15 Unnatural Acts: Building the Mature Firm's Capability for Breakthrough Innovation

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Background and Motivation

The contemporary competitive environment has been and continues to be driven by technological revolution, globalization, hypercompetition, extreme emphasis on price, quality, and customer satisfaction—with a resultant increasing focus on innovation (Hitt et al., 1998). These factors cause increased competitive complexity and dynamism, requiring an increasing emphasis on innovation as a strategic competence.

The competitive landscape began to change drastically during the 1980s, when technology-rich U.S. firms experienced increasing difficulty competing in various industries such as semiconductor memory chips, office and factory automation, and consumer electronics (Morone, 1993). Some have attributed these failures to an inferior capacity, relative to competitors, for achieving continuous and incremental improvements in products and processes targeted at increased quality and decreased costs. In response, in the past decade U.S. firms have focused on incremental innovation in existing products or processes, with an emphasis on cost competitiveness and quality improvements (Betz, 1993; Hamel and Prahalad, 1991; Morone, 1993).

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There are indications, however, that a focus on incremental innovation is an incomplete approach. Firms that hold the largest market share in one product generation often fail to maintain leadership when technologies shift (Bower and Christensen, 1995). Long-term competitive advantage comes from conflicting, yet ultimately complementary, activities such as maintaining a steady stream of incremental and continuous improvements in established business lines, and setting aside existing successful products for new innovations (Hitt et al., 1988). Thus, developing new businesses and products based on breakthrough (also termed discontinuous, radical, or game-changer) innovations becomes critical to long-term competitive advantage.

The distinction between incremental and breakthrough innovation probably stems from the definition of innovation proposed by Schumpeter (1934), who suggested that an innovation idea is the catalyst for a departure from existing practice supplanting standard operating procedures. March (1991), drawing on Schumpeterian themes, makes a distinction between exploration and exploitation. Exploitation has to do with refining or expanding existing products or processes, while exploration has to do with something fundamentally new, including new products, processes, or combinations of the two. Hence, breakthrough innovations are those that depart from the past and result in new products or services. Incremental innovations usually emphasize cost or feature improvements on existing products or services (Betz, 1993; Hamel and Prahalad, 1991; Morone, 1993). In contrast, breakthrough innovation concerns the development of new businesses or product lines based on new ideas or technologies (Morone, 1993) or substantial cost reductions that transform the economics of a business.

Although there may be significant risk and uncertainty associated with incremental innovation, generally uncertainty is more identifiable and manageable compared to breakthrough innovation. Hence, management practices utilized in the development of incremental innovations can be clearly defined and systematized. With respect to project planning, for example, a number of researchers have identified various stage-gate processes for incremental innovation development, which are widely understood and utilized in our sample companies (Cooper, 1990; Marquis, 1969). Since uncertainty is relatively proscribed, managers can define a continuum of project activities punctuated by a series of decision-making gates—where go/no-go decisions can be made.

By comparison, the uncertainty associated with breakthrough innovation is much greater. There is uncertainty about whether the technology

will work, what the markets are, and what the applications might be. This uncertainty is difficult to manage in a systematic manner. Although the concept of breakthrough innovation frequently appears in the literature (Wheelwright and Clark, 1992) in terms of its importance or definition, there are relatively few ideas of how to manage it.

Block and MacMillan (1993) and McGrath and MacMillan (1995) point to differences between managing incremental and breakthrough innovation. It has been noted that breakthrough and incremental innovation processes require different organizational capabilities (Henderson and Clark, 1990). Approaches to market learning are fundamentally different as well (O'Connor and Veryzer, 1998). Hence, we contend that the processes and practices appropriate for managing incremental innovation may be inadequate, and, in some cases, dysfunctional for the development and commercialization of breakthrough innovation where uncertainty, risks, and potential rewards are much higher.

Attempting to migrate the disciplined processes developed for incremental innovation into the breakthrough innovation domain may be inappropriate due to differences of the phenomena being managed. Managers of the companies in our study reported difficulty in trying to do this. The lack of clear managerial prescriptions in the literature and the confusion of the managers in our sample companies of how to manage breakthrough innovation provide the motivation for this study. In this chapter we describe and categorize a variety of practices in use—and in so doing, uncover critical issues facing managers with indications of approaches to solving them. Our goal is to provide managers with a starting point for experimentation with new practices and tactics for improving breakthrough innovation effectiveness and to provide researchers with fruitful directions for further study.

In this study, we define a breakthrough innovation project as a formally established project with an explicit budget and organizational identity; and one that is viewed as offering the potential for a factor of 5–10 times (or more) improvement in product performance, an entirely new set of product performance features, or a significant (>30%) reduction in cost. This definition was derived from three sources: a review of the various definitions of breakthrough innovation in the literature (e.g. Leifer, 1997), discussions among the research team members based on the various perspectives of their disciplines, and intense discussion with industry representatives on the Discontinuous Innovation Subcommittee of the Research-on-Research Committee of the Industrial Research Institute.

Research Methods

The project was a multiple case, four-year longitudinal study of twelve ongoing breakthrough innovation projects (1995–1998) in ten large, mature firms: Air Products, Analog Devices, DuPont, GE, GM, IBM, Nortel, Otis Elevator, Polaroid, and Texas Instruments. The study was underwritten by the Sloan Foundation and sponsored by the Industrial Research Institute (IRI), a professional association of Fortune 500 research and development managers. The multiple case study design allowed us to explore the similarities and differences of management practices across industries, companies, and projects.

The study team included six faculty and several doctoral students from various disciplines. The study was deliberately designed as an exploratory, theory-building study rather than a conventional, theory-testing study. A panel of informants from each company met with the study team for in-depth interviews. The informants typically comprised the technical inventor or discoverer, project manager, project champion, and a senior manager. Each interview was taped and transcribed, resulting in many thousands of pages of transcripts. In addition, the research team had access to project documentation, reports, and business cases.

Multiple Comparison Case Study Methodology

This research project employs a multiple case study methodology. Case study research involves the examination of phenomena in natural settings. The case study method is especially appropriate for research in new topic areas, with a focus on "how" or "why" questions concerning a contemporary set of events (Eisenhardt, 1989). Case study research that employs multiple cases should follow a replication logic (Yin, 1994). The complexity of case study research and the high level of interpretation that is necessary create an advantage for the use of research teams. Multiple investigators can bring to the research a variety of experiences and complementary insights. A mix of different perspectives can increase the likelihood of discovering novel insights. Convergence of opinions from various researchers can enhance confidence in the findings, and conflicting views can keep the research from premature closure (Eisenhardt, 1989).

Field Study Sample Selection

Each participating firm nominated one or more projects for research consideration. To be included, a project was viewed by the research and development (R&D) and project managers of the firm as a "game-changer"; i.e., that it meets the characteristics of breakthrough innovation defined above. The project had to be formally established—with a project team and a budget. The participating companies in conjunction with the research team selected one or two projects for inclusion in the study. Although we gathered contextual information at the firm level, the project was the unit of analysis.

At the point we began gathering data, the projects were in various phases of development, although none were close to commercialization. As will become clear below, it is difficult to characterize the projects' stage of development because breakthrough projects do not seem to follow clear stages of development. Over the four-year study, the following projects were commercialized or are now in the public domain: BIOMAX (a DuPont degradable material); the TI digital mirror device; Analog Devices' air bag actuator; the IBM SiGe chip; and the Otis Elevator bi-directional elevator. For the remainder, the identities of the breakthrough innovations are cloaked to protect the competitive position of the companies.

Findings and Their Relationship to the Literature

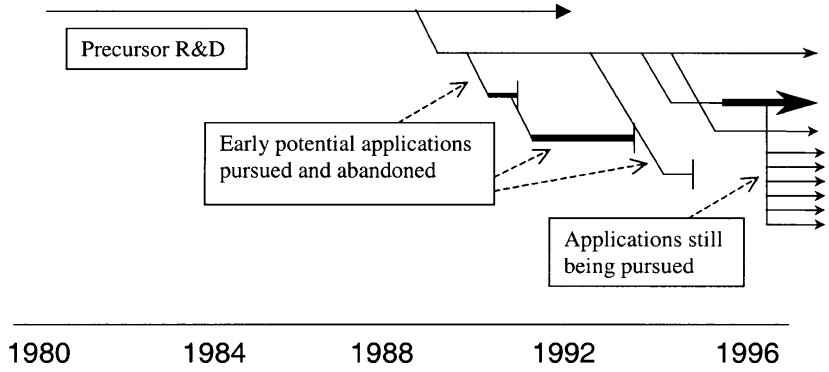
We begin with an opening discussion of the nature of the breakthrough innovation life cycle to provide a context for our findings.

The Nature of the Breakthrough Innovation Life Cycle

Our team developed timelines for each project. The timeline for Project 7, presented in Figure 1, provides a typical picture of the general findings related to the breakthrough innovation life cycle derived from all twelve field projects.

In this case, the stream of technology R&D activities that preceded the formation of the commercialization project team began in 1980. The lines represent the applications pursued, and the thickness of the lines represents changes in the level of commitment of human and financial resources. The life cycle diagram indicates that Project 7 waxed and

Figure 1
Timeline for Project #7.



waned throughout its history. In the late 1980s and early 1990s, several streams of development activity reached dead ends and were abandoned, requiring the team to generate ideas for new high potential avenues to explore.

The development effort often took off in directions unanticipated at the project outset, particularly in response to discontinuous events related to changes in personnel, the formation of internal and external alliances, and key funding milestones. In late 1996, the technology was successfully transferred from the R&D business development organization to a business unit for manufacturing. Uncertainty about target markets and requirements for adoption by lead users remains high; hence, a variety of market applications continue to be pursued. Though initial target applications were not judged to be adequate for achieving an acceptable threshold of revenues, initial market response was sufficient to warrant moving forward. In fact, one of our follow-up interviews revealed that visibility in the marketplace derived from initial product launches stimulated the identification of new and more promising application domains suggested by potential customers.

This project is typical of all the projects studied. The life cycle of breakthrough projects is profoundly different from that of continuous improvement projects. They are long-term (typically ten years or longer) and sporadic, with many stops and starts, deaths, and revivals. Projects are non-linear. These projects were fraught with uncertainty

about the technology, potential market applications, customers, and organizational/management issues. Finally, all the projects were context dependent. The development process was significantly influenced by personalities, personal preferences, organizational culture, and informal networks.

On the basis of this discussion, we conclude that management processes for breakthrough innovation are substantially different from those for incremental innovation. For example, we found that there is a desire to apply the stage gate system for managing product development developed by Cooper (1990). Cooper indicates that his system can be applied for the development of new products, not just extensions or incremental improvements. However, in practice, the stage gate system engenders a sense of linearity—with clearly specified stages and gates—whereas breakthrough innovation is characterized by non-linearity and uncertainty. The breakthrough implementation tactics we observed and which we describe below were designed to address the uncertainty and non-linearity problems of breakthrough innovations.

Tactics for Fostering Breakthrough Innovation

Our aim in this section is to examine our findings in the context of the strategy literature. We are focused on tactics that can be implemented in the organizations of today for increasing breakthrough innovation effectiveness. These five implementation tactics were based on an analysis of the empirical data. The first three tactics refer to necessary activities in the process of launching a radical innovation project, and the fourth tactic protects innovation projects from organizational pressure and resistance. The fifth tactic reflects our observations that, in current practice, breakthrough innovation relies on individual initiative rather than a systematic organizational process. The five tactics discussed are: stimulating attractive ideas; promoting opportunity recognition; evaluating and screening breakthrough innovations; creating incubating organizational structures; and catalyzing individual initiative.

Stimulating Attractive Ideas

Burgelman (1983) identified two kinds of strategic activities: those induced by the firm's current concept of corporate strategy; and autonomous strategic activities that fall outside the scope of the current strategy. It is useful to examine idea stimulation in our data set in the context of Burgelman's two kinds of strategic activities. The ten firms employed

a variety of mechanisms to stimulate breakthrough innovation ideas that led, eventually, to the twelve projects. Among these were articulating holy grails, articulating strategic intent, issuing requests for proposals, promoting connections to external sources of technical information, conducting technology forecasting exercises, convening think tanks, creating an idea generation "sand box," and rotating talent.

The first three mechanisms were used by management to communicate to the entire organization the importance of idea generation. This first kind of strategic activity targeted at stimulating breakthrough innovation ideas can be thought of as a "strategic push." Six projects emerged partially due to strong articulation by senior management of the need for new ideas. The responses to these three mechanisms relate to Burgelman's (1983) first kind of strategic activity; i.e., activity induced by the firm's current concept of corporate strategy.

The remaining five mechanisms were used to enhance the idea-generating productivity of specific individuals or groups within the organization. They provide a context that supports an organizational response to "strategic push" as well as the second kind of strategic activities identified by Burgelman (1983); i.e., autonomous strategic activities that fall outside the scope of the current strategy. The specific ideas that are generated may fall within or outside of current corporate strategy, but the strategic choice by senior management to create a facilitative, supportive context for stimulating idea generation brings the activity itself into the strategic framework of the firm. We discuss below how several of these mechanisms were utilized.

Articulating Holy Grails. In seven of the twelve field study projects, there was a shared awareness among researchers and research managers of a technical "holy grail" within their industries. A "holy grail" is a potential technical breakthrough that is generally recognized as a catalyst for transforming an industry, if it can be achieved. For example, in the auto industry a dramatic improvement in fuel efficiency to 80 mpg would provide substantial competitive advantage to the firm that achieved the technical breakthroughs required for achieving this holy grail. In the people mover industry, current elevator technology limits the height of buildings. If that technical limitation could be overcome, it would be possible to erect buildings substantially higher than is possible today, such as the proverbial "mile high building." In the information storage industry, creating the capacity to have gigabytes of memory on a floppy disk was seen as a holy grail.

Articulating Strategic Intent. In four cases, articulation of strategic intent created a heightened awareness of the need for idea generation and alertness to new ideas. Although articulating strategic intent can take the form of articulating the importance of pursuing a holy grail as a strategic goal, it can alternatively be expressed in less specific terms—a more general call to arms. For example, in one case, the CEO pushed for new businesses in the white spaces between existing business units. In another, the CEO challenged the company to identify new applications of the firm's breakthrough technology for a market in which the company was not currently active.

Issuing Requests for Proposals. In five companies, competitive pressures threatening the core businesses of the firm or the perceived need for new strategic opportunities caused senior management to issue a request for proposals—either to the company or to a business unit—to pursue breakthrough innovations. In two cases, hundreds of proposals were submitted for evaluation and screening.

Promoting Connections to External Sources of Technical Information. The innovation literature argues consistently that external information gathering (Utterback and Brown, 1972; Tushman and Nadler, 1986; Gluck, 1988; Betz, 1993; Martin, 1984) creates a foundation for idea generation. In five of the twelve field study cases, proactively connecting to external sources of information had a significant impact on the generation of the initial idea. External sources included a scientific paper read by a senior research scientist; ideas submitted by external sources; a scientific paper on a secondary area of interest for a scientist; a brown bag lunch with a university researcher; and awareness of an innovation in an adjacent market.

General Observations About the Practice of Idea Generation. With one exception, idea generating mechanisms were applied sporadically and in an ad hoc fashion—rather than systematically, continuously, and strategically. When the idea generation activity was generally undertaken through individual initiative, and not incorporated into institutional processes, that idea generation mechanism ceased with the retirement or departure of the individuals. Results indicate an opportunity for senior managers to create a facilitating context and strategic push as effective stimuli for the generation of breakthrough ideas.

Promoting Opportunity Recognition

We found that opportunity recognition was typically an event that followed idea generation and triggered the ensuing process of evaluation and screening. The critical role of opportunity recognition in the process of developing and commercializing a breakthrough innovation emerges from a number of sources. To take advantage of shifts in technology, market, and competition, the opportunity first needs to be recognized and interpreted within the context of the firm's environment (Myers and Rosenbloom, 1993). Since companies sensitive to environmental shifts are best positioned for discontinuous change (Utterback, 1994), success comes from an ability to imagine markets that do not presently exist, and then to invest in their development ahead of the competition (Hamel and Prahalad, 1991). To accomplish this, companies need to develop the ability to sense, communicate, and appreciate the early signs of change (Gluck, 1988).

It is interesting that all the researchers cited above refer to the capacity of the company, or of management in general, for opportunity recognition. In contrast, we found opportunity recognition was based on individual initiative rather than a capacity or practice of the firm (Rice and Kelley, 1997). Kirzner (1973) defines the pure entrepreneur as a "decision-maker whose entire role arises out of his alertness to hitherto unnoticed [profit] opportunities," or in the words of Rumelt (1984), "sources of potential rents." In research, opportunity recognition related to breakthrough innovation was highly dependent on individual initiative and capacity rather than on routine practices and procedures of the firm. It was not a random act, but was generally reactive in nature; and it was unusual rather than proactive and routine.

In nine of the twelve projects, a low- to mid-level research manager performed the initial act of opportunity recognition. In two of the twelve projects, senior scientists, who had control over discretionary resources to support initial feasibility testing of real or potential innovations, recognized the opportunity. In essence, these two individuals played dual roles—as researcher and research manager, rather than as a researcher only. In only one of twelve cases was a senior technical manager responsible for the initial opportunity recognition, and in no cases did a senior corporate manager fulfill this function. The initiative of individuals set in motion activities that resulted in the establishment of a project to commercialize the breakthrough innovation.

In the majority of cases, the scientists who envisioned, worked toward and/or accomplished the breakthrough innovations had some idea (typically general and somewhat vague) of the application domain(s) for their innovations, but limited understanding of the market (Rice and Kelley, 1997). In eight of the twelve cases, the idea generator was not the opportunity recognizer. The scientists' research managers, who recognized the opportunities associated with their breakthrough innovations, had sufficient understanding of the potential market or application, which, when combined with their technical expertise, allowed them to recognize the business opportunities. The frequent interaction between the first line research managers and the scientists who were the idea generators made it likely that they would be in the best position to learn of the breakthrough ideas and make the connections to potential business opportunities. Unless someone close to the idea understands its implications, there is little chance it will reach the radar screen of higher level managers.

The leap in thinking required of these research managers to recognize an opportunity is reflected in the comments of one research manager:

> We didn't know much about market size at the time. The market is big. It is enormous. It would be a killer technology in this application domain based upon my physical understanding of what would be required in that industry.

Breakthrough innovation opportunity recognition appears not to occur in a formal way, but rather is part of the organization's informal network and organizational culture. The report of an initial opportunity recognition that led to the establishment of one project is illustrative. Two research managers for two scientists involved in the initial research independently contacted two individuals within the business development group about an upcoming technical review of the research. They suggested that the business development people come to hear an about interesting idea. One of the two was too busy too attend. The other stated:

> I get a notice every day for all the technical reviews going on here. I've got so many other things to do that I don't go unless somebody tells me to go. I was invited in by the scientist's research manager who said that this technology has the potential for making product X. I would not have normally gone to that review.

It is likely that the initiation of this project would have been delayed, or missed altogether, absent the occurrence of the opportunity recognition event.

In all cases, the desire to pursue an identified opportunity caused the research manager to reach out to other parts of the organization for support or resources. Given the high degree of technical and/or market uncertainty, the research manager sought confirmation of his perception of the opportunity. In addition, successful pursuit of the opportunity would over time require a significant commitment of the company's resources, which in turn would require decision-makers with authority to commit resources to develop the innovation. The research manager became the catalyst for leading others in the organization to recognize the opportunity.

Evaluating and Screening Discontinuous Innovations

There was evidence in our study of competing for the attention and financial support of senior management via corporate requests for proposals and proposals to venture boards, but this competition was not driving the evaluation and screening process. In fact, the concern of managers involved in our study was focused on how to evaluate and screen innovations much earlier in the process, before making proposals to venture boards typically becomes an issue.

A critical facet of managing the breakthrough innovation process is knowing that the pursuit is worth the risk. R&D managers recognize that the evaluation process for fundamental new lines of business differs significantly from that of extension projects. Yet our field studies offered limited evidence that there is a deliberate process or strategy for evaluating these projects differently. Screening was either undertaken as part of the normal project evaluation process, or was treated in an ad hoc fashion. We note that in some cases, traditional evaluation criteria and methods were used, but were generally not perceived by the technologists and managers at the project level to be relevant to them.

The primary purpose of screening and evaluation activities was to support decision-making related to resource (financial and human) allocation and, as necessary, acquisition. In all twelve cases, a positive outcome of the initial screening and evaluation process caused a commitment of internal human and financial resources from the discretionary funds of a research manager to continue exploratory work. At this point, uncertainty on one or more dimensions (technical, market, organizational, financial) was so high that the initial commitment simply

reflected a conviction on the part of the research manager that the magnitude of the potential opportunity was large enough to warrant additional technical development.

In all cases, evaluation and screening at the project level was ongoing, initially centering on achievement of technical milestones, failure to achieve those milestones, or discovery of unanticipated technical hurdles (O' Connor and Veryzer, 1998). It also occurred with respect to market learning that came through interactions with early adopters and through the experience of lead users with prototypes. By comparison, evaluation and screening by senior management occurred in the context of periodic budgetary reviews and was conducted by an individual senior manager, a project "board of directors," and/or a venture review board, but still based on primarily technical considerations rather than on formal "business cases."

For breakthrough innovations, initial assumptions could be made about market- and economics-related issues, but generally there were one or more critical issues related to technical uncertainty that took precedence. These needed to be resolved in order to be able to embody the technology into some sort of prototype that could be used for market learning. Hence, the focus of screening and evaluation activities in early project stages was predominantly technical. The primary evaluative questions driving the radical innovation projects in this study included the following:

- What is the magnitude of the impact this technology can have on the market?
- What will this technology enable?
- Can this technology deliver the magnitude of benefit that is needed?
- What are the technical hurdles we must overcome to get this thing (or process) to work?
- What are the projected performance characteristics?
- What yield from the manufacturing process must be achieved to make the economics of the business attractive?

The focus of this set of questions was on the return of new value, in a variety of ways, to the market (O' Connor and Veryzer, 1998). The

long-term profit potential was assumed to be significant even though not currently quantifiable. In comparison, typical screening criteria for an incremental improvement investment is how much promise the project offered to the firm, characterized as, "What is the profit impact?" or "How fast will it grow?" or "How much market share can we expect to grab?" The focus of each of these questions is on a return to the firm over a given (usually specified) and relatively short time frame.

For breakthrough innovations we found an emphasis on a more experimental, hands-on approach and a reliance on past experience to assess the value of the technology to the market (Rice et al., 1998). Potential customers, or "lead users," were not the only vehicle for this. Perspectives of many constituents were sought, including leading members of the technical community, senior management at both the corporate and business unit levels, and line managers connected to the current customer base. There was a heavy reliance on "probes" to potential early adopters and others who were relatively sophisticated in relevant technical arenas, including: professional conferences and meetings, where data are presented for the technology community's reaction and to gain potential customer interest; the demonstration of the product via early prototypes for reaction within the firm; and evaluations by potential customers of early working versions over extended trial periods.

These probes were more experimental in nature than analytical, and they were designed for technical and market learning more than market evaluation (O' Connor and Veryzer, 1998). The purpose was not to assess the impact on sales, but rather to assess the degree to which potential users will experience value-in-use. Typically, several potential applications were pursued, usually serially, to test technical and market assumptions. Positive results of these activities were critically important for gaining support internally, both to sustain financial support of senior management and to increase the receptivity of business unit managers, who would eventually manage the product emerging from the project.

Creating Incubating Organizational Structures

Galbraith (1983) and Quinn (1985) state that organizations pursuing innovation require a specially designed structure that enables them to develop significant innovations not consistent with the existing organization concept. The appropriate structure is likely different in various situations and at different times. A structural design may need to

be changed as conditions change (Twiss, 1986). A number of authors recommend that separate structures should be maintained: an operating structure for routine lines and an innovating structure for new innovative products (Galbraith, 1982; Burgelman and Sayles, 1986; Kanter, 1989). They argue that the mainstream mode of operation is too slow and conservative to allow for development of projects characterized by high uncertainty, high intensity, and high autonomy. Innovative new projects are not likely to benefit from the existing organization's experience base (Kanter, 1989).

Breakthrough innovation seems to work best, especially in the front end of the process, when separated from ongoing business activities. For most operating businesses, breakthrough innovation is an unnatural act because the uncertainty is too high, the time horizon too long, and the investment too large given the inherent risks. Breakthrough innovation projects are badly aligned with the reward structure of operating businesses. The costs occur in the present and benefits do not arrive for perhaps ten years or more. Thus, regardless of potential long-term benefit for the firm, within the short time horizons of operating units the impact of breakthrough innovation is negative; i.e., depressing short-term profitability. For all these reasons mechanisms for protecting projects—incubating arrangements—functioned to allow projects to develop outside of organizational pressures and to find resources not normally associated with project development.

We found that successful breakthrough innovations developed in a variety of incubating arrangements. These incubating homes allowed innovations to develop enough maturity to be attractive to the operating units while being protected from short-term organizational performance metric requirements. The relative effectiveness of the various options varied with context. In early development, the home of the incubating organization is typically corporate research and development (CRD), a new business development group operating within CRD, a business unit, or a new ventures group operating at the corporate level.

Incubating arrangements frequently operated across internal and external organizational boundaries to bring needed resources into the project. Partnering was used for risk reduction throughout the breakthrough innovation development process. Participation of internal and external partnering organizations varied but had a significant impact. A wide variety of partners were observed, including government. In eight out of twelve cases, government agencies were a major source of funds after the project was formalized. Government funds were used to ex-

tend, expand, and accelerate projects, but in only one case was government funding a trigger or motivation for the project.

There was widespread use of alliances for a variety of purposes, including manufacturing, application development, market probing, and joint development of technology (Rice et al. 1998). A broad spectrum of partners were involved, including other large firms, universities, government laboratories, and small high tech firms. Strategic alliances served to contribute knowledge about markets and technology as well as to help managers gain visibility and legitimacy for their projects. They aided in monitoring the environment, and provided access to related cutting-edge technologies that could provide entrance into new markets.

All of this points to the importance of a resource view of the breakthrough innovation process. Since these innovations typically require expertise, funding, and the use of organizational resources (such as time in a fabrication facility or on a manufacturing line) outside of normal resource allocation processes, the success of breakthrough innovations depends on the ability of project managers, champions, and sponsors to find and acquire those resources.

Catalyzing Individual Initiative

In contrast to the literature that describes institutionalization of the incremental innovation process, we found that successful breakthrough innovation depended on the actions of individuals. Rather than relying on organizational systems to manage the process (as might be expected with incremental innovation), individuals were the prime movers and sustainers. We identified several types of key actors—creative scientists, opportunity recognizers, multiple champions and supporters, and project team leaders and members. All of these individuals demonstrate a common characteristic—a passion for and belief in the innovation. This passion overcomes and protects the innovation from organizational forces that naturally resist new ideas.

Creative Scientists or Engineers. Competitive advantage through technical leadership requires recruiting and development a cadre of talented scientists and engineers who have both technical skills and creative, out-of-the-box, idea-generating capabilities (Morone, 1993). In nine of the twelve projects, a single hero scientist or creative engineer had the initial technical insight that set off the chain reaction of events leading to the breakthrough innovation. Often, it was a creative, cognitive act that linked disparate bits of information together.

In organizations that had positions of research fellows, hero scientists (technical champions) emerged from the ranks of senior research fellows or technical people with high prestige. The support and championing of the breakthrough innovation arena was tolerated and protected by their status. Nevertheless, there was still immense difficulty, and the majority of these hero scientists simply stuck out their necks when advocating their breakthrough innovations. This, of course, comes at a risk, but the champions we observed were so passionate about their projects that they paid scant attention to potential downside to their careers.

Opportunity Recognizers. Taking the technical idea and recognizing the potential application or market opportunity was a critical event within the breakthrough innovation process. As indicated earlier in this paper, in eight of our twelve cases first line technical managers (themselves experienced engineers or scientists), not senior managers, were the individuals who first recognized the opportunity, even though they were not the ones who came up with the idea. These innovation recognizers were convinced of the significant potential impact of the innovation and had the confidence to champion it in the larger organization.

We also found that first line managers were not always heard and sometimes gave up; i.e., the opportunity recognizers were not necessarily the champions. They may make the links and communicate the nature of the opportunity to someone else, but then choose not to fight the battles that so often arise with unfamiliar, uncomfortable, or alien topics. Thus, although a creative capacity was necessary, it was not sufficient to achieve progress. Also important was a determination to get the attention of the larger organization and to fight for the resources to pursue the opportunity.

Multiple Champions and Supporters. We observed the importance of multiple champions playing multiple roles. As Day (1994) and Venkataraman et al. (1992) found, champions play multiple roles or there are multiple champions playing different roles. As the literature suggests and our data confirm, champions played a key role in driving these projects forward, especially in the face of obstructionism from other parts of the organization or when intensity and perseverance were required to overcome hurdles.

We identified several types of champions: technical champions, project champions, senior management champions, and business unit champi-

ons. Multiple champions are necessary to support and protect breakthrough innovations because organizational resistance comes from all sides, and the projects by and large do not have organizational legitimacy (Dougherty and Heller, 1994). Although it might seem a reasonable strategy to somehow coordinate the activities of these multiple champions, we found little of this happening. Champions seemed to act individually, though simultaneously, in support of the innovations. While occasionally a single person assumed multiple championing roles, more often than not different people played each championing role. Finding champions was critical to breakthrough innovation success.

Informal networks emerged as critical in all twelve innovations for gaining resources. These networks occurred vertically and horizontally within the organization, including within R&D; between R&D and the business units; and between the company and customers, suppliers and government. Informal networking played a prominent role in idea generation; idea evaluation; generating political/financial support; gaining access to scarce resources, e.g. manufacturing capacity; connecting with friendly customers for alpha testing; and attracting government funding. Due to the innovation's need for legitimacy, protection and access to resources as discussed above, champions tied into organizational networks were critical to overcoming these barriers. One project champion captured the importance of informal networks. *"It's important to know who the right people are in the company to get assistance and support; there's a secret way the company operates. Because of the way in which managers have grown up around here, you have these internal networks and you work them and that's what makes the place work."*

Conclusions

Based on a four-year study of twelve breakthrough innovation projects in ten large, mature firms, we concluded there were significant differences in characteristics and management practices of breakthrough vs. incremental innovation projects. Best practice management of incremental projects suggests a well-defined, linear path with clear go/no go decision points; e.g., the stage gate model (Cooper 1990). In contrast, breakthrough projects are highly uncertain and unpredictable, non-linear (with lots of detours, starts, and stops), stochastic, and managed more through individual initiative rather than through formal, established organizational processes. Due to these dynamics, championing/spon-

Table 1
Summary of Implementation Tactics and Their Effects

Implementation Tactic	Implementation Tactic Effect
1. Stimulating Attractive Ideas	Ensures a stream of high quality ideas for triggering breakthrough innovations; create a strategic context for push, develop goals as pull.
2. Promoting Opportunity Recognition	Sensing, recognizing, and supporting potential opportunities; low- to mid-level research managers most likely to play this role as they are closest to ongoing research.
3. Evaluating and Screening Opportunities	Criteria for continuing and supporting project; early development evaluated on technical considerations rather than on traditional business cases.
4. Creating Incubating Structures	Protects the innovation from organizational resistance until it is strong enough to compete for resources and support on its own merits.
5. Catalyzing Individual Initiative	Technically creative individuals, champions, and supporters necessary for ideas, recognition, securing resources, and organizational support and protection. Getting innovation on radar screen of organizational decision-makers critical to continued project existence.

sorship of senior management and reduced reliance on financial and market numbers as criteria for project continuation (at least early on) seem critical for long-term project success. The front ends of these projects seem to be extended compared to incremental projects, with extensive exploring and experimenting, probing, and learning rather than targeting and developing. Our data further indicates that when projects

reach a dead end in one line of exploration, they frequently cycle back to the front end again, exploring another idea or market opportunity.

We identified a set of implementation tactics for coping with these phenomena, as summarized in Table 1.

These implementation tactics were not applied in an isolated or sequential manner, but in a highly interactive manner. For example, both incubating organizational structures and senior manager championing reinforce each other, serving to protect radical innovation projects from the pressures and practices of the ongoing business. Idea generation is often the trigger for subsequent opportunity recognition—either by the idea generator or a second individual in close proximity—and opportunity recognition, in turn, stimulates a set of initial evaluations. Because of overall uncertainty in the early years of these projects, idea generation is an ongoing and interactive part of early opportunity recognition and evaluation/screening and development activities. Hence, these tactics are used to promote and protect the discovery process—which, in the short term, increases uncertainty—but that for successful projects will, in the long term, reduce uncertainty sufficiently so that the project can be transferred into an operating unit that utilizes traditional management practices.

Conventional management techniques are unsuitable until uncertainty is sufficiently reduced. It appears that the primary imperative driving these projects was to reduce uncertainty to the point where conventional management practices could be applied or where it became apparent the project should be abandoned. From our observations of the projects included in this study, it appeared that much of the breakthrough innovation process was not deliberately managed. While it may be true that conventional management techniques are inappropriate, we believe a more systematic approach can and will be developed. This more systematic approach, which can be derived from an understanding of the dynamics and characteristics of the breakthrough innovation project life cycle, can incorporate the five implementation tactics identified in this study:

- Senior management can develop and articulate the need for breakthrough ideas, delineate white space opportunities, and set "holy grail" challenges.

- Senior management can support opportunity recognition of breakthrough ideas with the recruitment, development, and placement of

technically prestigious individuals, well networked in the company, to act as sentries and scouts identifying and ferreting out new ideas.

- Senior management can evaluate and screen breakthrough projects with different metrics compared with those used for incremental projects. Evaluation based on technical feasibility, at least early on, will keep a project alive against ongoing financial pressures. Further, senior management can support alternative methods for accessing information used in the evaluation and screening process; e.g., experimentation and probes with potential customers for early market data.

- Senior management can support and protect breakthrough projects by developing incubating organizational structures in which projects can mature sufficiently to be able to withstand the scrutiny of more traditional project evaluation reviews. These incubating arrangements may be implemented within R&D centers, business development groups, or separately run departments or divisions. Finding partners and creating alliances with complementary technologies or capabilities supports resource acquisition and helps spread the risk inherent in breakthrough projects.

- Individuals play a critical role in developing and sustaining breakthrough innovations. Even in companies with effective incubating arrangements, senior management needs to support and protect breakthrough innovation projects visibly and vocally. Senior management can cultivate a set of individuals who operate within the organizational system and culture but at the same time challenge the organization by questioning current products and processes, thereby providing a catalyst for the initiation of breakthrough innovations and a medium for their development. Senior management can assist the process by making sure these unconventional (sometimes difficult) individuals are identified, supported, and rewarded. However, unless senior management plays the roles defined above, these out-of-the-box thinkers and actors may not emerge to play their roles.

Breakthrough innovation activity by its very nature is largely incompatible with mainstream business activity. Without stimulation and sponsorship by senior management, the flow of breakthrough innova-

tion activity will be severely restricted by the culture and the drivers that serve to optimize mainstream business activity. Without the protection of senior management via championing and the creation of incubating structures and mechanisms, breakthrough innovation will fail to reach maturity.

Problems of organizational legitimacy result in difficulties in obtaining necessary resources, funding, personnel, time, support, access to organizational support services, and the like. In a sense, the success of breakthrough innovations depends on obtaining a minimum support level of these resources. Most of the mechanisms for supporting the project—multiple champions, informal networks, hero scientists, top management support, discretionary resources, and external alliances as well as government funding—are designed to obtain needed project resources. Many project members agreed that without government resources, for example, the project would have died of malnutrition.

There are researchers who are skeptical about the capability of large established firms to pursue breakthrough innovation. Our findings suggest that senior management has the opportunity to exercise strategic decision-making that can result in fostering, tolerating, or squelching the development and commercialization of breakthrough innovations. The five implementation tactics identified in this study can be used to proactively manage the balance of core, mainstream business activity vs. the breakthrough innovation activity that can provide the seeds for future business development.

Our study extends the existing literature by providing a foundation for developing appropriate management practices, rather than simply highlighting their existence and importance. We hope that this research effort will stimulate the development of additional managerial techniques and a systematic approach for implementing them that will allow firms to maximize the yield from their breakthrough innovation initiatives.

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