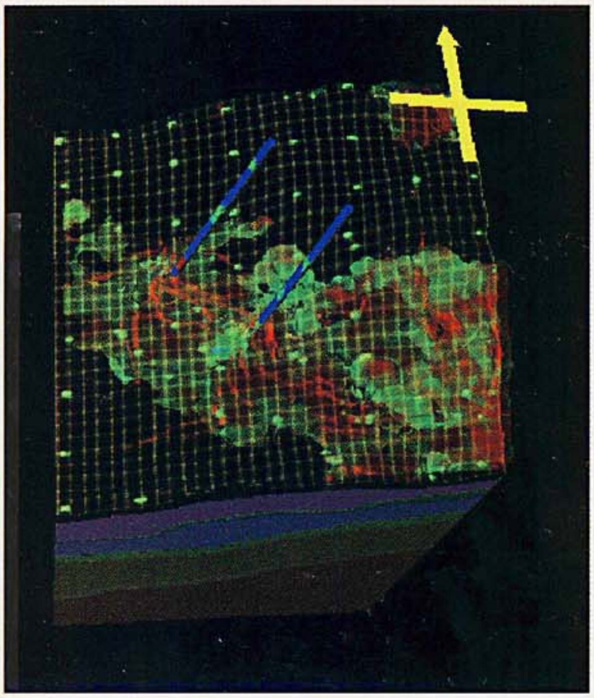


FIGURE 3



Here, 4-D reservoir monitoring tracks the flow pathways (red lines) for oil (green balls) toward two wells (A-12 and A-22). The result is more efficient drainage over the history of the field.

and when, within the context of the true intricacies in the rock that makes up the reservoir and seals?

Another goal is to allow for a more complex reservoir picture than what is presently available to production engineers. This involves the further development of pattern recognition and tracking software to get quantitative production predictions out of 4-D seismic data sets. The 4-D changes observed from the field–whether from seismic, workover logs, pressure and temperature measurements, or the fluid flow itself–must be matched against simulation models of what these changes should be if the reservoir were draining as expected. The integration of these software applications has not yet been done successfully in the industry.

LEGO™ Command Center

As mentioned, the E&P command-and-control center requires interoperation between hydrodynamic models and the results of 4-D seismic monitoring that poses unique computational challenges. We envisage the development of an architecture for LEGO™-type models, in which control centers are assembled from parts that are ever increasing in complexity and function, but are made up to the same fundamental computation and communication standards. These centers will be able to describe themselves to one another, and an interface layer will be able to adapt to a mutually specified set of needs, such as automated spatial and temporal communications.

This vision of the future involves the development of network-based and orchestration protocol layers that can understand the requirements of the models (such as variable mesh geometries among seismic versus reservoir simulator versus fluid flow models), and provide interpolation and unit conversion services between the models. Providing the "concert conductor" function as a network service can lead to profound data exchange bandwidth efficiencies. Providing semantic descriptions of the component-based modules in the LEGO set allows the migration of modules among different hardware and software platforms to load balance and provide security within and between computational resources.

Cost savings, computer cycles and communications optimization, and increased production volumes are the payouts that come from the improvements in scientific understanding of how fluids drain into well bores in the subsurface over time that are required for transition to a successful 4-D E&P command-and-control strategy. A better performing business portfolio is the result. That is, E&P companies can make more money than we ever have before by managing its scarce commodities much more efficiently and productively. ❐

GRI Study Documents Increase In U.S. Oil And Gas Reserves

ARLINGTON, VA.–U.S. oil and natural gas producers have been far more successful at adding to reserves in existing fields than most observers thought possible, according to a study by the Gas Research Institute.

The study–titled *Assessment and Characterization of Lower-48 Oil and Gas Reserve Growth*–concludes that during the past decade producers have replaced production with new reserve additions, and that most of that growth has come from existing fields rather than from new discoveries, a trend GRI says is likely to continue.

"The growth in reserves has matched the incremental increases in demand and has been especially strong in the past three years," declares John Cochener, GRI project manager.

Conducted for GRI by Energy and Environmental Analysis Inc. of Arlington, Va., the study used traditional growth curve analysis along with database growth analysis to evaluate trends in lower-48 reserve growth, and compared recent national growth assessments. In addition, GRI states, the new reserve assessment incorporates an analysis of vast amounts of historical oil and gas production and completion data from public and commercial databases.

The study produced new, revised estimates of reserve growth for use in the GRI Hydrocarbon Model, a key component of the annual GRI Baseline Projection, according to the institute. The result is that crude oil reserve growth potential from existing fields in the continental United States is estimated to be 29.9 billion barrels, while natural gas reserve growth potential in existing fields is estimated to be 433.8 Tcf (385.7 Tcf from non-associated gas and 48.1 Tcf from associated gas). Growth in natural gas liquids reserves in existing fields is estimated to be 20.7 billion barrels. The gas estimate is about 32 percent higher than that of the 1995-96 U.S. Geological Survey/Minerals Management Service assessment, which GRI evaluates along with estimates from several other organizations. ❐