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Implementing radical innovation in mature firms: The role of hubs

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Executive Overview

There is increasing evidence of the importance of radical or breakthrough innovation to long-term firm success in the competitive marketplace today. Although this recognition has permeated many established companies, there is uncertainty about how to accomplish such innovation. This article is based on a six-year longitudinal study of 12 radical-innovation projects in 10 large, mature companies. The life cycle of radical-innovation projects is unlike those of incremental projects, because of an abundance of uncertainties and discontinuities. These characteristics require that radical-innovation projects be managed quite differently from incremental ones. Seven key strategic imperatives are offered for successfully implementing radical innovation.

Why Radical Innovation is Important

The contemporary competitive landscape has been and continues to be driven by technological revolution, globalization, hypercompetition, and extreme emphasis on price, quality, and customer satisfaction, requiring an increased recognition and focus on innovation as a strategic competence. While there has been an emphasis on incremental innovation in the past decade, there has been less emphasis on radical or breakthrough innovation. Consequently, a great deal is known about implementing incremental innovation, but implementing radical innovation is poorly understood.[1] This is true even though the importance of radical or breakthrough innovation has been underscored by a number of consultants and business scholars.[2]

Radical or breakthrough innovations transform the relationship between customers and suppliers, restructure marketplace economics, displace current products, and create entirely new product categories. They provide the engine for long-term growth that corporate leaders seek. Unfortunately, recognizing the importance of radical innovations and developing and commercializing them are two different things.

Companies that have succeeded over the long haul punctuate ongoing incremental innovation with radical innovations that create new markets and business opportunities.[3] While it is clear that radical innovation is important to firms concerned with long-run growth and renewal, it is also clear that large, established firms have difficulty managing the radical-innovation process. Large, established firms have grown excellent at managing operational efficiencies, and at introducing next-generation products. However, the chaos and uncertainty that come with commercializing new technologies for markets that may not yet exist require vastly different competencies.

In 1995, we embarked on a study to learn how radical-innovation projects are managed in large, established U.S.-based firms. (See appendix.) Our expectation was that, by first observing and describing the nature of radical innovation, we could draw some insights into how management of radical innovation might be improved. Our observations led us to suggest a set of seven strategic initiatives for developing and sustaining an organizational radical-innovation competency.

The Nature of Radical Innovation

A radical innovation is a product, process, or service with either unprecedented performance features or familiar features that offer significant improvements in performance or cost that transform existing markets or create new ones. Examples

include computerized tomography (CT) and magnetic resonance imaging (MRI), personal computers, pagers, and cellular telephones.

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We came to a pragmatic definition of radical innovation after understanding the theoretical work of others and engaging representatives from the Industrial Research Institute (IRI), a professional association of the technology leaders of *Fortune* 1000 companies located in Washington, D.C.[4] We agreed that we would consider only formally established projects with explicit budgets and organizational identities. The definition of radical innovation that emerged from our study included one or more of these criteria: an entirely new set of performance features, at least a five-fold improvement in known performance features, and a significant (30-percent or greater) reduction in cost. A listing of the companies and a brief description of their projects can be found in Table 1.

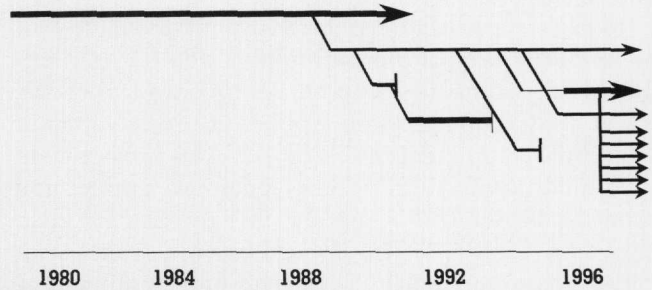
Uncertainties in the Radical-Innovation Life Cycle

Radical innovation has traditionally been defined as that arena where technical and market uncertainties are high.[5] Technical uncertainties refer to questions about the validity of the underlying scientific knowledge, whether the technology will work, technical specifications of the product, and ramping-up issues. Market uncertainties include issues related to customer needs and wants—either existing or latent forms of interaction between the customer and proposed products, and methods of sales and distribution. However, we found two other sources of uncertainty critical for radical-innovation project success. Organizational and resource uncertainties stemming from the conflict between mainstream organizations and radical-innovation teams more often caused projects to stall. Among the organizational uncertainties were questions about the capabilities of the project team; recruiting the right people; managing relationships with the rest of the organization; dealing with variability in management support; overcoming the short-term, results-oriented orientation of operating units, and their resistance to products that might jeopardize existing product lines; and counteracting vested interests in the current business model.

Resource uncertainties also claimed an unexpectedly large share of the teams' attention. Teams needed to find out what funding and competencies were required to complete the project, whether there were sources other than those allocated through the normal corporate budgeting process, who the right partners were, and how to manage their partnerships most effectively. Coping with these uncertainties is essential to managing radical-innovation projects and underlies the dynamics of the radical-innovation life cycle.

Dynamics of the Radical-Innovation Life Cycle

We constructed timelines for the 12 projects that show that the radical-innovation life cycle is long term (often a decade or longer), unpredictable, sporadic (with stops and starts, deaths and revivals), non-linear, and stochastic (with unpredictable exogenous events). (See Figure 1 for an example.) Radical-innovation projects are also context dependent in that corporate culture and informal relationships accelerate or retard progress. These characteristics contrast with the course of incremental innovation, which follows a more linear, orderly process with far fewer organizational and resource uncertainties.[6] As a result, managers of the two processes must take strikingly different paths.



Note: Arrows refer to applications pursued, thickness of arrows to resource commitment. A vertical line indicates the end of an application development.

FIGURE 1
DuPont's Biodegradable Polymer Project

The life cycle of DuPont's biodegradable polymer project, pictured as Figure 1, illustrates the impact of these uncertainties on a radical innovation's time horizon. Each solid horizontal line represents a market application that was pursued, the thickness of those lines indicates the level of re-

Table 1
Companies and Project Descriptions

Company	Projects
Air Products Corporation	• An ionic transport membrane (ITM) for separating oxygen from air.
Analog Devices, Inc.	• A micro-electromechanical system (MEMS) accelerometer, a small microchip capable of detecting changes in speed, initially targeted for automobile airbag acutators.
DuPont	• A new material that emitted light that made it attractive in electronic-display applications. • An environmentally friendly polyester film that could be recycled or decomposed.
General Electric	• A digital x-ray imaging system that would replace existing film-based x-ray systems.
General Motors	• A hybrid vehicle capable of drawing power from both electrical and conventional engines.
IBM	• A new generation of communication chips using silicon germanium (SiGe). This innovation aimed to increase switching speeds and greatly reduced power requirements. • Development and integration of a high-density display, and memory and battery technologies to help create an electronic book.
Nortel Networks (and its spinoff, NetActive)	• A technology allowing digital content to be rented over an Internet link between the consumer and a NetActive server.
Polaroid	• The creation of low-cost, high-capacity computer memory-storage devices.
Texas Instruments	• A Digital Micromirror Device capable of creating a screen image by bouncing light off 1.3 million microscopic bidirectional mirrors squeezed onto a one-square-inch chip for business conference projection systems and large-screen movie theaters.
Otis Elevator Division of United Technologies	• An elevator that could move vertically and horizontally for solving the problem of moving people within extremely tall buildings.

source commitment, and the short vertical lines mark discontinuities that were unsuccessful market applications, any of which could have killed the project.

The four types of uncertainty discussed above were found in this project. Technical uncertainties emerged from different potential applications. For example, how can the degradability, biodegradability, and manufacturability questions be answered for each potential application explored, since each application required a different polymer characteristic?

Market uncertainties abounded and accounted for most of the project discontinuities. The original application, disposable diapers, disappeared when the OEM that requested the application development withdrew its interest in the project. The project went into hibernation until another potential application was identified. Unfortunately, this application also proved a dead end. The project was also beset with other market uncertainties—dead-end applications, environmental regulations that were rumored but never enacted, and improper management of beta trials at potential customer sites. This set of application investigations and subsequent dead ends characterizes the major form of the project life-cycle diagram. Organizational uncertainties included three different project sites and a changing cast of scientists, technicians, and project champions. Resource uncertainties included fluctuating financial support, which at one point supported only two part-time people.

The greatest opportunity for enhancing the possibility of radical-innovation success, we believe, is to expend energy on managing resource and organizational uncertainties. These factors are, in fact, under managerial control. If firms learn to reduce these uncertainties in a systematic way—through leadership and organizational and managerial approaches—then radical-innovation project teams would be better able to address the less controllable and more chaotic market and technical uncertainties.

Based on patterns observed in all 12 projects and on feedback from workshops, seminars, and discussions with almost 40 other companies, we isolated seven key strategic imperatives for developing and driving radical-innovation projects to success. While none of the participating companies demonstrated a competence in all of these strategic imperatives, the full range of implementing these imperatives can result in greater quantity, shorter project life cycles, and increased project success of radical-innovation projects.

Imperative No. 1: Build a Radical-Innovation Hub

A radical-innovation hub can oversee and help nurture projects by reducing uncertainty without increasing bureaucracy. A radical-innovation hub can serve as a repository for cumulative learning about managing radical innovation, and is a natural home base for those who play pivotal roles in making radical innovation happen: the idea hunters and gatherers, internal venture capitalists, members of evaluation and oversight boards, and

corporate entrepreneurs experienced in the realm of high uncertainty.

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At Air Products, for example, a business development manager in corporate R&D helped formulate cost estimates and worked on developing full-system concepts with project teams. At DuPont, a director of new-business development connected technological discoveries with market opportunities and built project teams to help explore the market potential for new technologies. At Polaroid, a new-business division was set up to handle innovative efforts that could not be nurtured in one of the company's two major business units. Finally, at Nortel Networks, a Business Ventures Group was structured to receive, evaluate, and help develop novel ideas that could not gain the attention of business-unit management. They also helped build the project teams and advisory boards for each project.

Effective radical-innovation hubs perform several functions for reducing organizational and resource uncertainties. They capture radical-innovation ideas by recruiting and training idea hunters and gatherers and establishing skilled early-evaluation boards. They build and train radical-innovation project teams and serve as mentors during the incubation period, advising project teams about resource acquisition, market-learning methods, project-evaluation criteria, and management of interfaces with existing business units and senior management. They organize and recruit project advisory boards, decide when a project should transition to a receiving unit (a currently existing operating unit, a newly formed one, or a spinout venture), and organize a transition team to facilitate this transition. Hubs also recruit and develop those who thrive in the radical-innovation environment of risk, uncertainty, and potentially high payout. Radical-innovation hubs thus provide oversight and management from a project's inception to its commercialization and build and accumulate expertise in overseeing a portfolio of radical-innovation projects for the firm. Finally, they create performance benchmarks for senior management. They assemble and update a knowledge-management system that shows how long it takes for radical innovations and markets to develop, and how much money is required. An example of how this might play out is illustrated with the hub at Nortel Networks.

The hub at Nortel Networks was called the Business Ventures Group. In addition to issuing a request for proposals, the hub organization developed a Web site that helped employees get started on articulating ideas. The initial contact person in the hub engaged the idea generator before the idea was fully formulated to help develop the concept. Hub personnel judged the potential attractiveness of the opportunity. Finally, the hub decided whether or not to fund the concept development, leading to a business case for evaluation by senior management. If the business-case evaluation resulted in a sanctioned project by senior management, the hub was able to provide project-incubation services: finding the right people, putting the team together, and providing business-development skills, marketing, and financial-management assistance to the team.

Imperative No. 2: Deploy Hunters and Gatherers

Good ideas can come from everywhere—business units, R&D, senior managers, bench scientists, even people outside the organization. Idea generators need a place to take their ideas for a quick back-of-the-envelope assessment, for help with extending or redirecting their thinking, or with articulating the idea's potential. To move radical ideas forward, firms need to first recognize opportunities. The technical and market uncertainties associated with radical innovations, however, often make this difficult. In 10 of our 12 cases, the individuals who generated the ideas did not recognize the opportunities. In incremental innovation, opportunities are more easily recognized. They are typically derived from analytically based market research, and are built on known technologies. But when markets do not yet exist, and there are many alternative directions that the technology-development path can take, opportunity recognition is much more challenging. The boundaries of the firm's current markets and organizational structure further complicate recognition; it is sometimes difficult to recognize and pursue an opportunity that one knows will seriously challenge parts of the established organization. Those who do recognize potential breakthrough opportunities have the market knowledge and organizational perspective to connect ideas with applications. They can think broadly about potential scientific connections, social trends, markets, and customers.

Opportunity recognition depends more on individual initiative than routine practices and can be either reactive or proactive. Gatherers are alert

and ready to react to promising radical ideas, while hunters take responsibility for actively seeking out ideas with business potential.[7]

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Opportunity gatherers are receivers of ideas. They have the experience, skills, judgment, and motivation to be alert to activities that are going on in R&D or that appear from other sources. They have the technical and market sophistication to assess what they encounter. In most of our cases, the first-line or midlevel research managers and senior scientists played the gatherer role. They viewed their responsibility as helping the idea generator acquire the resources needed to develop the idea. The gatherer at DuPont played a critical role in the discovery of a new kind of fiber.

A researcher at DuPont was working on characterizing materials, and noticed unexpected properties in the fiber he was working with. Under certain conditions, the fiber emitted light at an unusually high speed. When his project was coming up for a technical review, his boss said: "This might be of interest to the new-business development guys." He went to the director of corporate business development (the gatherer) and said: "You should come to this review." In our interviews, the director commented: "I get invitations all the time, but on this one, they grabbed my attention and would not let me go." Once he saw the presentation, he was impressed. He called his buddy in the electronic materials division, who indicated he would inherit the project if and when it was ready for commercialization.

Opportunity hunters take a more active approach. They go out into the organization, asking questions to uncover latent ideas, and making connections. One respondent told us that, after sniffing new ideas out of the lab, he would tell scientists: "I know you just invented this yesterday, but, wow! Can I see a market for this!" Like gatherers, hunters have technical training, but are also experienced in marketing or business development. Perhaps as important, a successful hunter knows how to articulate the opportunity in compelling terms that gain the attention of higher management, a skill few bench scientists have.

IBM hired an individual to play the role of hunter. His job was to troll for ideas and evaluate them at a very early stage. He described his job this way: "I started looking through our research organization to uncover intellectual property that I could leverage into the marketplace. I was actively scanning and knew [that one scientist] had been running around evangelizing [the technology] for two or three years. He hadn't been able to build a case that got it recognized and funded, which is what I did." The hunter worked with this scientist to develop a business plan that articulated the opportunity in a way that senior management could understand. Together, they were successful in gaining high-level attention and support for the development of the silicon-germanium chip technology that became one of IBM's promising new ventures.

Hubs can help in generating ideas

Unlike these ad hoc, nonsystematic approaches, hubs can take responsibility for fuzzy front-end functions, imposing continuity and system on a catch-as-catch-can set of activities. Hubs create a network of idea generators, hunters, and gatherers, and actively develop their skills. Figure 2 is a diagram of a hub structure, portraying hunters and

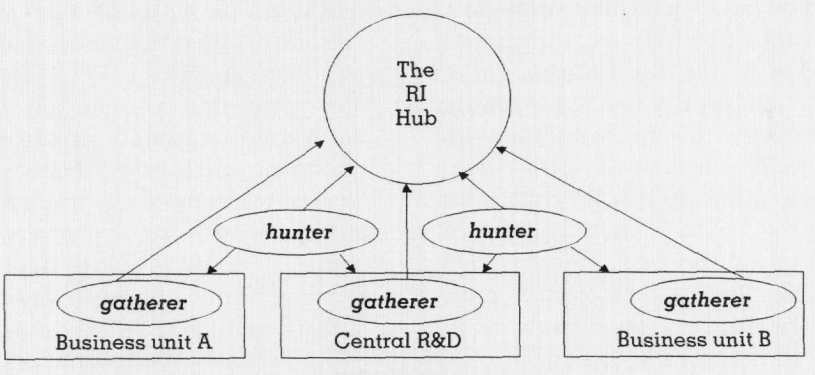

FIGURE 2
A Radical-Innovation Hub with Hunters and Gatherers

gatherers as interfacing with various organizational units, as well as working in those units, but reporting to the radical-innovation hub that coordinates them.

The venture-development organization at Nortel Networks was a radical-innovation hub. It used a request for proposals to stimulate idea generation and a Web site to help collect them. The initial hub contact person would help the idea generator articulate and develop ideas into business concepts, and would help sort out the known from the uncertain. Once the idea was submitted, the hub team performed a preliminary screening. If there was a compelling opportunity, a business-development specialist worked with the idea generator to further develop it. Eventually, a three-person team judged the attractiveness of the opportunity and decided whether to fund it. Funding at that point did not sanction a formal project, but rather a commitment to develop a business proposal for senior management. That commitment ranged from several weeks to several months. According to the hub director: "The overall competency that we brought as a team was the ability to take technology and translate it into compelling business propositions."

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Imperative No. 3: Monitor and Redirect Projects

The inevitable uncertainties of radical-innovation projects contribute to ad hoc, crisis-oriented management practices. What is needed is an uncertainty-reduction mindset quite different from that held by incremental project managers. Radical-innovation managers must relinquish the traditional control-to-task mentality in favor of a monitor-and-redirect mindset.

The four kinds of uncertainties in radical-innovation environments make control-to-task impractical. After the head of GE Medical Systems (GEMS) decided that the investment in digital x-ray project technology was a distraction from the short-term budget, the project manager was forced to seek funding from outside the corporation. At the same time, his manufacturing partner failed to meet expectations, forcing him to bring manufacturing into R&D. These resource-uncertainty problems were compounded with organizational ones. Since the head of GEMS was more concerned with cost cutting than innovation, he was not ready to market the project. The project languished in R&D until he was replaced with a more innovation-minded president who brought the project to commercialization within six months. Technical-uncertainty issues continued to beset the project as difficulties were experienced going from a small demonstration unit in a laboratory to a commercially viable product. Market uncertainties were also present. Although customers were identified—GEMS knew all users of x-ray machines worldwide—the substantial cost increase of the new machine required educating a price-sensitive market on how this innovation would still be cost effective—by eliminating film and film storage, for example.

Of course, not all uncertainties can be confronted simultaneously. By cataloguing uncertainties, the team can focus on some while deferring or even outsourcing others. The natural tendency is to confront the uncertainties with which the team is most comfortable and put the others on the shelf. This is a particular problem for teams dominated by scientists or engineers who may prefer to focus on technical challenges.

Progress can be monitored by checking off assumptions as they are tested. The learning that results can then be documented, along with the decisions made as a consequence of that learning. According to one respondent, radical-innovation evaluation was based on the amount that was learned for the amount of money invested in the project, rather than tracking task completion against budget and schedule.

Besides managing internal progress, the project manager must manage interfaces with the mainstream organization. This requires gaining legitimacy for the project, preparing the organization to assimilate it as a mainstream activity, and securing resources to continue incubating the project. Our research suggests that when radical innovation is incubated in the mainstream organization, both the project and the organization benefit from the mutual learning. They can achieve greater success than do skunk-works projects, which develop in isolation from the rest of the organization without the wealth of resources that the mainstream organization has to offer. For example, the IBM project manager was able to borrow a chip fabrication facility during a slow period to test his ideas. The IBM book project worked closely with IBM Solutions to identify a beta test partner. And at DuPont, connections to the internal network caused a senior technical researcher in a division other than where the project was working to identify a potential market opportunity.

Successful managers used several practices to integrate radical-innovation projects into the mainstream. They maintained regular and frequent communication with the mainstream organization. They capitalized on the desirability of preempting other innovators, and introduced testimony from potential customers as ways to get an operating unit to recognize the importance of the innovation. And they assembled influential advisors. A board of brand-name people provided internal legitimacy as it contributed the insights and support of its members.

Hubs can reduce uncertainty

A hub can proactively engage radical-innovation project teams and provide experts and mentors who help projects understand the nature of the radical-innovation life cycle and how to reduce uncertainties. A hub establishes radical-innovation project-management systems, refines them through cumulative experience, and then helps teams implement them. It teaches teams new market-learning approaches and implements resource-acquisition strategies. A hub can be most effective in helping the project leader manage the interface between the project and the rest of the organization; using its own informal network to complement that of the project leader, it acts as a conduit for money, human resources, advice, facilities, and legitimacy.

Imperative No. 4: Develop a Resource-Acquisition Skill Set

Radical-innovation projects typically outstrip available research resources. Getting money, facilities, and people is universally difficult for radical innovators; they must spend an inordinate percentage of time and energy chasing resources.

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When a radical-innovation project is established, it is generally given a small formal budget. The time required for a technology or market to mature may take many years. Investments in radical-innovation projects take a long time to demonstrate any tangible returns. Furthermore, radical-innovation projects based on new technologies often require development funds far beyond normal budget limits. Because a radical-innovation life cycle may span many years, a project can expect to see its supporters and funding sources change two or three times during its lifetime. Consequently, project leaders must approach a variety of potential funding sources and even reorient their projects to suit whoever holds the purse strings. Acquiring resources is a dynamic process. In all 12 projects in our study, the persistence of project champions in acquiring resources was critical.[8] The price paid for this persistence was substantial, since time spent chasing money was time not spent on project development.

After three years of effort, part of the hybrid-vehicle development effort at General Motors was in danger of losing its funding. In an effort to save it, the project team staged a technology demonstration for GM's corporate executives. Though the demonstration was impressive, it failed to produce continued funding. "You put on a good show," the director of GM's development group informed the project team, "but we've received orders to close you down. Our budgets can't handle you." A month later, a GM manager found himself sitting on an airplane next to a U.S. Department of Energy (DOE) official, whom he had known for some time. The GM manager described the hybrid-vehicle project to the DOE official, who liked what he heard, and agreed to recommend the project for federal funding. Approximately one year later, that funding was authorized. GM participated in the Partnership for a New Generation of Vehicles (PNGV), a consortium of the Big Three U. S. automakers, each of which was working on a hybrid vehicle. The GM project was significantly increased in scope by the funding, and effort within and by the original development group was consolidated under one project heading. In the view of the project team members and manager, the project would surely have folded without this funding.

Hubs can facilitate resource acquisition

The hub has an important role in helping teams develop a resource-acquisition capability. First, it can assign someone to the team who has a track record of acquiring resources for radical-innovation projects. Alternatively, it can train the project manager or a team member in that skill set, or assign a resource-acquisition specialist, who can identify internal and external financing and develop funding proposals on an as-needed basis.

At Nortel Networks, the project manager was assigned the role of obtaining resources. As one member of the project told us: "I think [he] has made a very, very good decision in terms of insu-

lating the organization from the business of going out and getting money. And the reason I say that is because I worked at an Internet startup for 13 months before I joined [this project], and what happened is they did IPOs and money getting, and all that sort of thing, but they got everybody really excited and it was the sexy thing to do in the company. So what happened was that they took their entire general management staff, the CFO, the CEO, the COO, and, for six months, they went away (to get money), so the company basically went to hell in a handbasket."

The hub can also explore alternative venture-capital models. During the six-year period of our study, we witnessed firms' experimenting with several approaches to venture-capital funding. These initiatives were directed at internal ventures, potential spinoffs, and external startup ventures of strategic interest to the firm. In some cases, the firm opted to develop an internal venture-capital investment capacity. In others, the firm chose to partner with external venture-capital firms. Firms that make a strategic decision to pursue radical innovations can learn from the experience of others and choose an approach to funding that is consonant with their objectives.

In addition, the hub can assemble an appropriate decision-making board for radical-innovation investments. The higher level decision-making process required for ramp-up and transition-funding decisions should involve people with sufficient experience, capacity, and independence from the operating units that they can make objective and effective decisions. There is no more certain way of making a venture-funding board irrelevant than staffing it with managers who are driven by the short-term interests of their own business units, or who lack the skill and judgment to make appropriate decisions. Senior management must be involved in making decisions on radical-innovation projects because of strategic considerations, but the decision-making team can and should include people experienced with radical innovations and the technologies in question, and with venture-capital background.

Some decision makers may come from outside the organization. This was the case at Lucent, which hired a venture capitalist to run its new division, whose purpose was to incubate internal technologies and opportunities. The venture board was composed of the president of the venture-capital division, three vice presidents, and industry experts. Funding came from the corporate budget for investment purposes and additional funding was sought from outside investors.

Imperative No. 5: Accelerate Project Transition

Projects cannot stay in R&D forever. At some point they must be transitioned to a receiving unit in operations for ramp-up and market introduction. The transition from project to operating business presents its own set of hurdles. After conquering technical, market, organizational, and resource uncertainties, this last hurdle turns out to be quite difficult.

The transition from project to operating business presents its own set of hurdles.

During transition, market and technical issues continue to beset the project. Early adopters are often willing to accept a prototype and work with the innovating firm to define the form and function of the new product, but customers buying a commercial product expect development to be fully completed. The new radical-innovation product is sufficiently different from current products that potential customers and the sales force need to be educated. Technical specifications that were adequate for the prototype stage require substantial revisions, since the new product is customized for specific applications. A project team and an operating unit often have quite different perceptions of a project's readiness for transition.

When the project team transitioned its product at DuPont, the operating-unit manager exclaimed: "I can't believe they sent it to me this early." In his mind, the technical and market uncertainties had not been sufficiently resolved. Because additional applications-development work was required before significant production could be undertaken, the project team remained involved even after the transfer. A project manager in the business unit was assigned the task of completing the technical and market development. Unfortunately, after he had only begun the effort he was promoted. The project was at a standstill for almost a year until a new product manager was assigned and brought up to speed. The second project manager forced his team to assess more than 30 leads and to focus on four. The search for commercial applications continued until, in frustration, the manager sent the project back to R&D. If the project had, in fact, been ready for transition, with a clear market opportunity identified, the confusion in the operating unit could have been avoided, time to market reduced, and revenues realized. Since it was transitioned too early, none of this occurred.

In most cases, neither the receiving operating unit nor the project team should be expected to

possess the competencies needed to accelerate the project through this transition. A transition team—formed and supported by the radical-innovation hub—can be a more effective organizational approach. Although this requires two handoffs rather than one—from project to transition team and from transition team to operating unit—it is easier to bridge two small gaps than one substantial gap.

Hubs can smooth the transition process

As we saw at DuPont and GE, transitioning is where several projects really stalled. A series of actions will make the transition process work more effectively. First, transition readiness needs to be assessed from both the project and operating-unit perspectives. A key output of the transition-readiness assessment is the transition plan. This also facilitates buy-in by key leaders from R&D, the operating unit, and corporate levels, creating a strategic push to consummate the transition. Second, a transition team should be created, composed of personnel from the project team and the receiving operating unit, transition-management experts, market-development specialists, and a special oversight board. Funding should come from a corporate fund, because neither R&D nor the operating unit feels an ownership of the project at that point in its development. Hub staff, through repeated assessment exercises, eventually develops a competency in expediting this process and ensuring the quality and usability of the outcome.

The transition team develops a detailed transition plan that defines tasks, timetable, roles, and responsibilities. A senior-level-management transition champion gives the transition process the high priority it needs to be successful. The transition team oversight board is a useful organizational mechanism for concentrating the power of senior-management supporters. It also provides a natural mechanism for reviewing the progress of the transition team and ensuring cooperation among the various stakeholders.

The ultimate goal of any radical-innovation project is a successful business. From a market-development perspective, that goal can be reached via several paths. It is difficult, but critically important, to set realistic expectations in the transition plan about the likely evolution of the market. At IBM, the program manager in the microelectronics unit, which received the silicon-germanium project, told us that the project almost did not make his unit's list of priority projects because projections of market size were too long-term to be credible. The projections were predicated on the telecommunications market, but the immediate market application, satellites, was much smaller and required too much work to develop for enough short-term revenues.

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Imperative No. 6: Find People Who Drive Radical Innovation

Radical innovation will not happen without the right people. People with risk-taking propensity, drive, and out-of-the-box thinking were involved in every project we followed. Nevertheless, we saw few deliberate attempts to recruit, develop, and retain such people; they either emerged or had the maverick personality that is attracted to radical innovation. In some cases, people volunteered onto project teams when they heard about them through the grapevine. Large companies will have a difficult time retaining these people, as they are often entrepreneurial and ambitious, and often at odds with the organizational framework within which they work. Developing a reward system is therefore a critical organizational problem. A few organizations, including Proctor & Gamble, 3M, and Lucent, experimented with implementing appropriate reward systems for radical innovators, but even these firms were dissatisfied with their approaches.

Cross-functional teams formed for incremental innovation typically include a technical guru, an engineer, a designer, a manufacturing expert, a marketing specialist, and even a financial person. Radical innovation requires a core group of multifunctional individuals, particularly in the early stages. They may be technical people first and foremost, but their value to the team is enhanced if they understand marketing enough to think broadly about application possibilities, are interested in the financial impacts of alternative courses of development, appreciate the consequences of development choices on manufacturing, and build connections to internal and external partners.[9]

None of the companies we followed had developed human-resources strategies for coping systematically with the personnel dimensions of radical innovation. Virtually all the managers we interviewed understood that people who drive radical innovation have different characteristics from those in more traditional roles, but had not translated those realizations into organizational poli-

cies. Recruiting, developing, and providing career opportunities for people who can drive radical innovation appears to be a major gap in the radical-innovation competencies of firms.

Hubs can search for talent

Firms need to learn how to attract, develop, reward, and retain people who carry out radical innovation. The first step is to discover the radical-innovation types already within the firm. The hub serves as a magnet, drawing them out of the corporate woodwork, and can also actively search the organization for radical-innovation talent. Going beyond the hub, dynamic leadership, an effective innovation-support infrastructure, and deep reservoirs of technology, competencies, knowledge, and talent all create a corporate culture that appeals to the innovators and entrepreneurs who are most likely to promote radical innovation.

Imperative No. 7: Mobilize the Multiple Roles of Leaders

Since senior management has a great impact on the capacity of an organization to succeed or fail at radical innovation, it follows that senior-management turnover produces disruption, both positive and negative, in the radical-innovation culture of organizations. At one company in our sample, the retirement of a senior officer resulted in the dismantling of its radical-innovation hub. At Texas Instruments, the sudden death of the CEO who instigated and supported the Digital Light Processor threw the young project into turmoil. Fortunately, the vice chairman and most of the senior staff had voiced support for the project, which had achieved formal status in the organization, with a budget and personnel. But the project was not out of the woods until the new president also demonstrated support. We identified three ways that senior managers can champion radical innovation.

Executives as patrons

Just as the powerful and rich have supported and protected artists throughout history, a system of patronage works in corporate innovation. In all firms in our study, one or more senior executives played the role of patron, variously providing organizational protection, resources, and encouragement to maverick innovators. We found across most projects that the patron had faith in a project champion because of the champion's personal characteristics, a lengthy relationship between the two, or the champion's track record in bringing other important projects to fruition.

To be an effective patron, the senior executive must be accessible, especially to the middle managers who generate many radical innovation opportunities. The senior executive must also have a passion or personal liking for the project, and must give sustained support, or pass that support on to another executive. In half the companies studied, the executive who followed a project's departed patron either slowed or killed the project.

In half the companies studied, the executive who followed a project's departed patron either slowed or killed the project.

Executives as provocateurs

In 90 percent of our sample companies, executives played an active role in driving radical innovation by issuing a call to arms that stimulated innovation. The CEO of Air Products voiced his concern that the company had missed an earlier game-changing innovation, and declared: "By God, we're not going to miss the next one." At one of his regularly scheduled monthly meetings with his top managers, Otis Elevator's CEO challenged his team to produce ideas for an elevator in an imaginary mile-high building. An elevator car that used electric motors rather than conventional cables was the result. Such executives stimulated both the level of activity and its direction, impelling their organizations to launch major new efforts.

Executives as shapers of culture

An executive's greatest contribution to radical innovation is to shape the organizational culture in ways that make it natural, accepted, and valued. Ray Stata put his own stamp on the culture of the company he founded, Analog Devices. Early in the history of Analog Devices, Stata wanted to acquire a company that offered the opportunity to expand into integrated circuits, a technology he believed would become important over time. Although his board of directors disagreed, Stata used his founder's stock to acquire the company, which has since become a cornerstone of Analog's success.

This story is frequently cited as the basis of an entrepreneurial culture that justifies breaking the rules to pursue an attractive business opportunity. Stata reinforced this culture when he came back from retirement to help support and protect the solid-

state accelerometer project. The project did not have a home at the time, and was passed from operating unit to operating unit. Largely because of Stata's support, a new division was established to develop, manufacture, and sell the innovation. One of its applications allowed the replacement of three separate airbag initiators with a single solid-state accelerometer. Subsequent applications emerged in areas as diverse as medical devices and video games.

Developing a Mature Radical-Innovation Capability

Radical-innovation maturity comes when an organization has systematically implemented processes for initiating, supporting, and rewarding radical-innovation activities. Depending on an organization's level of radical-innovation competency, there are different approaches to solving the major challenges identified in this article. Moving from lower to higher maturity is not easy. However, failure means that firms must rely on a combination of luck and extraordinary individual effort. In firms with a mature radical-innovation capability, radical-innovation hubs can play a supporting role in some tasks and take the lead in others. An integrated diagram of the hub and its relationship to the project team and the larger organization is contained in Figure 3. The hub sits at the interface between the radical-innovation project team and key internal and external stakeholders. Internal stakeholders include various operating units, R&D, and senior management. External stakeholders include early-adopter partners, manufacturing partners, technology-development partners, and funding partners. The hub acts as a source of radical-innovation expertise and facilitates constructive relationships between the radical-innovation project and its stakeholders.

As a firm builds a more mature radical-innovation capability, its leadership sets expectations, creates an innovative, supportive culture, establishes a radical-innovation hub, and develops appropriate goals and reward systems surrounding the hub's activities. Since radical innovation is critical to long-term organizational success, such organizational arrangements are absolutely critical. Without them, radical innovation will remain a haphazard and ad hoc activity.

Appendix

A multiple case-study design was used, since there is little research concerning new-product development for radical innovation. Case-study research is especially appropriate for this type of exploratory research, with a focus on documenting a phenomenon within its organizational context, exploring the boundaries of a phenomenon, and integrating information from multiple sources.

This research was conducted in cooperation with the Industrial Research Institute (IRI), with the financial support of the Sloan Foundation. All the participating companies were members of the IRI, and volunteered projects on the basis of the definition of radical innovation provided in this article. We lost no companies over the course of the research. The findings represent the results of a longitudinal (since 1995), multidisciplinary study of the management of radical innovation. Six researchers represented the management disciplines of entrepreneurship, marketing, operations, product design, organizational behavior, and technology management. All six participated as interviewers, and met regularly to review and interpret the data. We collected interview data, as well as company records, in real time rather than retrospectively to control for the history effects that weaken case research. Data were gathered at multiple times, at least once per year, as each project moved forward. To learn about each project, we interviewed senior management (including directors and vice presidents of R&D and corporate development), project managers, and

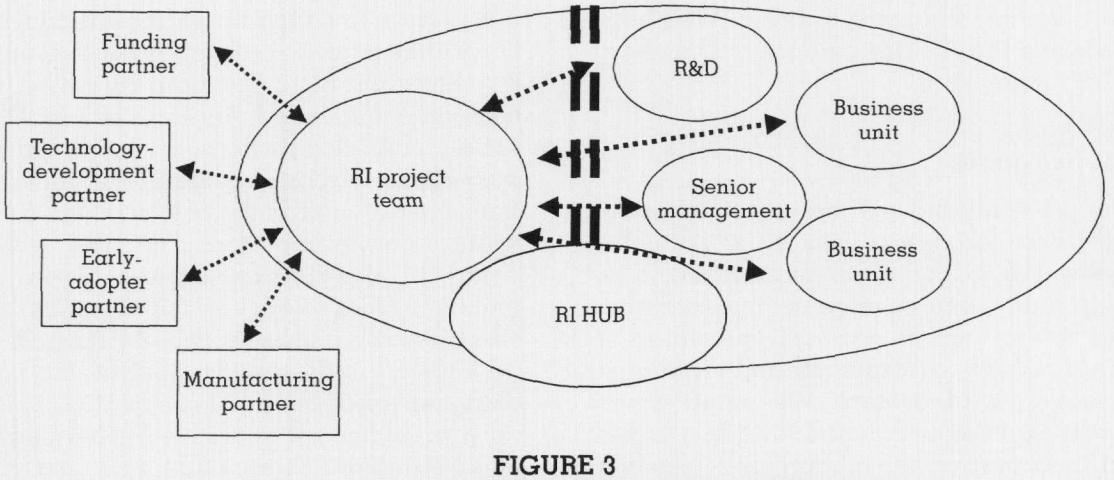


FIGURE 3
The Radical-Innovation Hub's Role in the Organization

individual team members. Using multiple interviewees reduces the risk of undue influence that an individual interview may have on the case study, and develops a richer portrait of each case.

Endnotes

[1] See, in particular, Foster, R. 1986. *Innovation: The attacker's advantage.* New York: Summit Books; Utterback, J. M. 1994. *Mastering the dynamics of innovation.* Boston: Harvard Business School Press; Christensen, C. 1997. *The innovator's dilemma.* Boston: Harvard Business School Press; and Hamel, G. 2000. *Leading the revolution.* Boston: Harvard Business School Press. This article builds on research reported in our book, Leifer, R., McDermott, C. M., O'Connor, G. C., Peters, L., Rice, M., & Veryzer, R. W. 2000. *Radical innovation: How mature companies can outsmart upstarts.* Boston: Harvard Business School Press. However, our conclusions and recommendations reflect new thinking beyond those presented in the book.

[2] Numerous other writers have recognized the difficulty of managing radical innovation in large, established firms. Christensen, ibid., indicates that it is highly uncommon for firms that manage established lines of business well to anticipate and respond effectively to a disruptive technology coming from an external agent, much less to commercialize one themselves. Also see, Leonard-Barton, D. 1995. *Well-springs of knowledge: Building and sustaining the sources of innovation.* Boston: Harvard Business School Press; Katz, R. & Allen, T. 1985. Organizational issues in the introduction of new technologies. In P. R. Kleindorfer, (Ed.), *The management of productivity and technology in manufacturing:* 275–300. New York: Plenum Press; Kanter, R. M. 1989. Swimming in newstreams: Mastering innovation dilemmas. *California Management Review,* Summer: 45–69; Tushman, M. & O'Reilly, C. 1997. *Winning through innovation: A practical guide to leading organizational change and renewal.* Boston: Harvard Business School Press; Dougherty, D. 1992. Interpretive barriers to successful product innovation in large firms. *Organization Science,* 3(2): 179–202; Block, Z. & MacMillan, I. 1993. *Corporate venturing: Creating new businesses within the firm.* Boston: Harvard Business School Press, provide actionable prescriptions to enhance an organization's readiness to commercialize radical innovation.

[3] See Morone, J. 1993. *Winning in high tech markets.* Boston: Harvard Business School Press, and Tushman & O'Reilly, ibid.

[4] Abdul, A. 1994. Pioneering versus incremental innovation: Review and research propositions. *Journal of Product Innovation Management,* 11: 56–61; Lee, M. & Na, D. 1994. Determinants of technical success in product development when innovation radicalness is considered. *Journal of Product Innovation Management,* 11: 62–68; March, J. G. 1991. Exploration and exploitation in organizational learning. *Organization Science,* 2(1): 71–87.

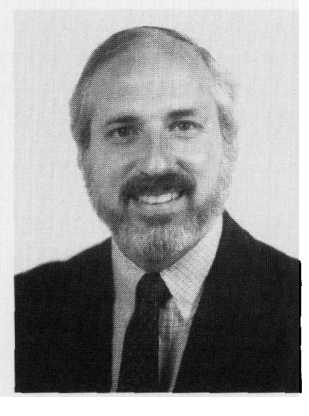
[5] See Ansoff, H. 1957. Strategies for diversification. *Harvard Business Review,* September–October, 35: 113–124; and Booz-Allen & Hamilton, Inc. 1982. *New product management for the 1980s.* New York: Booz-Allen & Hamilton.

[6] For an excellent discussion of stage-gates, see Cooper, R. G. 1990. Stage-gate systems: A new tool for managing new products. *Business Horizons,* May–June: 44–54. See also Cooper, R. G. 1993. *Winning at new products: Accelerating the process from idea to launch,* 2nd ed. Reading. MA: Addison-Wesley.

[7] Rosabeth Kanter's concepts are most similar to ours. She refers to "scouts" and "coaches." A scout is the receiver of new ideas and has corporate money to allocate to them, and the coach is the more active role, helping refine the idea and create the sales pitch to help senior management understand its importance and eventually find a funding sponsor. See Kanter, R. M. 1989. *When giants learn to dance.* New York: Simon & Schuster.

[8] See also Dougherty, D. & Hardy, C. 1996. Sustained product innovation in large, mature organizations: Overcoming innovation-to-organization problems. *Academy of Management Journal,* 39(5): 1120–1153; and Angle, H. L. & Van de Ven, A. H. 1989. Suggestions for managing the innovation journey. In A. H. Van de Ven, H. L. Angle, & M. S. Poole, (Eds.), *Research on the management of innovation: The Minnesota studies.* New York: Harper & Row.

[9] Leavitt, H. & Lipman-Blumen, J. 1995. Hot groups. *Harvard Business Review,* 73: 109–116; Wenger, E. C. & Snyder, W. M. 2000. Communities of practice: The organizational frontier. *Harvard Business Review,* January–February: 139–145.



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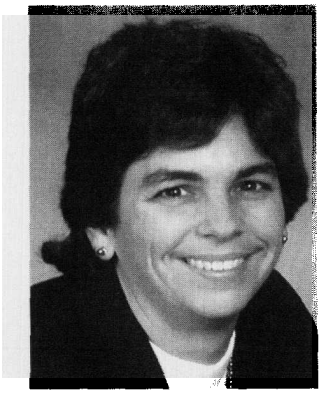

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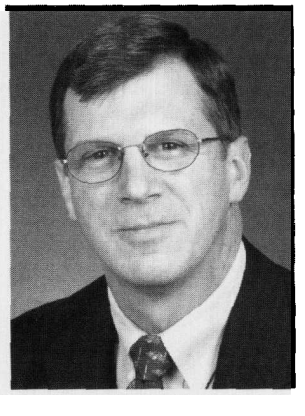

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