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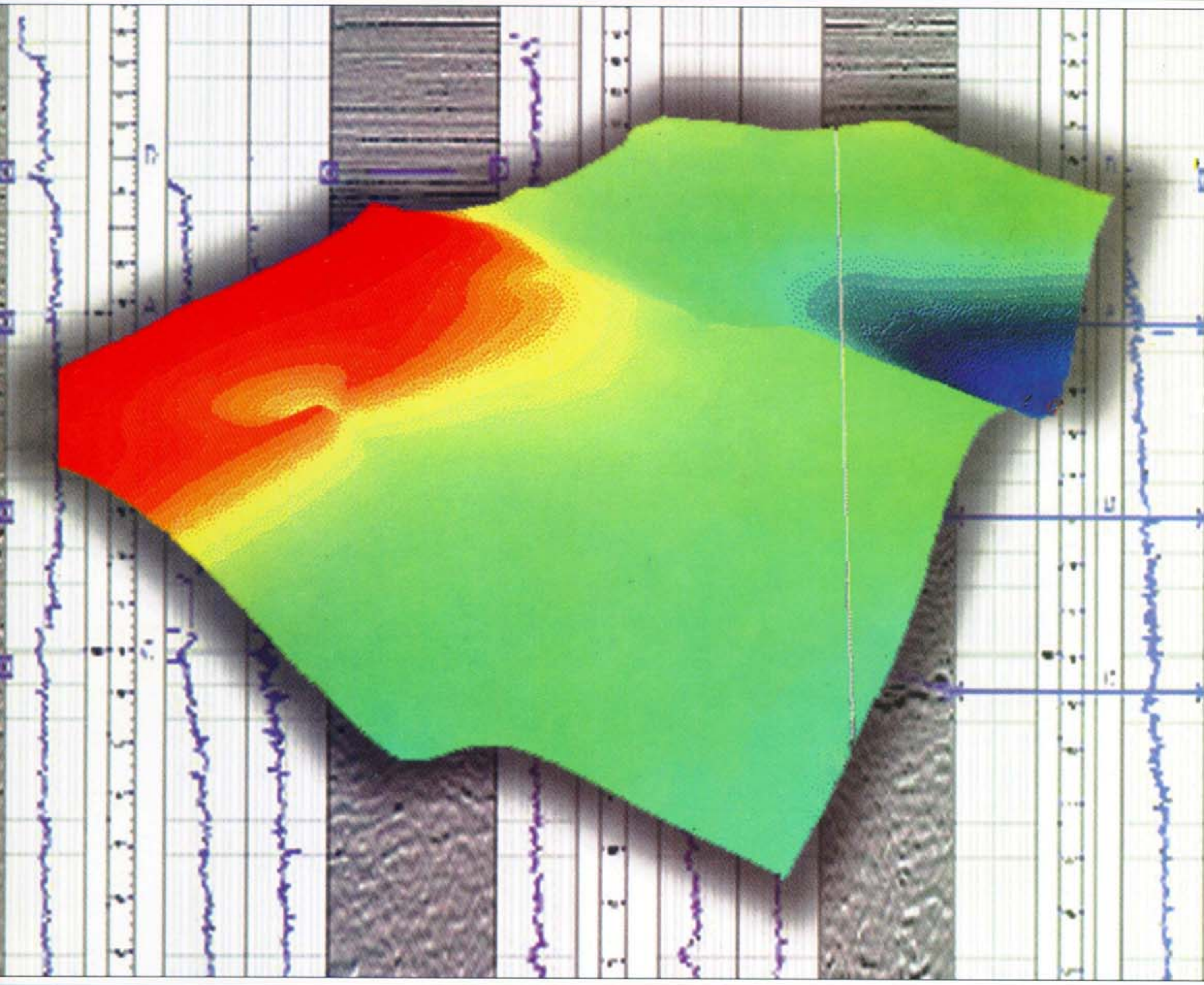

EXPLOITATION DATA MANAGEMENT PAGE 36

Quantitative Tools Link Portfolio Management With Use Of Technology

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The exploration and production (E&P) business is in the midst of a major transformation from an emphasis on cost-cutting to more diverse portfolio management practices. The industry has found that it is not easy to simultaneously optimize net present value (NPV), return on investment (ROI), and long-term growth. The result has been the adaptation of quantitative business practices that rival their subsurface geological equivalents in sophistication and complexity.

The computational tools assess the risk-reward tradeoffs inherent in the upstream linkages between 1) the application of advanced technologies to improve success in exploration and in exploitation (reservoir evaluation, drilling, producing, and delivery to market) and 2) the maximization of both short- and long-term profitability.

Exploitation is a critical link to the industry's E&P profitability, as can be seen from the correlation between earnings growth of the international majors and production growth (Fig. 1). This correlation is taken from 1997 business plans, prior to the latest price dip, which has temporarily affected earnings throughout the industry.

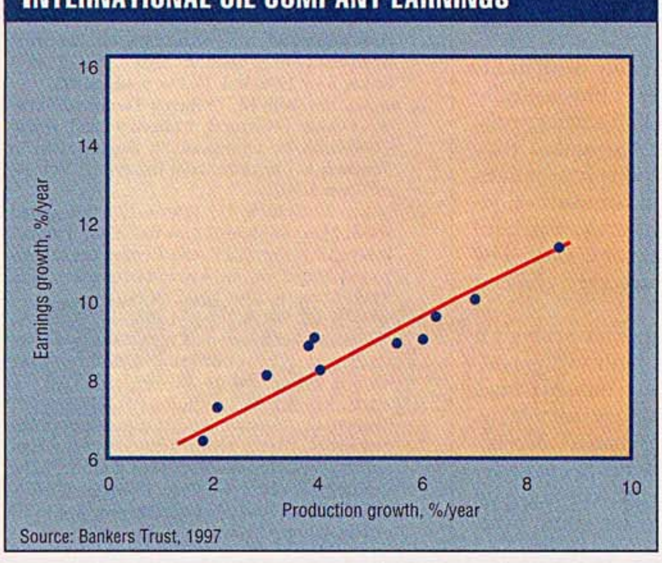
Yet production growth must be matched by growth in reserves; otherwise, an oil company shrinks in value over time (Fig. 2). More than half of the reserves growth booked in 1997 by the international oil companies represented in the figure was from exploitation growth in known fields, rather than from new exploration discoveries.[1] As new petroleum reserves become more and more difficult to discover, exploitation will become even more important. Only those companies that know how to apply exploitation technologies to new growth opportunities will survive over the long term.

Recent performance of companies varies widely, from those that both find abundant new exploration and exploitation reserves and produce their known fields well (companies in Quadrant I of Fig. 2) to those that are good at either production (Quadrant II) or exploration (Quadrant III). Some companies have not had much recent success in either exploration or exploitation growth (Quadrant IV).

Though the balance sheets of the Quadrant IV companies look fine for the near term (and share prices are holding), they are neither booking sufficient new reserves to replace those being produced nor efficiently exploiting the fields they own. How then do companies that are not optimized for both production and reserves growth chart a path forward to improve their technical performance

Fig. 1

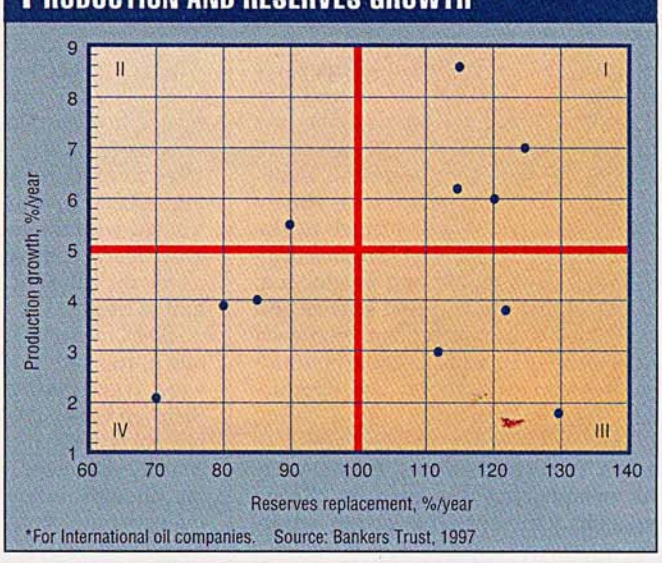
INTERNATIONAL OIL COMPANY EARNINGS



Source: Bankers Trust, 1997

Fig. 2

PRODUCTION AND RESERVES GROWTH*



*For International oil companies. Source: Bankers Trust, 1997

Fig. 3

GENERIC E&P PORTFOLIO

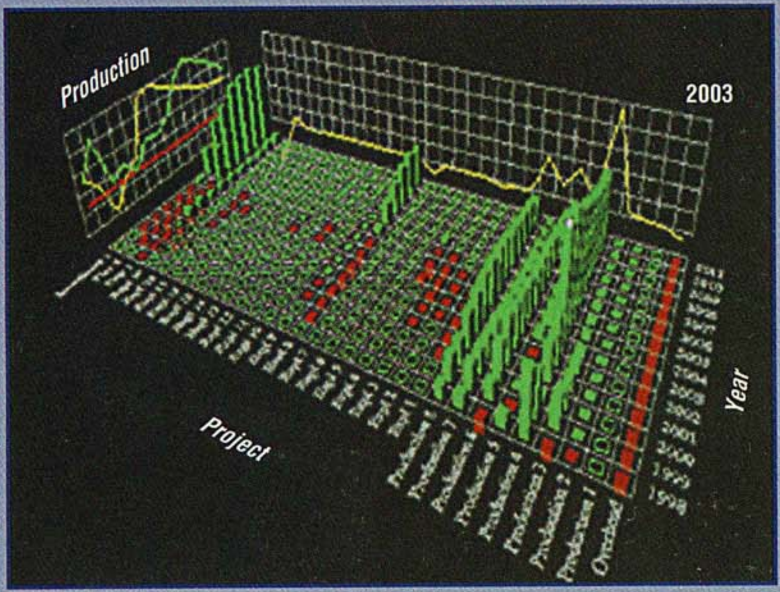


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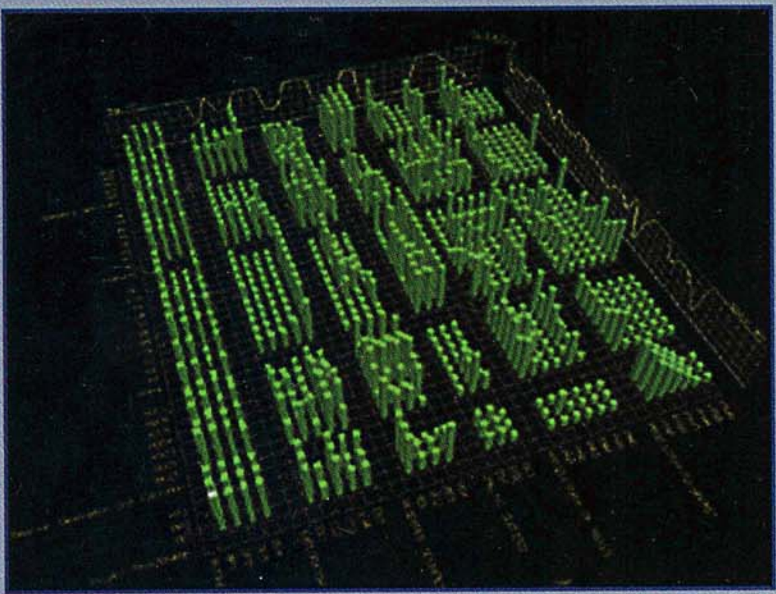
Fig. 4

TECHNICAL SUITABILITY MATRIX



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and keep themselves in business over the long term?

The exploitation portfolio

The first step to improved performance is to identify the importance of each field to the business unit's overall portfolio.

Every company is different and must uniquely balance NPV, ROI, and growth in order to prosper. Fig. 3 presents an example of the portfolio of a generic E&P business unit that is trying to both increase its NPV and grow. This portfolio has 8 producing properties, 19 exploration possibilities, and 3 recent property acquisitions. Near term cash flow must come from producing properties. Only one exploration property (exploration No. 8) and one acquisition need pay out for the business plan to succeed, assuming that the exploitation program succeeds.

However, production properties No. 6 and then No. 4 are scheduled for big development efforts that must be successful in order to provide out-year cash to meet the business goals of the unit. It is obvious that expenditures on whatever technologies that are necessary to make these developments succeed will be cost-effective to the overall business objectives. But cash flow takes a big hit in the 2 years prior to the onset of the benefits from the developments. That makes the performance of properties No. 3 and No. 7 also critically important because they are providing the near-term cash to allow for the long term development of properties No. 4 and No. 6.

In order to realize overall portfolio improvement, technologies likely to enhance production must be appropriately selected and applied to fields in the order dictated by the portfolio: first No. 3 then No. 7, No. 8, No. 6, and No. 4. It makes little sense to apply enhancement technologies to other properties that do not have the potential to improve the business unit's overall economic performance. Properties No. 1, No. 2, or No. 5 are too small and too far along the depletion curve.

Technical suitability matrix

The next step is to evaluate the appropriateness of the various development technologies available to the industry to solve the specific production problems relevant to performance of the portfolio.

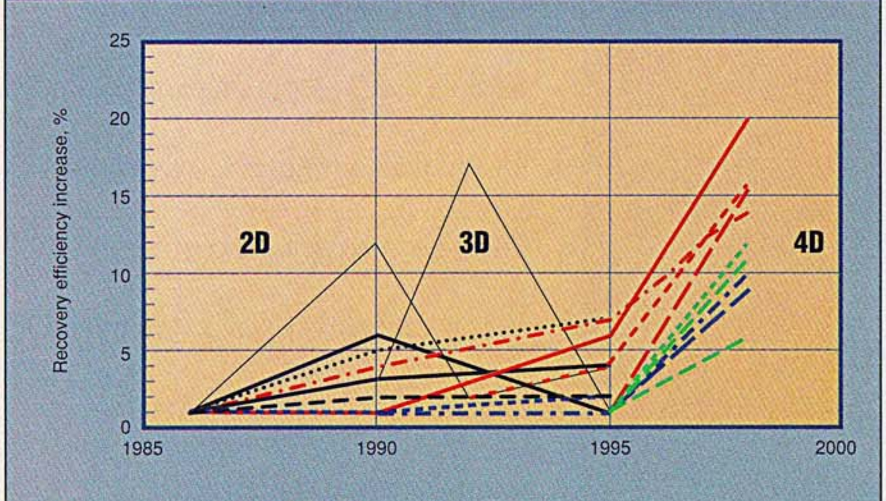
Technologies are related to reservoir characterization, drilling, producing, and integration (rows in Fig. 4) and must be selected on the basis of their suitability to boost specific performance attributes that produce cash or grow reserves, such as the petroleum system in exploration, and reserves definition, drilling success, producibility of wells, and production to market in exploitation (columns in Fig. 4). Only technologies that are suitable to specific problem attributes accrue true benefit to the portfolio as a whole (highest peaks in Fig. 4).

How does a company make the correct choices?

We suggest that it use a technology suitability matrix, which is defined as an organization-specific method of logical-

Fig. 5

Increased productivity from 20 case studies



*2D baseline in 1986, 3D from 1986 to 1995, 4D since 1995.

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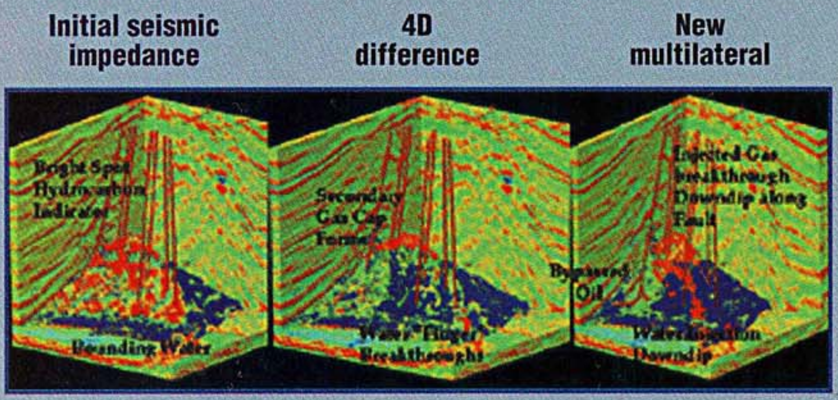
Fig. 6

Exploration strategy using 4D monitoring*



*Combined with advanced multilateral completions to drain by-passed pay chamber.
Source: Anderson, Scientific American, March 1998

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ly focusing the expertise of the company toward best-practice applications of reservoir management consistent with the entire portfolio of the company. In such a matrix, the company rates the suitability of the various technologies available to each field to attributes specific to improve performance of its portfolio.

We have created a technology suitability matrix for the generic portfolio in Fig. 4. Peak correlations represent the most suitable technology-attribute pairs in the matrix for this particular portfolio. The company can select and prioritize where to use which technologies, in what order, and when to use portfolio analysis tools that measure the impact of the technology application on the metrics of the portfolio (see accompanying article). A technical suitability matrix such as that in Fig. 4 must answer questions critical to the performance of the portfolio, such as the following:

1. Which technologies are required in what fields to meet a specific set of complex business goals such as x% NPV growth, y% return on capital employed (ROCE), and z% reserves growth (row 1)?

2. Which technologies enable an advanced understanding of the complex flow of hydrocarbons necessary to maximize drainage from the reservoir to wellbores in those fields of critical importance to the portfolio (row 2)?

3. Which fields are most in need of applied rock physics to analyze and understand seismic and well log responses in terms of porosity, clay content, fluid saturation changes over time, and other physical properties that are critical to meeting portfolio goals (last half of row 2)?

4. Which fields require exotic well trajectories, wellbore damage repair, or improved remedial stimulation to make the flow rates required by the business plan (first half of row 3)?

5. Which wells require changes to drilling and completion fluids and treatments for asphaltenes and paraffins that are costing the portfolio cash that might be critically needed by the business goals (last half of row 3)?

6. Which water or gas floods need to be modified to correct for anomalous fluid front movements that are inhibiting overall field performance (row 4)?

7. Which production teams must be immersed into visualizations of reservoirs and surrounding rock and fluids so that troublesome oil, gas, and water production patterns can be understood in critical fields (row 5)?

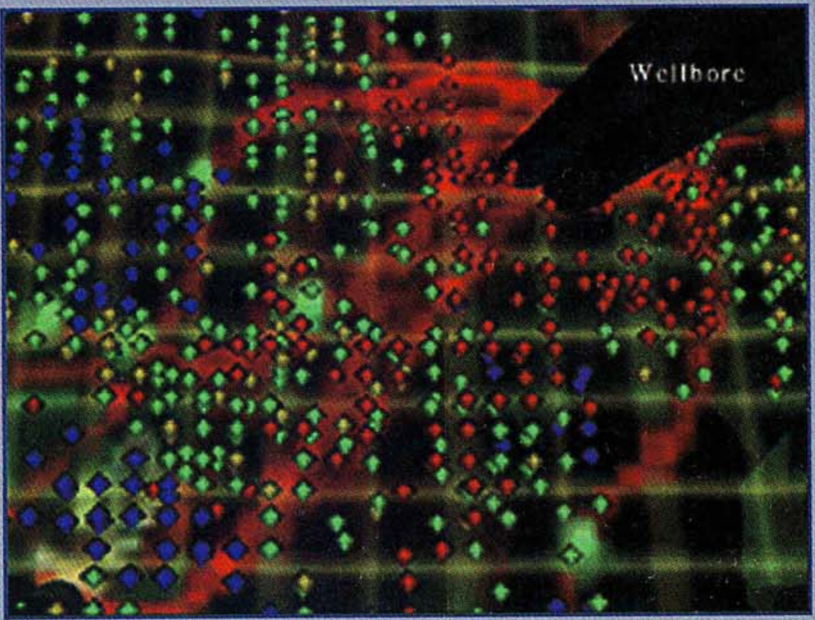
Consider some of the technologies in Fig. 4 that have high suitability within our generic portfolio. For example, 4D seismic monitoring (also called time-lapse 3D) can give quantitative interpretations of the movement of fluid fronts to compare to reservoir simulation predictions. Four-D seismic monitoring provides technologies (row 2 of Fig. 4) that can improve not only reservoir description and characterization (column 3), but also producibility of specific wells (column 5), and speed the delivery of product to market (column 6).

However, 4D works best where multiple, high quality 3D seismic surveys exist (it is more difficult mixing old 2D with new 3D seismic surveys, particularly outside an immersive environment). Four-D also works better offshore than onshore and in soft, unconsolidated sands rather than in hard, carbonate reservoirs. In order to evaluate the business case for deciding in which fields to apply 4D within a business unit, rock and fluid changes must be transformed from acoustic changes (additional components of row 3) into volumes of recoverable oil and gas likely to have been bypassed in each field (column 5 of Fig. 4).

Also, 4D can clearly increase the recovery efficiency of a field (Fig. 5). However, 4D is expensive and can add more than $1/bbl to the cost of producing subsequent oil in a field. If oil critical to the business goals is needed within the generic portfolio (row 1), even at the higher exploitation cost (column 3), then expenditure for 4D technologies is

Fig. 7

Reservoir simulation streaklines*



*Tracking flow of oil (orange) compared with 4D seismic monitoring changes: blue = seismic dimming (water encroachment), red = brightening (gas out of solution), green and yellow = sustained high amplitudes (remaining pay).

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Fig. 8

Portfolio optimization center

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called for. But the increase in production from the application of 4D technologies first arrives at market 2, 3, and more years out (4D takes time as well as money).

Will the added performance arrive too late to effectively optimize the portfolio?

Is the field large enough and the timing early enough in its production cycle to provide maximum economic benefit to the portfolio? For example, if a new deepwater field is predicted to provide a significant percentage of the cash flow of the entire portfolio in the out years, 4D monitoring is cost-effective if only for its added hedge against nasty surprises.

The geological producibility of a new, large field is not well enough known to show up in a normal feasibility study of the probability of success for a 4D study to be cost-effective. If the field is large and important enough, the 4D monitoring becomes a technology option taken out to hedge against failure to meet portfolio objectives in the future.

An example of the importance of getting both the timing and the cost-benefit analysis to fit the portfolio is perhaps best demonstrated with an analysis of a specific 4D field study. In this offshore reservoir, 4D reservoir monitoring has identified a compartment where drainage has bypassed a significant volume of oil (Fig. 6, left vs. center panels). The bypassed pay is isolated from the producing wells by a previously unmapped, subseismic fault (a common occurrence).

Subsequent gas injection fails to recover this oil when the gas instead breaks out along another fault (Fig. 6, right panel; the time-lapse images were obtained with 4D seismic surveillance). Subsequently, a complex, multilateral well is drilled into the compartment, and water is injected in the downdip spur. A large volume of oil is then drained from two other branches of the same well, producing needed midterm cash that is critical to meeting the portfolio's production goals.

Though this example appears on the technical suitability matrix only as a few peaks of correlation (Fig. 4), the field asset team has to execute a quite sophisticated and diverse series of tasks in order to succeed.

First they have to identify and quantify the seismic changes to be expected in terms of changing oil, gas, and water saturation changes. Then they have to image unswept and bypassed hydrocarbon compartments, water and gas breakthroughs, and poor well sweep (Fig. 7). They have to locate bypassed oil and gas volumes quickly and precisely. They have to then steer the drill bit into both the water and oil limbs of the bypassed compartment within a 150 ft thick reservoir more than 10,000 ft below the surface. They have to process and analyze the results of measurement-while-drilling logs and completion tests quickly and accurately in nearly real time.

The effort is expensive and takes 2 years from the beginning of the 4D project to the production of first oil, but this well in this reservoir in this field produces the cash required for success with

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that particular portfolio, so the expenditures are fully justified.[2]

However, the technical suitability matrix indicates that monitoring should not end with the completion of the multilateral well in the example. The water and gas injections must continue to be imaged, and the monitoring of the well's performance must also be tracked (row 4, columns 5 and 6 correlations in Fig. 4). Why? Because most water and gas injection programs in the world inject fluids that do not go where they are expected to go, and that is the case here as well.

The important question of whether this added long-term expense is worth the risk of attaining additional business objectives of the portfolio is answered by the technical suitability matrix.

The matrix also indicates that petrophysics, 4D monitoring, redrills, and remedial water injection designs might not be all that are needed to improve performance in this key field, however. Near-wellbore drilling damage appears to be affecting the producibility of some wells (row 3, column 6 correlation in Fig. 4). Again, this is not surprising because a significant degree of damage is present in 50% of producer wells worldwide.

Other new exploitation technologies are available then to repair the near wellbore damage so that remediation can be planned, but only after it is determined that the added expense is appropriate to the risk of increasing the cash delivered to the business goals of the unit by a substantial amount.

Other technologies related to drilling and producing, such as oil-behind-casing, fractured reservoir permeability, flow unit determinations, low resistivity pay logging, and new formation damage assessment technologies (rows 3 and 4 in Fig. 4), do not show high suitability to needs of the portfolio for this particular example.

New computer visualization technologies, however, do appear to be cost-effective. They allow measurements from the 4D seismic monitoring to be more fully integrated into the 3D view of the volume of the earth in and around the reservoir that is particularly suitable to steering new wells successfully into the bypassed-pay targets (row 5, column 4 suitability in Fig. 4).

Exploitation mission control

Just as the portfolio is combined with the suitability matrix to provide a front end to guide in the selection and prioritization of which technologies are appropriate to implement, where and when, the immersive visualization environment provides an excellent back end for optimizing overall portfolio performance (Fig. 8).

The business unit must interact with a whole range of critical fields as production enhancements proceed over the life of the portfolio. Recent events remind us that other industries have already perfected the capability of visualizing complex system operations: NASA's mission control and the U.S. military's Northstar battlefield control center are two famous examples.

We believe that the industry is making concrete progress toward maximizing the value to shareholders not only through new and wonderful below-ground technologies and proficient, skilled experts but also from an intense focus on improving business performance through portfolio management.

Such performance enhancement requires interoperation between hydrodynamic models of the subsurface and business models at the surface that poses unique computational and human challenges. The latter appears to be the more difficult problem.

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MANAGING

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Modern portfolio analysis tools give decision-makers in the oil and gas industry analytical support and specific guidance to the intuitive sense that the best balance for the business lies in a combination of tactics and simultaneous actions on multiple projects.

Because of the complexity of considering several projects or tactics simultaneously, decision-makers tend to treat their projects and tactics as independent of anything else in the business.

Yet all of the projects in the business interact with one another. Project interactions arise from factors such as price-resource sharing, performance targets, commercial and market interactions, and technical risk.

Knowledge of how projects interact and how the aggregation of all projects sum to meet balanced business requirements should guide decisions. A portfolio perspective helps the decision-maker understand the total impact on business balance resulting from a single decision.

With portfolio tools, the decision-maker is ultimately able to frame options in terms of the probability of meeting a suite of balanced performance targets.

Basic portfolio management

The following example illustrates many of the concepts of portfolio management and the benefits associated with managing assets from a portfolio perspective (interdependence model) rather than from a project-by-project perspective (independence assumption).

We emphasize the decision-maker's perspective. However, the example also illustrates the impact that engineering, geology, and geophysical technologies can have on the portfolio analysis.

Portfolio management serves as the link between a business strategy and the projects selected to exercise that strategy. Thus, the corporate strategy is

E&P ASSETS FROM A PORTFOLIO PERSPECTIVE

the starting point. Decision-makers must select metrics to quantify their strategy as well as multiyear targets for each metric. The targets must be defined for all years of the planning horizon. The time period must be long enough to describe the investment and profit cycle for major projects (e.g., deepwater and large international E&P projects), but not so long that it becomes inaccurate.

Fig. 1 depicts the strategy of a company measuring itself using four metrics—production, reserves, net cash flow (NCF), and earnings—with a 15 year planning horizon. The bars represent the targets, while the area plot represents the company's existing base business.

The base business consists of producing assets, developing assets, and exploration assets. Gaps between the base business (area plot) and the targets (bars) define the performance shortfalls of this company. The gaps clearly define business performance issues the company must resolve.

The company has a small gap in earnings in 1999-2003, which expands dramatically from 2004 until 2013. The company has no gap in production in 1999; however, the production growth goal creates an ever-expanding gap from years 2 until 15.

The reserve metric demonstrates a similar gap, yet here the shortfall begins in the first year and extends over the life of the portfolio. The good news is that the company has excess cash flow between 1999 and 2009 to invest and correct the shortfalls in the other financial and operational metrics.

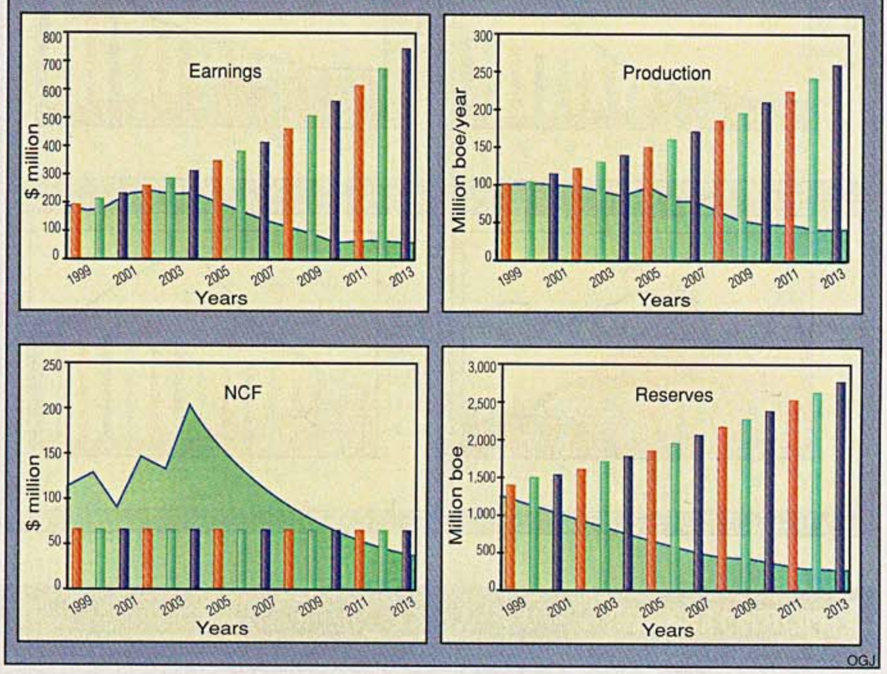
The decision-maker in this company has a formidable challenge. He must identify the appropriate selection of assets to acquire, divest, and reshape such that excesses in certain metrics can be used to fill shortfalls in other metrics. This challenge goes beyond finding good investments.

Good investments must complement the existing asset base and meet the required performance metrics. The likelihood of solving this performance problem by selecting one project or one tactic at a time is very small.

Using portfolio analysis, the decision-maker can describe a range of projects, including exploration, acquisition, and exploitation opportunities. The portfolio model uses linear programming to determine which projects should be selected, what interest

Fig. 1

PRESENT METRICS OF A GENERIC E&P PORTFOLIO



should be taken in the projects, and when the projects should be done. If an appropriate combination of projects can be found that fills the performance gaps, the model is determined to be feasible. If the model is infeasible, additional or different projects may be required, or different performance metrics or targets must be defined. Sources of the infeasibilities represent significant information.

A feasible solution is illustrated in Fig. 2. The target bars and reference area plots are identical to the targets and base business reference data in Fig. 1. However, Fig. 2 includes a dark line that depicts the portfolio solution. The heavy line is always equal to or exceeds the target bar for all metrics, for all years, except for the reserve target in the year 2013.

This target (or constraint) had to be removed to find a feasible solution. The model will be run against these modified constraints for all subsequent analysis. Any place the heavy line exactly equals the target bar (earnings, 2000-2006; production 2002-2004 and 2006; reserves, 1999-2000), the model is tightly constrained. These metrics and timeframes are the critical performance points for this company.

Efficient frontier

Knowing the model is feasible, the decision-maker can proceed to investigate the range of options he has to meet the performance metrics and balance his business performance.

By running the model with increasing portfolio value targets—cumulative net present value (NPV) of all investments—the decision-maker can define the efficient frontier, as seen in Fig. 3. Each point on the efficient frontier represents a different collection of projects (a different portfolio). All portfolios on the efficient frontier have two characteristics in common: Each portfolio meets the modified performance metrics, and each portfolio represents the minimum risk collection of projects that generate the appropriate portfolio value.

The efficient frontier characterizes the range of portfolio values ($350-750 million) and the associated risks. Risk for each portfolio is defined as the mean deviation of all outcomes from a given portfolio that produce results less than the target value. Mean deviations are computed with a Monte Carlo analysis, which samples the various possible outcomes associated with each project. The shape of the risk

Fig. 2

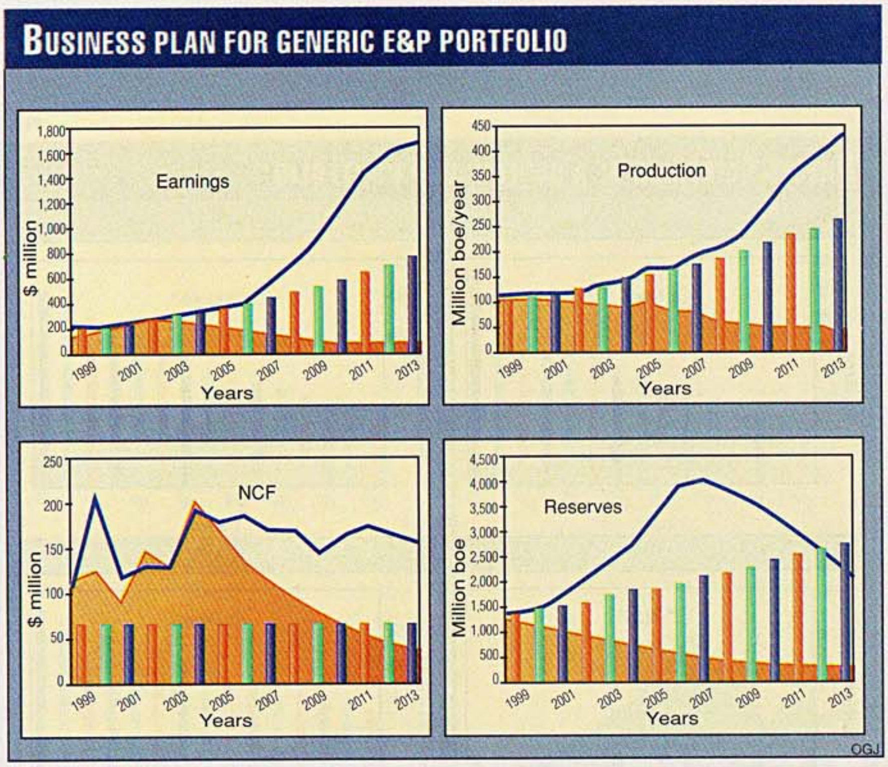
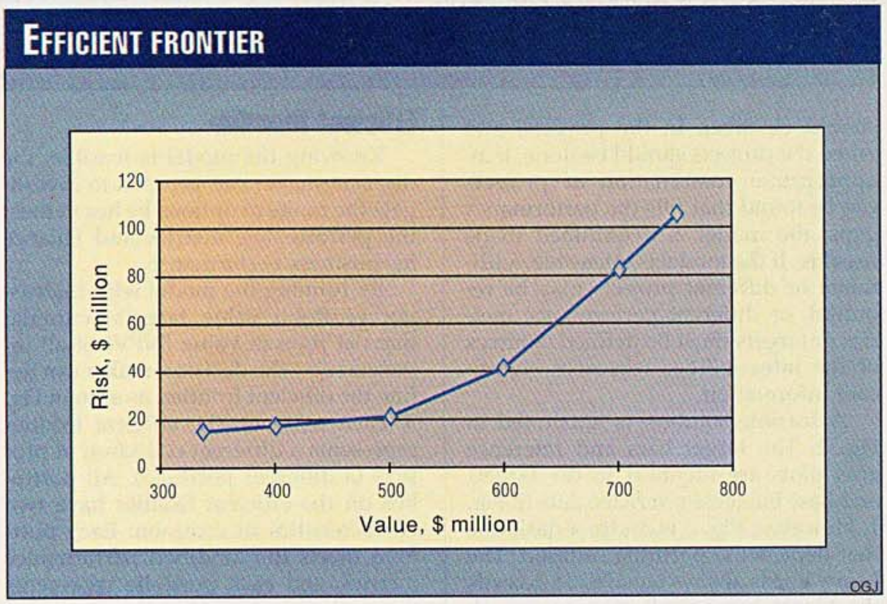


Fig. 3



curve is very informative, but the absolute risk measurement provides only limited information to aid the decision-maker.

Probability diagnostics

A much more informative perspective for decision-makers comes from computing the probability of meeting or exceeding each performance target (Fig. 4).

Figure 4a plots the probability of meeting or exceeding the net cash flow (NCF) targets for two different portfolios. The orange line defines the probabilities associated with the $500 million portfolio shown from the efficient frontier in Fig. 3. The blue line characterizes the probability of meeting the NCF targets for the $750 million portfolio on the efficient frontier.

These results fit the intuition of many decision-makers. The $750 million portfolio is a higher risk portfolio on the efficient frontier, and the likelihood of meeting the NCF targets decreases as the risk on the efficient frontier increases.

Fig. 4b portrays a different result, which is not intuitive to many decision-makers. Fig. 4b clearly illustrates that the probability of meeting the earnings targets are similar in the early years. However, by the fifth year, the probabilities of meeting earnings goals are notably higher (70%) for the high-risk, $750 million portfolio than they are with the $500 million portfolio (40%).

The fact that the probabilities of meeting NCF targets behave inversely to the probability of meeting earnings goals creates a complex situation. The decision-maker dealing with this situation clearly must balance the tradeoffs between meeting these two goals. Decision-makers must realize that the metrics associated with any business are related in very complex ways. High-risk portfolios on the efficient frontier may translate into portfolios with a high probability to meet performance targets.

The same high-risk portfolio may have very low probabilities of meeting other goals. The role of the decision-maker is to understand and manage these tradeoffs. The two sets of curves shown in Fig. 4 compare two portfolios (two points on the efficient frontier curve), for only two metrics. Similar curves can be generated for all the metrics used in the portfolio model.

Project significance

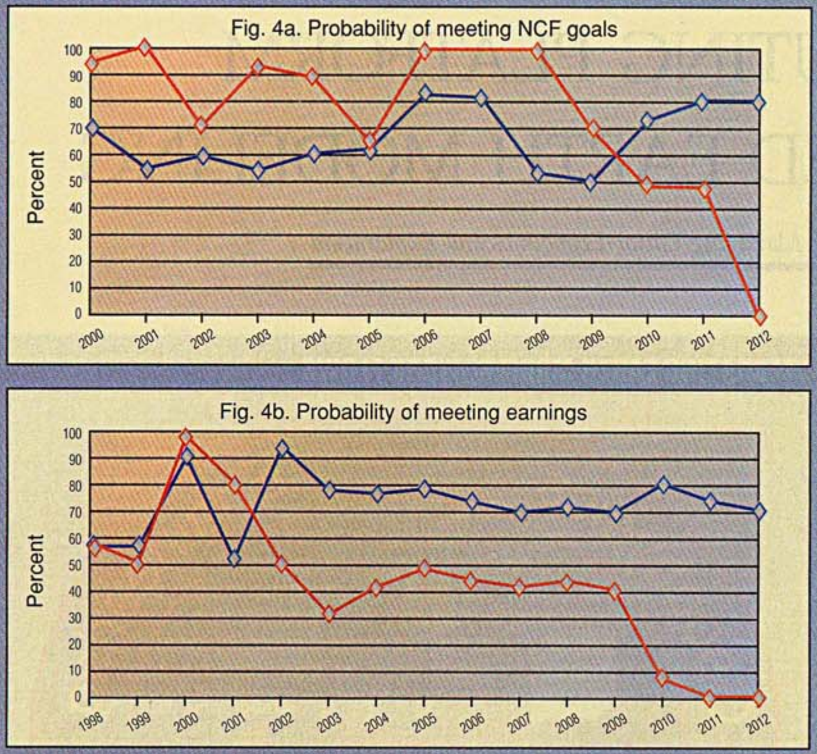
A decision to meet the earnings goal and therefore to select the $750 million portfolio described above leads to investigation of the project contributions to the resulting portfolio.

Fig. 3 in the preceding article illustrates the contribution of each project to the NCF profile for the $750 million portfolio. The X and Y axes define the projects and their contribution to the NCF target for each of the 15 years. The Z axis reflects the magnitude of the NCF contribution by year and project. The back wall of the Project axis sums each project's contribution across all 15 years.

This figure clearly illustrates that production projects No. 4, No. 6, No. 7, and No. 8, exploration project No. 8 and No. 9, play No. 1 and No. 2, and investment No. 1 are the most significant contributors to NCF. The production contribution meets most of the early years' NCF targets, while the exploration projects and Plays No. 1 and No. 2 along with investment No. 1 contribute significantly to the last third of the time period. The NCF of different projects fills NCF needs for different

Fig. 4

PROBABILITY DIAGNOSTICS*



*Orange lines are for the $500 million portfolio on efficient frontier in Fig. 3.
Blue lines are for the $750 million portfolio.

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time periods of the model.

Also, production project No. 1 was not selected at all. This reflects a divestment opportunity. Similarly, many of the exploration assets were not selected. However, investment No. 1 (an acquisition) was chosen.

Thus, in this one model, the decision-maker is presented with simultaneous acquisitions and divestment opportunities. This illustrates the power of the interactive analysis of the portfolio model. Projects and tactics are simultaneously evaluated to optimize the business.

Similar diagnostics can be generated for each of the metrics. Learning can be enhanced by comparing plots for different metrics: Projects often have a dominant metric, which causes them to be significant (chosen at a high level) to a given portfolio. The significance of any project is partly a function of the project, partly a function of what the company is trying to achieve, and partly a function of what other projects are available to the portfolio. Therefore, decision-makers need to understand why projects are significant to the portfolio, not just that they are significant.

Some projects will be absolutely critical. This means that they cannot be replaced. Another way to identify critical projects is to observe that if they are removed from the portfolio, no feasible solution can be found.

All too often projects that fail to stand out in the decision-maker's mind end up being critical contributors to the portfolio. Unfortunately, these are the projects that end up low on rank tables or similar scattergrams, and they are thus the frequent targets of divesting programs. Guiding decisions from a portfolio perspective will prevent decision-makers from unknowingly divesting critical assets.

On the other hand, projects that are critical to the portfolio can be identified and enhanced further. Applying the appropriate technologies, as described in the accompanying article, can enhance the significance of an asset.

Another way to view the significance of an asset is to assess the portfolio value of the asset. A given asset may have an NPV of $50 million but a portfolio value of $200 million. How is this differing valuation possible?

If the asset is totally independent of other assets in the portfolio, the portfolio value is $50 million. However, if the asset interacts with other projects, the portfolio value becomes the aggregate improvement in portfolio value associated with this project, as well as all of its interdependent projects. Thus, if the portfolio is optimized without this project available and the aggregate value of the portfolio decreases by $200 million, the net value to the portfolio of this asset is $200 million, not $50 million.

Decison guide

Portfolio tools are designed to guide, not replace, the decision-maker. The portfolio perspective illustrates the possibilities, tradeoffs, and issues associated with the company's strategy and the pool of projects with which the company has to work.

With this perspective, the decision-makers can learn how the metrics and projects interact and use this knowledge to guide decisions rather than fall into the cycle of implementing a solution and dealing with its consequences.

Portfolio management provides a methodology for decision-makers to determine if their strategic targets are achievable. Furthermore, decision-makers can assess the likelihood or probability of meeting their targets.

The tradeoffs associated with any single portfolio option become easily apparent before any option is implemented. Ultimately, these tools allow the decision-maker to focus on issues that help balance business performance.

The portfolio management tool is to the decision-maker as a reservoir simulator is to the reservoir engineer. Neither tool provides "the answer." Yet both tools reduce complex problems to manageable understanding that can be analyzed consistently and logically. ■

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