Technical innovation: An E&P business perspective

ROGER ANDERSON, Energy Research Center, Columbia University, Palisades, New York, U.S.

Technical innovation in the E&P business is surprisingly difficult. It is a puzzling anachronism because the improved performance that the use of high technology brings to the industry is often counted on to improve our collective performance in the future. In any industry, it is easy to identify the financial benefits that accrue from an overriding philosophy supporting innovation, and it is fair to say that the present technology and information world outside oil and gas has been built on just such a foundation. It is my view that our difficulty arises not from a lack of infrastructure but from the inherent complexities of our "manufacturing" process. There are just simply so many variables that can go wrong during implementation of an invention in our business.

In this article, I present two case histories (one in E, one in P) that illustrate the complex unknowns that must be accommodated during the exploitation phase of an innovation if the new technology is to succeed in the marketplace. I want to first dispel a rather commonly held view that it is difficult to quantify the financial benefits that new technological innovations bring to our industry. When successful, the results are quite spectacular. For example, those companies that invested the largest percentages of their E&P budgets in R&D over the last 15 years have clearly outperformed their competitors.

We at the Energy Research Center at Columbia have studied the performance of 27 publicly traded E&P companies using the 12 business metrics most commonly followed by Wall Street to track success. We have monitored profit, profit per barrel, reserves size, new reserves discoveries, reserves replacement %, reserves replacement costs, production, production costs, return on capital employed (ROCE), net present value (NPV), Capex, and market capitalization for all 27 companies. We have compared these to our innovation metric mentioned above—this ratio of R&D expenditures to overall E&P capital expenses. The R&D / E&P ratio correlates with excellent performance in all other metrics for 16 of the 27 companies and with a clear majority of the metrics for the rest! Although correlation does not itself verify cause and effect, it does hint strongly. In Figure 1, for example, I present a three-axis crossplot of profit versus ROCE versus R&D / E&P ratio. I've added a fourth metric, profit / bbl, represented by the size of the discs, with the more profitable companies represented by smaller discs. Each red disc represents the performance of one of the 27 companies listed at the left. The blue arrows represent the pattern of overall public company performance relative to the three axes, and I've shown the ROCE versus R&D / E&P and profit versus R&D / E&P alone by the blue shadow dots in the background. This shows that profit correlates better with R&D / E&P than does ROCE.

A dendrogram connects similar clusters in *all* 13 dimensions of business metric performance that we have been examining to form a connectivity "tree" of the most "like-clustered" companies. The horizontal lines in Figure 2 show relationships and pairings that sometimes are not obvious to visual inspection in a spreadsheet table, for instance. In our case, all 27 companies were plotted in 13-dimensional

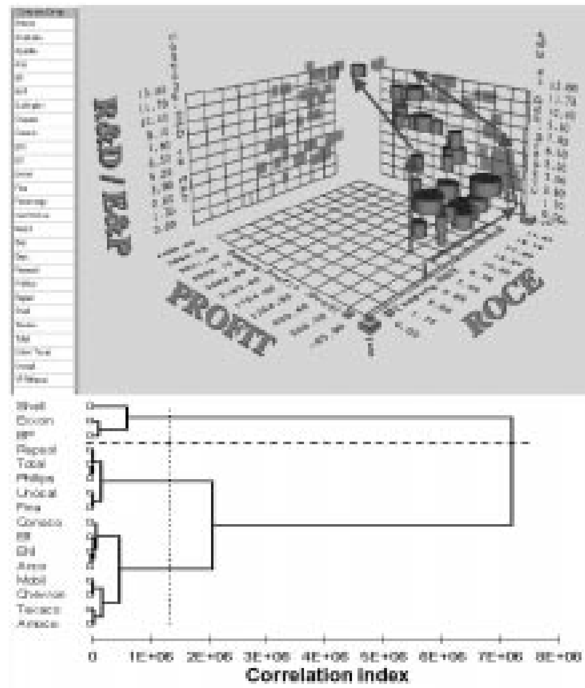

Figure 1. Correlation index of R&D/E&P to 12 other business metrics. The 16 companies with positive correlation are grouped according to similar overall performance in the dendogram below.

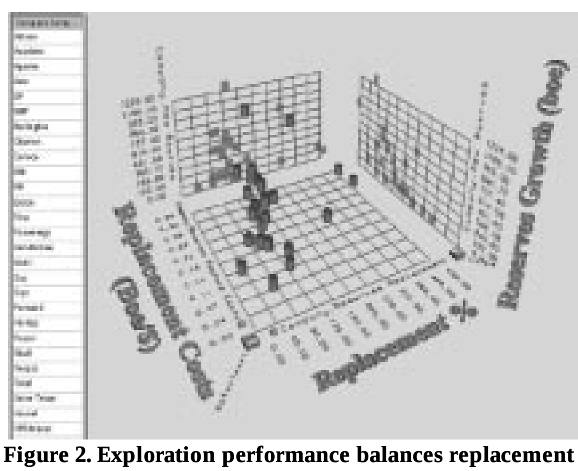

Figure 2. Exploration performance balances replacement percentage, costs, and reserves growth.

space—one axis for each business metric—using principal components. Those that had strong positive correlation between metrics and R&D / E&P are shown with the horizontal lines in the figure. The vertical lines link the most-alike companies from a performance standpoint. The dendrogram tree shows that Shell, Exxon, and BP formed a performance cluster that was different from that of the other 13 companies. There is no "better-than" information in this type of plot, just "similar-to" data. The other companies, in turn, are paired into three additional clusters.

The conclusion from this analysis of Figures 1 and 2 is that the supermajors have indeed reaped significant advantages from their technological leadership of the industry, yet have not differentiated among themselves to date. Yet this R&D / E&P expenditure ratio for all companies has steadily declined throughout the 1990s.

We see elsewhere in this issue that the very business model being developed by each major player in the industry is undergoing a varied and widely diverging evolutionary metamorphosis. How is it then that, with all the divergence in business models, the one common parameter that we have found is the decline in *all* models of the R&D / E&P ratio (with the notable exception of Exxon)? One reason, I believe, is a fundamental misunderstanding among all stakeholders in our industry (management, Wall Street, and entrepreneurs like myself) of the complexity of the business case supporting increased technology innovation. Adoption is not nurtured through the complexity in our industry like drug developments are in pharmaceuticals, or like new chip designs are in the semiconductor world, or like new communication devices are in the computer world.

So where is the disconnect? And how do those of us in the industry who consider ourselves entrepreneurs (sometimes translated as "lab rats") cope with this extremely complex innovation environment?

Let's start with the basics. How do we establish the cost-effectiveness of technological innovations before we launch into commercialization? E&P companies make money based on their skills in identifying a portfolio of oil and gas properties and utilizing technologies to discover, produce, and sell oil and gas produced from those properties in an optimal and sustainable manner. So new technological innovations are at the very core of our success as companies.

Superior E&P performance rests in the capability to know how, when, and in what order we chose to execute technologies that in turn bring oil and gas to market. Business benefits such as increased earnings, ROCE, production volumes, NCF, and reserves additions must be balanced against the cost of adoption to obtain a maximum likelihood of successful execution of any new technology in the oil patch. Any technological innovation must speak directly to these business metrics if it is to have any hope of widespread adoption.

Exploration innovation. Exploration performance of companies varies widely, from those that consistently find abundant new reserves at cheap cost to those that have recently found little at high cost (Figure 3).

This variability is surprising given the widespread commercial availability of sophisticated new technologies such as 3-D seismic surveys and multilateral drilling. Although the balance sheets of the poor exploration companies often look fine for the near term (and share prices are holding), they are not booking sufficient new reserves to replace those being produced (they are liquidating). Such a crisis environment should spur the use of new technologies, and yet the recent price fluctuations have served to mask the danger more than enhance its solution. With oil at $12 / bbl, cost cutting was all the rage, and now at $30 / bbl, companies look good even if they invest little in technological innovation. Such instability is a definite detriment to successful innovation because it raises the risks of failure substantially. Let's examine the hazards learned from one high technology exploration start-up that I was involved in that went into bankruptcy with the collapse of the oil price in 1998.

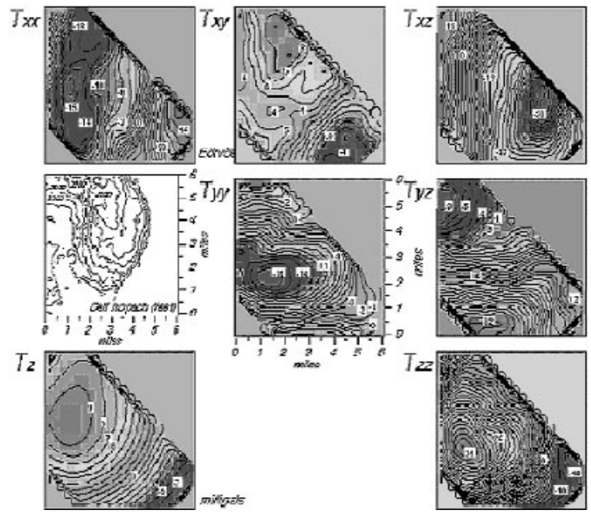

Figure 3. Bell Geospace's exploration surveying business suffered when oil prices plummeted. A more conservative method of deploying its surveying instruments may revitalize the company's operations.

Bell Geospace is a spin-out created in 1994 by my group at Columbia University and management from Bell Aerospace, then a Textron company. Financing was spearheaded by ARCH Venture Partners (an investment firm begun by Argonne National Laboratories and the University of Chicago, see *Fortune*, October 26, 1998, page 143). Grace Brothers and Donaldson, Lufkin, & Jenerette provided additional financing. Bell Geospace holds exclusive licenses to oil industry applications of Bell Aerospace's 3-D Gravity Gradiometry System (see *Scientific American*, June 1998). Bell (now a division of Lockheed Martin) was the inventor of this highly innovative stealth navigation device for the Trident Submarine program. The Bell gravity gradiometer, a complex instrument that measures the full 3-D tensor of the earth's gravitational field, was deployed late in the cold war as a way for ballistic missile submarines to silently navigate via the mapping of the gravitational gradients of the seafloor (no acoustic pings are needed). A real-time map was acquired with the Bell device and compared to known seafloor topography to create "windows-under-the-sea," as the U.S. Navy referred to the program.

My group first became engaged in the highly classified technology when seafloor topography "phantoms," or structures that did not exist, kept appearing in the data —in troubling locations such as west of the Shetlands, the Gulf of Mexico, and the Persian Gulf. It soon became apparent that the gravity gradiometry instrument was detecting subsurface basalt and salt features.

With the end of the cold war, deployment of the system was curtailed. However, the U.S. Navy was anxious that the technology not go away, in case it might be needed in the future, so it suggested that we and Bell apply for declassification of the data (but not the instrument), under the Pentagon's newly emerging dual-use program. In order to attract venture funding, we had first to convince the Pentagon's deputy director of RD&E (research, development, and engineering) that national security issues would not be compromised by use of the technology for worldwide oil and gas exploration. That decision rested with Anita Jones, who ran the nation's most elaborate R&D organization, DARPA, among other responsibilities.

I will never forget making the presentation to Dr. Jones in the Pentagon's "inner ring." Our industry was very lucky because, as I was just beginning to launch into my case for both the importance of oil and gas to the nation's future and the difficulties in finding it beneath salt and basalt, Dr. Jones stopped me. Turning to several admirals in the audience, she said that she knew the technology would be useful because her father had been a Schlumberger field engineer for many years! "Any new measurement that helps with this problem will be welcomed with open arms by the oil industry!" she assured the admirals. In any event, she fast-tracked the declassification process but with a prescient warning to me that the business model for how to sell the data, not just the technology, would still have to be made by our new spin-out.

The company was formed in late 1994, and by 1997, new specially built gravity gradiometry instruments had been deployed on two specialty ships in the North Sea and Gulf of Mexico. The Bell business model concentrated on reducing exploration uncertainty in 3-D depth imaging by high-grading seismic models derived from velocity measurements of the subsurface with density measurements made by the gravity gradiometry system. The gravity view of a salt dome (Figure 4, lower left) can be contrasted to the much higher resolution of the six independent tensor views of the various edges of that same salt dome in the upper right panels.

As Bell expanded its market, the technical acceptance curve was being overcome slowly but steadily, with more than 1000 blocks surveyed in the deepwater Gulf of Mexico by late 1997. Plans were in hand for deployment west of the Shetlands and in offshore West Africa by 1999.

Then the price of oil collapsed, and Bell's exploration surveying business dried up. In retrospect, the problem that caused Bell difficulties (subtle at the time) was that the gravity gradiometry instrument was built for deployment on a fast-moving submarine (maximum speeds are classified but very fast). Deployment on a seismic ship, as is common practice for standard gravimeters, would result in an order-of-magnitude slower acquisition speed and a slower ramp-up for the new business. So the company took long-term leases on ships that did nothing but gravity gradiometry surveying (and the required accompanying swath mapping of the seafloor).

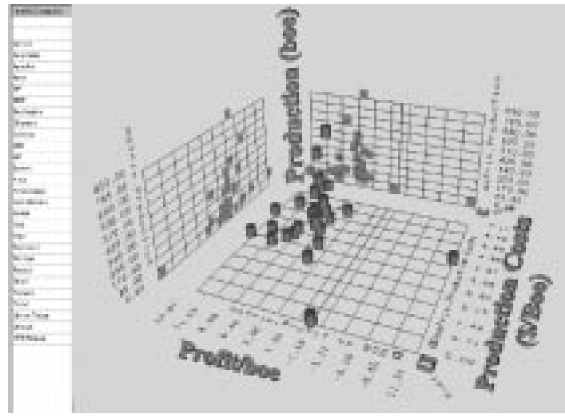

Figure 4. Production performance balances growth, costs, and profit per barrel.

The E&P industry has a maxim that good technologies never go away, only business models change. The gravity gradiometry measurement is physically sound. The industry knows that gravity gradiometry is useful as an exploration tool because many giant fields, such as Long Beach, were discovered with crude versions of this technology way back in the early 20th century (then, a special wooden shack had to be built out in the field to make a single tensor measurement that the Bell system makes every .0.01 s while steaming at full speed in the open ocean).

In retrospect, the risk of price variability dictated that the instrument should have been deployed on seismic vessels and in much cheaper land deployments. Bell will soon reemerge from bankruptcy using this much more conservative deployment model. Lessons learned from this case history are that the transition from invention to exploitation to innovation is fraught with unpredictable business complexities. Unquestionably, innovation is easier in other industries where more stable pricing is enjoyed.

Production innovation. The widespread use of new technologies has not resulted in uniform improvement in production metrics either. The performance of producing companies is also all over the map from a business perspective. Consider, for example, a comparison of production, profit / bbl, and cost / bbl for our 27 E&P companies (Figure 4). The highest volume producers have the lowest costs / bbl (as might be expected from economies of scale), but they also have the lowest profit / bbl (an interesting puzzle, suggesting cheaper but more inefficient production).

The trick for any of these companies, of course, is to assess the risks versus rewards inherent in the linkages between (1) the application of new technologies to improve production of reservoirs versus (2) the maximization of both short- and long-term profitability. The low-volume producers seem to be all over the map with regard to decisions related to this mix of technology choices versus business benefits.

There are many new and exciting technologies related to reservoir characterization, reservoir simulation, and seismic observations and models that boost field performance. However, they must be cost-effective in a varying pricing environment that produces cash and / or grows reserves of constantly changing valuation. Technologies that discover bypassed reserves, improve drilling success, produce better performance of individual wells, speed delivery to market, etc., should be easy for any E&P company. However, only the best companies have been adroit at recognizing the technologies that accrue true benefit to the portfolio as a whole.

A production case history. The tracking of oil, gas, and water drainage over time is a required condition for any cost- and profit-efficient reservoir management system. Consequently, 4-D (time-lapse) seismic differencing holds great promise as the keystone to an integrated reservoir management strategy. 4D Technology, Inc., was a new spinout from my group at Columbia and BBN (now the Internetworking division of GTE). BBN built the original DARPA Net for the military that has evolved into the Internet and has for years specialized in integrated systems management for the U.S. military. BBN is most famous, perhaps, for putting the @ in all e-mail traversing the planet!

In any event, my group at Columbia was approached by BBN for help with commercialization of a reservoir optimization system for oil fields. BBN had the systems integration experience but not the core competency required to develop the software and data integration necessary to build such a system on its own. The connection was again fortuitous in that Billy Meadows, VP for Business Development at BBN, was an avid reader of the *Oil & Gas Journal* because his father had a long career in international communications at Motorola (and oil companies were a major client base).

Together, we identified a market need for a 4-D rapid analysis and interpretation tool kit for quick differencing of multiple vintages of 3-D seismic surveys. In its formative stages, this software had been developed through a DOE contract and was in the process of being patented by Columbia. The DOE project was itself an out-of-the-box experiment in Eugene Island, Block 330, offshore Gulf of Mexico, that was designed to drill into a fault zone pathway of oil and gas migration from deep, subsalt sources into shallower producing reservoirs (the “refilling” oil field that you may have heard about). Identification of the migration pathway required the differencing of multiple 3-D seismic surveys (in this case four different vintages of 3-D seismic surveys, all acquired over the same field).

4D Technology, Inc., then conducted a market analysis of how best to exploit the new technologies. Instead of going directly to market as a start-up company, 4D Technology took the alternative path of licensing the software tool kit to a major oil services company. This 4D Rapid Analysis and Inversion (RAI) software is now being marketed by Western Geophysical (recently acquired by Baker Hughes, International). That product helped Western acquire a significant number of 3-D reshooting surveys, particularly in the North Sea. When combined with its expertise in 4-C multicomponent seismic acquisition and processing, the new software gave Western Geophysical a significant competitive advantage in the newly emerging 4-D marketplace.

4D Technology, Inc., is an example of a holding company that profits in turn from successful implementation, deployment, and marketing by a larger, more established oil services company. There are many models for technology deployment. The form and degree of complexity of the technology itself often dictate the appropriate business model for proper exploitation.

My group at Columbia and Western Geophysical have since followed up on the success of the 4D RAI technology with a new, jointly owned Internet spin-out called Vpatch, Inc.

For decades, the oil and gas industry has envisaged and sought what has remained the Holy Grail of reservoir management: the technology to interoperate among multiple software applications and many large data sets using a flexible and customizable work-flow engine.

Vpatch has built a computational operating framework for this complex computing environment—one that E&P companies require for their daily business. We hope that our technology will place us in a unique position to aggregate software applications through a Web-based integration platform and become an application services provider (ASP) for the E&P industry.

An ASP is a contractual service offering to deploy, host, manage, and rent access to many different vendor applications from a centrally managed facility. ASPs are responsible for either directly or indirectly providing all the specific activities and expertise aimed at managing software applications or sets of applications both inside the client’s Intranet and over the Internet.

The ASP Internet world has leveled the playing field so that start-ups such as ours can compete with the big service companies for direct marketing of enterprise management systems to even the largest E&P companies. What remains to be dealt with are the unforeseen complexities that, together with the skills of the management, will decide the fate of this latest of our innovation experiments. Alhough the outcome is unpredictable, the ride will certainly be something to behold. TLE

Corresponding author: anderson@ideo.columbia.edu