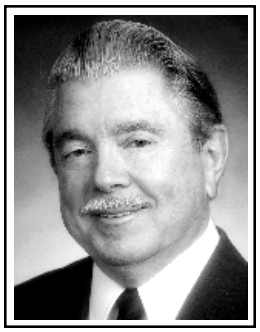
# Technology Forecasting: A Practical Tool for Rationalizing the R&D Process

John H. Vanston, Ph.D.



Dr. John H. Vanston is an internationally-renowned consultant, educator, and author in technology forecasting, technology/market integration, and technology management in uncertain environments. His clients include Weyerhaeuser, Hughes, Kerr-McGee, Rosemount, Texas Utilities Electric, Gas Research Institute, and Edison Electric Institute. Dr. Vanston is chairman of the board of Technology Futures, Inc., a company he founded in 1978, and director of TFI's public seminar, *Technology Forecasting*. He co-authored the book, *Innovate!*, and a recently-completed EEI research report entitled, *Industrial Electrification in the Information Age*. Dr. Vanston is a graduate of the U.S. Military Academy, Columbia University, and the University of Texas at Austin.

In a recent interview in *Business Week,* Mr. Louis Gerstner, Chairman of IBM, noted that the most troubling challenge facing business executives today is that they must make plans for a decade into the future based on technologies that are changing dramatically every year.[1] To address this very fundamental challenge, it is obvious that executives must be able to project, with reasonable accuracy, the nature, rate, magnitude, and implications of future advances in technology. Fortunately, a number of practical, proven techniques, commonly grouped under the designation *technology forecasting*, are available for making projections of this type.

In fact, technology forecasting (TF) techniques can be used not only to project advances in technology, but also to identify and evaluate markets for new technologies, define potential competitor strategies and actions, and examine how the new technologies will impact the business operating environment. The extension of technology forecasting considerations into these non-technical business areas is particularly fortunate given the increasing pressure on corporate R&D to concentrate on programs and projects that best support the corporation's business activities.

Although the concept and practice of formal technology forecasting has been around for more than three decades, two recent developments have revitalized interest in its practice.

The first of these developments is the enormous increase in the cost of conducting research and development. Under pressure to contain these costs, it has become increasingly important for R&D programs to focus on projects that will result in enhanced profits and sustainable competitive advantage.

The second development is the integration of market considerations into technology forecasting processes. In simple terms, "If nobody buys it, it doesn't matter." Technology forecasts take this reality into consideration, and a major goal is to determine what advances in technology will result in increased sales, enhanced profits, and delighted customers. When done properly, technology forecasting can assist in rationalizing the R&D process by better targeting R&D activities and by tying together technical advance and market opportunity.

It should be noted that technology forecasts are embedded in all meaningful business decisions. The failure to take formal cognizance of a new development in technology is an implicit forecast that such a development will not materially impact the organization—or will allow the organization to react expeditiously to the changes as they occur.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In this paper, four topics will be addressed:

- The importance of making valid projections of technical advances in developing effective business plans and strategies.
- How technology forecasting approaches can assist in making credible, timely projections.
- How technology forecasting can be used to better evaluate longer-range R&D activities.
- How technology forecasting projects and programs can be effectively integrated into ongoing business activities.

## Importance of Valid Technology Forecasting

For more than two centuries, Western nations have depended on technology to solve their most perplexing problems, whether they involve hunger or health, finance or physics, transportation or trade. In recent years, this dependence has extended to the non-Western world as well. Even when the technologies themselves have created problems, we have relied on other new technologies to solve them. When new production technologies, for example, created unacceptable environmental pollution, we employed other technologies to clean it up. As we get ever deeper into the Information Age and begin to be drawn into the Biological Age, our reliance on new technology and the implications of this reliance can only increase in magnitude and impact.

Today, it is hard to imagine a business of any size that is not materially dependent on complex, sophisticated technology—if not through products themselves, then in the way they are produced, distributed, marketed, financed, and supported. Moreover, if businesses are to continue to succeed, or even survive, it will be necessary for them to stay at or near the forward edge of technical capability. It is not, however, sufficient for companies to merely commit to the goal of technological currency; it is also necessary for them to determine what new technologies will be appropriate for adoption, how and when these advances should be employed, how they should be integrated into existing operations, and how they can contribute to customer confidence and commitment.

The business world is replete with examples of companies that have been able to gain material benefits from new technologies. Likewise, there are a myriad of examples of companies that have taken the wrong technological path, that have misjudged the proper timing for the adoption of new technology, or that have badly misread the signals from the marketplace. Wal-Mart understood the impact that new information technology would have on distribution, inventory, and market analysis and used this realization to gain dominance in the discount sales market. Sony projected the potential market for a lightweight, portable cassette player and developed the extremely profitable Walkman. Northern Telecom appreciated the promise of digital telecommunications equipment and gained a significant standing in telecom equipment manufacturing. Microsoft recognized the growing importance of software and established an almost unassailable position in that area.

On the other hand, Wang suffered significant financial losses from its attempts to produce and market instant home movies. RCA reportedly lost more than a half billion dollars on its laserdisc project. IBM failed to commit sufficient effort to the development and marketing of workstations and allowed Sun to establish a dominant position—and Xerox failed completely to exploit the pioneering personal computer innovations developed by its Palo Alto Research Center.

The reasons for these successes and failures, and others like them, are complex and not always easily identified. However, a good case can be made that the successes reflect an ability to effectively project the needs for new technology, identify the technologies available to meet those needs at a particular time in the future, and evaluate the relative attractiveness of alternate technologies that might serve the same function. The failures, in large measure, reflect insufficient attention to changing technological realities. For example, it appears that Wang failed to appreciate the relative advantages of electronic photography over film photography for home movies. RCA failed to take notice of the rapid rate of decline in the price of recording heads for VCRs. IBM failed to realize the potential size of the market for computers with capabilities between those of mainframes and PCs, and Xerox failed to grasp the significance of the innovations it had at its disposal. One of the basic roles of technology forecasting is to minimize the probability of such business misjudgments.

## The Role of Technology Forecasting in Market Analysis

In its earlier years, the primary objective of technology forecasting was generally thought to be the projection of new developments in technology. In

recent years, however, the role of TF in defining new market opportunities has become increasingly important. In reality, the nature and pace of technical advance is most often driven by marketplace realities. Thus, to be effective, analysis of future technical capabilities and markets for those capabilities must go hand-in-hand. However, experience has shown that projecting market needs is no easy task.

Recently, there has been a great deal of emphasis on companies listening to their customers when planning future products and services. Although such attention is obviously useful, the reality is that, most often, customers identify with their immediate needs and desires—not developments that can lead to quantum improvements. Typically, customers want something that is a lot like what they already have—only a little better, a little cheaper, a little faster, and a little more reliable. Often, consultation with the customer can cause companies to overlook, or even reject, innovative new technologies on which dramatic business successes are often built.

In fact, the decision processes that are quite appropriate for short-term decisions are often ones that are incompatible with those appropriate for developing longer-term opportunities. In a recent *Harvard Business Review* article,[2] Bower and Christensen point out that each time smaller computer storage discs were proposed, customers were adamant that they were not willing to give up total storage capability for smaller size. However, in each case, the added convenience of the smaller discs, together with continuing increases in their storage capacity, resulted in standard sizes decreasing from 14" to 8" to 5.25" to 3.5", with the 1.75" disc becoming increasingly attractive.

Because of the importance of defining potential markets for innovative new products and services and because of the shortcomings of traditional approaches, it is necessary to turn to approaches such as those embodied in the concept and techniques of technology forecasting. By combining projections of market needs and advances in technology, relevant technology forecasts can assist corporate management in better aligning R&D efforts with potential business opportunities.

## Technology Forecasting Approaches

Dr. Eric Jantz, one of the pioneers in the practice of technology forecasting, once identified over 150 different TF techniques. However, at present, there are some 18 to 20 techniques being used by various business and government organizations for practical forecasting purposes. Since these techniques are widely discussed in the literature,[3,4] no attempt will be made to examine them in detail in this article. However, a few comments about the nature of forecasting techniques might be in order.

Basically, all forecasting efforts involve an extrapolation of past experience, modified by subjective judgment about how the future will be different from the past. Thus, forecasting techniques involve methods for:

(1) Identifying, organizing, and extrapolating patterns of past technical development.
(2) Gathering and consolidating the opinions of people with special expertise in the areas to be forecast.

Techniques such as technology trend extrapolation, precursor trend analysis, biological analogies, content analysis, and new product substitution analysis fall into the first category. Techniques such as Delphi surveys, nominal group conferences, and structured and unstructured interviews fall into the second group. Some formal forecasting techniques, such as alternate scenario planning and stochastic modeling, are utilized to combine forecasts of individual technologies and/or market developments into an integrated whole. Formal and informal surveillance techniques, such as scanning, monitoring, and tracking, are used to ensure the timeliness of input data for other techniques.

Although familiarity and experience in the use of the various forecasting techniques is essential to the formulation of a valid technology forecast, it is often important to consider the different perceptions of the future that underlie these techniques and the importance of these perceptions in the practical application of TF in real-world situations.

In our work, we have found that there are five basic approaches to viewing the future. We define the people who subscribe to each of these approaches as follows:

(1) *Extrapolators* believe that the future will represent a logical extension of the past. Large-scale, inexorable forces will drive the future in a continuous, reasonably predictable manner, and one can, therefore, best forecast the future by identifying past trends and extrapolating them in an intelligent manner.

(2) *Pattern analysts* believe that the future will reflect a replication of past events. Powerful feedback mechanisms in our society cause trends and events to occur in identifiable cycles and predictable patterns, and one can best address the future by identifying and analyzing analogous situations from the past.
(3) *Goal analysts* believe that the future will be determined by the beliefs and actions of certain individuals and institutions. The future is susceptible to modification and change by such entities. Thus, the future can best be projected by examining the stated and implied goals of various decision makers and trendsetters, by evaluating the extent to which each can affect future trends and events, and by evaluating what the long-term results of their actions will be.
(4) *Counter-punchers* believe that the future will result from a series of events and actions that are essentially unpredictable and, to a large extent, random. One can best deal with the future by identifying a range of possible trends and events, by carefully monitoring technical and social changes, and by maintaining a high degree of flexibility in the planning process.
(5) *Intuitors* are convinced that the future will be shaped by a complex mixture of inexorable trends, random events, and the actions of key individuals and institutions. Because of this complexity, there is no rational technique that can be used to forecast the future. Thus, the best method for projecting future trends and events is to gather as much information as possible, and, then, to depend on subconscious information processing and personal intuition to provide useful insights.

Obviously, there are strengths and weaknesses to each of these approaches. In fact, almost everyone uses all of these approaches, to some extent, in his or her attempts to deal with the future. However, most people tend to give more credence to one or two of these approaches. Although there is not a one-to-one correspondence, we have found that, in general, most engineers tend to be extrapolators, pure scientists to be pattern analysts, marketing personnel and salespeople to be goal analysts, lower and middle managers to be counter-punchers, and high-level managers to be intuitors.

The purpose for defining each of these approaches is not to determine which is most logical or useful, but, rather, to increase the overall validity of forecasting efforts. One of the major reasons for poor forecasts in the past has been the use of inappropriate forecasting models. Obviously, one means of minimizing the possibility of falling into this particular trap is to consciously subject preliminary projections to each of the listed approaches. This can be accomplished in several ways. For example, if a group is established to make projections, technical or otherwise, it will be prudent to balance the membership to reflect different approaches for addressing the future. If one is planning a forecasting project or program, one should select techniques that accommodate each of the different approaches. (Table 1 provides guidance on which techniques best reflect different approaches to projections of the future. These classifications are not exact, and some techniques can be used to support different approaches.) Finally, when individuals are making their own projections, they need to understand and appreciate their own predilections and, therefore,

Table 1
**Technology Forecasting Techniques**

| Approach | Technique |
|---|---|
| *Extrapolator* | Technology Trend Analysis<br>Substitution Analysis<br>Growth Limit Analysis<br>Learning Curves |
| *Pattern Analyst* | Analogies<br>Precursor Trends<br>Morphological Analysis<br>Feedback Models |
| *Goal Analyst* | Implication Analysis<br>Content Analysis<br>Stakeholder Analysis<br>Patent Analysis |
| *Counter-Puncher* | Scanning<br>Monitoring<br>Alternate Scenario Planning<br>Monte Carlo Models |
| *Intuitor* | Delphi Surveys<br>Nominal Group Conferencing<br>Structured/Unstructured Interviews<br>Comprehensive Opportunity Analysis |

*Source*: Technology Futures, Inc.

force themselves to consider the implications of other approaches.

### Using Technology Forecasting to Better Evaluate Longer-Range R&D Activities

In today's environment of restricted R&D budgets, there is increasing pressure to concentrate R&D efforts on projects and programs that can be directly related to the business activities of the organization.

In practice, this translates into emphasis on projects that are limited in scope, low in risk, and short in time-to-commercialization. Obviously, research that is based on well-understood technologies, has well-defined objectives, and is limited in scope has a high probability of success and a low probability of cost overrun. The opposite is true for broader-scope projects based on more innovative technologies and more imaginative approaches.

Another factor, however, that mitigates against longer-term, more innovative R&D projects is the concept of the "time value of money." For example, if a company's required rate of return on investment is 20%, a dollar invested in R&D today must offer a guaranteed profit of $2.50 in five years to meet the required criteria. When the normal increased risk associated with longer-term projects is taken into consideration, it becomes very difficult to justify expenditures on such projects. (A recent conversation with a planner at the Battelle Memorial Institute indicated that, if present project selection criteria had been applied, the Institute would have rejected the Xerox process that has been, by far, its most successful and profitable undertaking.)

Countering the proposition that a dollar spent today is more valuable than a dollar earned tomorrow is the fact that, quite often, R&D efforts provide significant business opportunities that are not realized when the project is in its early stages. The transistor, for example, was originally viewed only as a replacement for the diode vacuum tube. The radio was primarily seen as a means for ship-to-shore communication. The personal computer was seen as a means of storing recipes and balancing home checkbooks, while no practical use at all was seen for the laser.

Although decision-makers are usually aware of the possibility of unexpected opportunities for the use of a new technology, quantification of the value of such opportunities is difficult. Hence, conventional evaluation processes often fail to give sufficient weight to such ancillary, follow-on opportunities. Technology forecasting, on the other hand, is specifically structured to provide a means for identifying opportunities at an early stage of technology development and evaluating the significance of the opportunities.

### Integrating Technology Forecasting Activities Into Business Operations

One of the most frequently asked questions about technology forecasting is where such activities should be located in the business structure. (This is, of course, part of the larger question of how these activities can best be integrated into the operations of the business.) In practice, TF activities have been successfully located in many parts of business structures—in R&D laboratories, corporate planning groups, new product development groups, and special TF sections that report to directors of technology, management committees, or offices of the chairman of the board. Although local circumstances will influence how organizations can best organize their TF efforts, there are a few general considerations that should be taken into account in planning TF integration.

The first consideration is to define the objectives that the organization hopes to achieve through these activities. Although technology forecasting projects have been—and continue to be—used by organizations for a variety of purposes, these uses tend to fall into four categories:

- Assisting in the development of forward-oriented business and technology strategies.
- Assisting in the identification and evaluation of new business opportunities.
- Providing useful input to organizational decision processes.
- Assisting in the communication of technical realities within and outside the organization, particularly to people with limited technological backgrounds.

These four uses are often closely related and overlapping. However, the relative importance of each will vary between organizations. Therefore, TF activities must be tailored to meet the specific needs and culture of each individual organization.

Another factor that should be considered is that TF has proven to be most useful for projections in the two- to eight-year range. Thus, TF activities will be of the most value in providing insight into developments that may fall into that time period. Normally, technology forecasts will be of limited value in areas of the

business that are concentrated on short-term, day-to-day operations. TF can be of value for planning projects beyond the eight-year range, but projections become increasingly unreliable after that time.

Because technology forecasting is most valuable when it simultaneously involves future market needs, potential advances in technology, and assessment of possible competitor actions, the TF activity can be most effective if it is located at a place in the organization where these factors are all of significant import. Moreover, since one of the most important roles of TF is to assist in the decision-making process, it is essential that TF activities be organized so that TF results will be communicated routinely to the people responsible for key organizational decisions.

Experience has shown that TF activities are most effective when they are conducted on a continuing basis, rather than on a one-time basis. Although it is sometimes useful to conduct a special forecast in a particular technical area using an ad hoc group, an ongoing, permanent TF organization will be of far greater value in the long term.

A final consideration in determining where TF activities should be concentrated involves the matter of acceptance. If TF efforts are to be useful to the organization, the people responsible for TF activities and the people to whom TF results are presented must have confidence in the validity of TF methodologies. Such confidence does not imply blind acceptance of the forecasts, but rather the belief that the use of formal TF techniques can provide information about the future that will be useful to the organization—and that will not be provided by any other means. If TF results do not routinely contribute to effective decision making in the organization, they are essentially a waste of time and resources.

Once the objectives of the TF activity to the organization have been defined and the location of this activity has been determined, resource allocation, operating procedures, evaluation criteria, and similar considerations can be intelligently addressed.

## Conclusions

In their seminal book, *Reengineering the Corporation,*[5] Hammer and Champy state three basic principles for continuing success in today's increasingly competitive environment:

- Companies must achieve quantum improvements in operations—improvements of 50%, 80%, or even higher.
- Improvements of this magnitude can only be achieved by more effective use of information technologies.
- Plans for improvement must be based on the use of information technologies that will be available in the future, not those that are available today.

In large measure, these three principles reflect the concepts of technology forecasting. Because of the requirement that companies be responsive to both present and future customer needs, management must often make decisions based on projected market opportunities, advances in technologies, and actions by competitors. Well conceived, organized, and executed technology forecasting activities can assist managers in making and evaluating such decisions.
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[1] "We Won't Stop Until We Find Our Way Back," Interview with L. Gerstner, *Business Week* (May 1, 1995):116-117.
[2] J. L. Bower and C. M. Christensen, "Disruptive Technologies: Catching the Wave," *Harvard Business Review* (January-February 1995):43-53.
[3] J. H. Vanston, *Technology Forecasting: An Aid to Effective Technology Management* (Austin, TX: Technology Futures, Inc., 1994).
[4] A. L. Porter, et al., *Forecasting and Management of Technology* (New York: John Wiley, 1991).
[5] M. Hammer and J. Champy, *Reengineering the Corporation* (New York: Harper Business, 1993).