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The human side of radical innovation

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Abstract

Radical innovation requires organizations to move into unknown territory and experiment with new processes that largely elude systemization. In this paper we report on a 6-year longitudinal study of 12 radical innovation (RI) projects in 10 large established US based firms. In actuality, there are a number of organizational factors that leverage the human side of making radical innovation happen that, if viewed systematically, could be utilized more broadly for greater radical innovation success. We report on gaps and mismatches that emerged in the sample as well regarding the expectation for radical innovation to happen and the mechanisms by which people are incented to do so. We link our observations to the evolving dynamic capabilities literature as it is currently being extended into high velocity domains.

Keywords: Radical innovation; Corporate human interface

1. Introduction

Radical, breakthrough, discontinuous, step out, horizon 3, gamechanging innovation are all labels adopted in the academic literature and management practice to identify projects whose objectives are to create new to the world offerings and, concomitantly, whole new lines of business for companies. They are distinguished not only by the promise of reward they offer, which is not only large in scope and strategically important to the corporation in terms of organizational renewal, but also by the risk and uncertainty that accompanies their potential outcome. They are characterized by long-term (typically 10 years or more) development time and millions of dollars of investment. Because these projects operate in domains of high uncertainty, management practices associated with them must logically differ from those applied to new product development (NPD) projects whose

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targeted outcome is more incremental and thus, well understood (Morone, 1993; Leifer et al., 2000).

Typically radical innovation (RI) has been considered the domain of start up entrepreneurial ventures, who reject the processes and infrastructure of the large established company in favor of flexible, discovery based approaches to commercializing novel technologies. Large established firms have learned to excel at incremental or even generational improvement, operational discipline, and continuous refinement of known processes. Yet, even large companies cannot save and refine their way to strategic renewal, nor can they hope to achieve it solely through acquisition. Over time, lines of business wither and must be replaced. The value of specific capabilities erodes as they become established best practices throughout an industry (Eisenhardt and Martin, 2000). General Electric, Motorola, 3M, Kodak, Dupont, Texas Instruments and other large icons have, every once in a while, managed to spawn whole new lines of business through radical innovation. Previous research on radical innovation has focused on factors impacting firms' willingness to adopt them for their own use as a source of competitive advantage (Ettlie et al., 1984; Damanpour, 1988, 1991; Nord and Tucker, 1987), while others focus on the efforts (or failures) of firms to create radical innovations and leverage them in the marketplace (Burgelman, 1985; Christensen, 1997; Dougherty and Heller, 1994; Leifer et al., 2000; Tushman and O'Reilly, 1997; Van de Ven et al., 1989; Kanter et al., 1991).

The vast majority of the literature analyzing how and why radical innovations were successfully developed and commercialized focuses on the importance of the individual, his persistence, vision and drive to getting things done in the face of doubters and the bureaucratic systems of the company as a critical element in how radical innovation happens in large companies. Additionally, the need for senior management sponsorship as the project requires more and more investment is well understood. Yet few studies have reviewed, in a systematic way, the myriad mechanisms used in large companies to leverage the human element necessary for radical innovation. The objective of this paper is to build on the growing body of field research in radical innovation, with a focus on the human connections. We draw our observations from a recently completed longitudinal field study of twelve radical innovation projects in ten large established companies. We focus on practices that organizations are using, albeit unsystematically, to leverage the humanness of RI in ways that advance projects. We also note practices being used that, in fact, retard RI progress.

The research questions that guided this specific line of inquiry were rather simple—(1) what factors enable entrepreneurial people in organizations to succeed? (2) what factors inhibit their success? (3) what specific people related factors advance radical innovations in large established companies, and (4) what people related factors inhibit their advancement?

Given the importance of people's passion and unique talent in driving RI, it seems critical to consider mechanisms that work and don't work to leverage these human aspects of radical innovation. While the highly uncertain, highly volatile domain of RI requires situation-specific knowledge that is not necessarily codifiable as are more predictable business processes (Eisenhardt and Martin, 2000), a thorough understanding of the human side of RI will lead academics to consider how to develop support mechanisms, appropriate governance techniques, and enabling infrastructure to work with, rather than frustrate, those with talent and acumen for radical innovation.

2. Methodology

The research reported in this paper is part of a 6-year (1995–2000) prospective study of radical, or breakthrough, innovations. Our intent was to observe management practices of these projects as they were unfolding, and to consider them in comparison to practices for incremental innovation that are so richly defined in the literature today (Cooper, 1989, 1990; Cooper and Kleinschmidt, 1986). We expect that through careful observation and description, practice that has not been previously documented can be identified, and, ultimately, tied to project success. In the interim, insights may be gained through comparative studies about managerial practices that appear healthy and fruitful with those that do not. Through observation and involvement with project participants, we are able to clarify necessary roles and structures that may serve to guide management thinking and academic theory building.

2.1. Defining radical innovation

There are many ways to define breakthrough, or radical innovation (Garcia and Calantone, 2002), though conceptually agreement converges that it is linked to high risk, high uncertainty projects with the potential to vastly influence the marketplace and bring returns to the firm. To operationalize the definition for purposes of qualifying projects into the study, we worked in conjunction with the Industrial Research Institute (IRI). We ultimately defined a radical or breakthrough innovation as the creation of a new line of business—new for both the firm and the marketplace. By "new" we mean a product or process either with unprecedented performance features or with already familiar features that offer potential for a 5–10× (or greater) improvement in performance, or a 30–50% (or greater) reduction in cost. By this definition, CT and MRI were discontinuous innovations in the field of diagnostic imaging, but none of the subsequent incremental and generational improvements in the technologies were. The first PCs were discontinuous innovations, but the many subsequent improvements were not.

2.2. Qualifying the sample

The Industrial Research Institute, an association of R&D managers and Senior Technology Officers of Fortune 1000 firms in the United States, sponsored this study. The IRI is thus our sampling frame, and it therefore must be noted that our results cannot be generalized to all types of innovations, but only to those whose earliest development was housed in a Central R&D function and whose discontinuity is based on a technological leap.

In order to become a participating project in the study, projects had to meet the following criteria—(a) they must have been formally recognized in their organizations with an identified team and a budget (we did not want to start with projects that had gone underground or were being pushed along by one or two impassioned individuals, though nearly every one of our projects had begun that way and many went through those periods sometime during the observation period), (b) management had be express the belief that the project had the potential to become a radical innovation. The companies and their projects are listed

Table 1
Sample companies and projects

Company	Project description
Air products	An ionic transport membrane (ITM) for separating oxygen from air targeted at two fundamentally different applications: (1) users who need small amounts of oxygen (i.e. welding shops, hospitals) and (2) large, commercial customers who require air filtering for manufacturing plants.
Analog devices	A micro-electromechanical accelerometer, a small microchip capable of detecting changes in speed, initially targeted for automobile airbag actuators.
DuPont (project 1)	A fibrous material that emitted light making it attractive for electronic display applications.
DuPont (project 2)	A biodegradable polyester film that could be recycled or decomposed over varying specified periods of time.
General Electric	A digital X-ray system that incorporates movement.
General Motors	A hybrid vehicle capable of drawing power from both electrical and conventional engines.
IBM (project 1)	A new generation of communication chips using silicon germanium for increasing switching speeds and reduced power requirements.
IBM (project 2)	An electronic book that embeds integration of a high density display with reduced power requirements
Nortel Networks	Technology for allowing digital content to be rented over the Internet
Polaroid	A low-cost, high capacity memory storage device.
Texas Instruments	A digital micro-mirror device capable of creating a projected digital image
United Technologies (Otis elevator)	An elevator that could move both vertically and horizontally for solving people moving problems in very tall (mile high) buildings.

in Table 1. More details on each case can be found in McDermott and O'Connor (2002), O'Connor and Rice (2001), Leifer et al. (2000), and McDermott (1999).

2.3. Data collection and analysis

Case study research involves the examination of a phenomenon in its natural setting. It is especially appropriate for research in new topic areas, where the focus is on understanding "how" or "why" questions concerning a contemporary set of events, and the objective is on gaining insights to build a theory rather than on testing hypotheses (Eisenhardt, 1989). Multiple cases are generally regarded as more robust than single cases studies, in that comparisons across cases allow for a greater robustness in the development of insights, and a consideration of their context dependency (Yin, 1994).

To guard against post hoc rationalization of the reasons and motives for particular actions, a prospective approach to data collection was taken. That is, firms were enlisted for their participation while the cases were ongoing. We collected data about the project's history on our first round of interviews, but from there we collected data in real time as the team was being confronted with successes and challenges in the course of the project's development. To date, eight of the projects have been introduced into the marketplace to varying degrees of success, one is still under development and three have been abandoned.

Information gathering techniques included in-depth interviews, surveys, reviews of project documentation and teleconferences. Where possible, copies of materials prepared for early evaluation boards were also collected and analyzed. All interviews were taped and transcribed.

We gathered information from a variety of company representatives associated with each project from a variety of functional perspectives.

During the first year of the study, the participant firms hosted a minimum of two site visits and provided access to the appropriate individuals—senior managers, project managers and project team members—who could provide both historic and current information and insights with respect to the research questions of interest. As projects moved into operating units, new transitional team members were added to our interviews.

Following Miles and Huberman (1994), the transcripts and documents were reviewed and coded in a systematic manner, independently by each author. We did not employ any specific content analysis software package, but instead relied on note-taking, categorizing, and memo-writing techniques so as not to miss any issues that may not arise through key word searches required by content analysis packages. Themes that emerged regarding the human connection were collected and discussed between the two co-authors. One author identified approximately six, and that other identified approximately ten themes for discussion. There was significant overlap. The authors then discussed the themes, and began to elaborate them together with examples from the data. The themes were reorganized and grouped throughout this process, and themes for which the discussion did not generate enough richness were discarded.

3. Results

We divide the discussion of the results into four sections. First we consider the multiplicity of roles required to successfully manage radical innovation. While this topic is not new, we identify several unique roles that have not been mentioned in the literature, and we observe the dynamics between those roles as a potential area for managerial intervention to improve the management of radical innovation. Secondly we address team composition issues, both at the outset of the project and then over the course of the project's evolution. Next we examine the depth and breadth of informal networks in the radical innovation context, and offer some ideas for maximizing and leveraging them, given their extreme importance to the initiation and continued development of RI projects. Finally, we note the mismatch between risks required of those engaged in radical innovation and reward mechanisms currently in place.

3.1. Observation 1: there is a multiplicity of roles required to successfully implement radical innovation, and there is a lack of continuity within those roles and a lack of connectivity across many of them

It is not surprising that a broad set of skills must be unleashed on the RI challenge. Multiple roles are required, and no one person can fulfill them all (Roberts and Fusfeld, 1982; Katz, 1997). Roberts and Fusfeld (1982) identified five critical functions necessary to innovate successfully—(a) idea generation, (b) championing, (c) project leading, (d) gatekeeping, and (e) sponsoring or coaching. We observed each of these roles across the projects in our sample, but, in addition, there were two others. The first, that of opportunity recognizer, is a role that occurred in addition to idea generation. While idea generators discovered interesting technical phenomena, opportunity recognizers could make the link between

the technical discovery and the commercial applications that ultimately motivated senior management to invest in the project. In our cases, opportunity recognizers were typically low to mid level research managers, whereas idea generators were bench scientists (O'Connor and Rice, 2001). The leap in thinking required to recognize an opportunity is illustrated by one research manager we interviewed:

> Although I didn't do much with the business unit that would ultimately market this technology, I knew something about the field. It did seem important to me. If you look at the history of innovation in this field, there really hasn't been much. This . . . really had the potential to change the game.

It is important to recognize the distinction in these two roles. In 10 of our 12 cases the idea generator was not the opportunity recognizer. In fact, idea generation does not always precede opportunity recognition. In six of our cases, ideas were generated first. Of those, three of the cases stalled for a period of time because the idea generator did not have the motivation, in some cases, or the skill, in others, to also recognize and articulate the opportunity to get appropriate organizational attention (Rice et al., 2001).

In the remaining six cases the reverse was true. An opportunity was recognized, and then idea generation of a set of very talented individuals was focused on solving the articulated problem. Given that most ideas are sourced from lab benches, or even from outside sources (e.g. university research was the source of four of our cases) one realizes the requirements for deep technical expertise for idea generation. Opportunity recognition, as indicated by the quote above, requires a good understanding of a breadth of technological arenas, along with a wide-ranging curiosity and at least introductory knowledge of potential application markets.

The second addition to Roberts and Fusfeld's list is that of project alumni. These are individuals that were associated with the project team at one time or another in a leadership role, but who rotated out of the project into other parts of the organization during the course of the project's development. In eight of our 12 cases, we witnessed turnover in the project champion/leader roles. While this is not always best for projects' rate of progress, turnover can help broaden the base of support for the project, serving to educate other parts of the organization regarding the project's potential for the company. As such, project alumni served an external championing role, and became key elements of the project teams' informal networks.

These two roles arise in the radical innovation domain for several reasons. First, opportunity recognition is a much more challenging task in the high uncertainty domain of radical innovation, due to the width of the chasm between problem identification and potential solutions that exist. This implies a need for purposeful identification of these as separate roles, and for managerial mechanisms to ensure connections are made between them. It is less likely that this challenge is experienced so heavily in the incremental innovation domain, wherein market needs can be more clearly articulated and validated, and the domain that the corporation stakes out is so clear. Idea generation processes for this sort of project are well known and include the use of methods such as focus groups, lead user analysis (Von Hippel, 1986), surveys of current customers, and observation of competitive offerings at trade shows or via the intelligence gathering activities of the sales force and other marketing personnel (Kotler, 1994).

Project alumni exist in the radical innovation domain because of (a) the length of time over which the project matures, (b) the need for specialists over the course of the project's evolution, and (c) the tumultuous nature of radical projects themselves. Researchers other than the core team cycled on and off projects, especially given the irregular financial support that the projects were given over their lifespan. Professional career path development also drove a number of team members to take new assignments even though the project had not yet come to fruition. This behavior is in contrast to that of task teams (Gersick, 1989) that typically focus on incremental innovation projects. When objectives are clear, schedules are set, and uncertainty is relatively low, the team stays very focused on the task, on clarifying roles and responsibilities among the members, and on driving to completion (Gersick, 1989; Gersick and Davis-Sacks, 1990). Tools to ensure alignment of team members around a common end goal, such as the product innovation charter (Crawford and Di Benedetto, 2000), are highly recommended to reduce the chance of deviations from plan (Bacon et al., 1994). But when the objectives are not clear at the outset, when uncertainties are high and time frames are long, as in the RI domain, we see turnover on the team. The issue to consider is how best to leverage this reality.

Another interesting element that emerged through our case studies is how fragile the links are between the roles, and how vulnerable the RI project's potential is if those links are not made. As mentioned, in ten of our twelve cases, the idea generator was not the opportunity recognizer. In one case, in particular, a research scientist in Central R&D who was developing a technology for an avionics application realized that the same technology might have applications for a second business unit (BU). He raised the idea with some of his contacts in that second business unit, but they were not drawn to the idea because of the profit pressures that the BU was experiencing at the time. The research scientist let the idea drop. Two years later, a research manager within R&D who was dedicated to serving that second BU heard of the idea. He couldn't believe they'd been sitting on this technology for two years and not moved it forward . . . a missed opportunity.

Similarly, in most of the sample cases and consistent with other reported research (Markham and Aiman-Smith, 2001), the opportunity recognizer was not the project champion, who provides the drive and persistence required to ensure the project receives management attention Especially with the turnover described, generations of project leaders were required, each needing to evolve into champions in order to assume the leader role responsibly.

The implication of this example, and others like it, is how important it is for firms to ensure that the roles get connected to one another. If they don't, RI ideas get dropped or not pushed forward. In two of the firms we studied, the opportunity recognizer role was somewhat formalized in a single individual. In one firm, it was a formal role, titled Director of New Ventures. Idea generators knew they could go to this individual get help in enriching their ideas and articulating them in a manner that management could evaluate. In the second instance, the individual was universally known as a person with years of experience in the company who was connected to many sources of information, and who could link technologies to potential markets. Because he was the sole 'go-to' person for research scientists, he was aware of most of the ongoing activities and created linkages as needed. But sometimes he played a more active role as well. When he heard about a particular research endeavor, he would visit the scientist to learn and understand. He

would sometimes be perceived as 'nosy' in his constant pursuit of novel technologies with commercial promise. But this was a very effective mechanism for converting ideas to radical innovation projects.

While we observed individuals playing this role in other companies as well, turnover was quite high in a number of these cases. For example, in one of our cases, an individual was designated as the business development person within R&D, and was expected to play a role similar to the one just described. Interestingly, though, he became so enamored of the first opportunity he recognized that he joined that project as a team member. The fortuitous gain for the project team came at the expense of having that reservoir of experience and knowledge base available to the rest of the R&D community. This situation occurred in more than one of our cases.

Continuity is critical in these roles, as people cumulate an understanding of the opportunity paths that have been previously pursued, as they cumulate a vast network of contacts within the company, and as they cumulate expertise in judging opportunities of this magnitude. The importance of retaining this cumulative experience of opportunity recognition within the firm is critical, but also presents a challenge in today's firms, largely due to a lack of recognition of its importance. In one case, a long standing group of R&D directors informally, but periodically got together to review ideas that came in to the R&D group from employees in the lines of business or from inventors outside the organization. Over time, the board accumulated knowledge of the range of ideas that kept arising, and were able to evaluate when it appeared worthwhile to raise one of them up as technological advances marched on, or as a combination of the ideas, together, created a potential blockbuster. Their consistent activity was rare, in that it provided the firm with a constant barometer of the opportunities available over time. Yet, when one of the three individuals retired, the informal board stopped meeting, and the cumulative knowledge was lost. No organizational attention was devoted to considering ways to capture the cumulative experience of those people, or mechanism for transferring it from one generation of reviewers to the next.

Given that radical innovation is so rare, that it's high level of uncertainty on many dimensions make it a "high velocity environment" requiring simple, non-codified routines (Eisenhardt and Martin, 2000), it follows that firms would be best served if these critical roles were filled by individuals who have performed the task over and over to leverage the intuition they gain as a result of rare, infrequent experience. This is consistent with the notion of developing a radical innovation hub that we have discussed elsewhere (Leifer et al., 2000).

3.2. Observation 2: radical innovation team composition is different from incremental innovation team composition both at the initiation of the project and as the project matures

We observed that the project teams were comprised of a rather small (5–6) group of core members, who were central to the project. Typically, it is prescribed that new product development teams be composed cross-functionally, with specialists in marketing, manufacturing, engineering, and other functions to make smart decisions regarding issues that arise in the development process (Hollahan and Markham, 1996). We did not observe this composition in the sample, especially early in the projects' lives. Rather, we characterize the core teams as a small set of cross-functional individuals. Each of the 4–5 team members

demonstrated deep knowledge and experience in one discipline, but also a significant degree of competence, curiosity and understanding of several others (McDermott, 1999). For example, a member of the team at air products was a mechanical engineer with a materials background and had had fabrication experience. At IBM, one member was a PhD manufacturing engineer with a materials background. Some had manufacturing and science mixes. Some had deep science and marketing mixes. Some had deep science and a clear view of economics/cost. All had more than one, and most had three dimensions of depth, as the following quote from a commercial development person on one of the sample teams describes:

> Most of my people, myself included, have a cross-sectional experience-based background of manufacturing, R&D, sales and marketing, and finance. In our company's environment I insist they have chemical engineering backgrounds as well.

This multi-dimensionality within core team members is extremely important in radical innovation domains for several reasons. First, opportunity recognition and invention are creative individual acts rather than organizational processes. The link between a problem and a number of potential solutions is a cognitive one that happens in a single individual's brain (Amabile, 1988; Angle, 1989). Cognitive psychologists call this talent 'associative fluency,' defined as an ability to produce a variety of ideas related in a specified way to a given idea (Guilford, 1959). When the solution path to a set of problems is well defined, associative fluency need not be high to see the opportunity, as it is rather straightforward. But when the path between the problem and the solution is not clear at all, as in the case of radical innovation, a high degree of associative fluency is necessary. Many ideas must be produced, and some of their relationships to the given idea may be more tightly linked or obvious than others. The fact that core team members are multidimensional increases the probability that associations are made where others may not see them.

Secondly, when a problem is vaguely defined, as in many of the radical innovation initiatives we studied, unless team members have a broad range of skills to drawn upon, they may search for the solution among the few sets of expertise resident on the team rather than considering alternatives. One team leader told us

> We have to really think about how to augment our team. If we add physicists, they'll approach this as a physics problem. But maybe it should really be approached as a biochemical problem.

As such, multidimensional individuals tended to avoid "narrowing" when the team should be thinking more broadly.

Finally, it is important to recognize that radical innovations are not built on a single discovery or invention. Rather, they require innovation, discovery, and opportunity recognition all along the development path (O'Connor and Rice, 2001). While the scientific discovery allows for something new, associative thinking is required to consider potential application markets that may not yet exist, to identify alternative technological development directions around specific problems that arise, to develop new manufacturing processes to enable production, to consider alternative business models that the technology may enable, and to create ways to incent key agents to take part in the value chain. Decisions in any of these domains impact on the others. Therefore, the cross-functionality within team members is critical.

Regarding initial team formation, we also observed interesting trends that are contrary to what is known regarding traditional task force team formation. Hackman (1990) and his colleagues define and characterize a variety of types of teams. One of these, a task team is defined as a group of people brought together specifically to complete a specific assignment in a limited time. A new product development team is an example of one type of task team. The task team is typically formed at the behest of some other person or group, and so it is dependent upon that person for legitimacy. Their objectives are clear and specific, and are articulated by the person or group who called for the team's formation. In addition to classifications regarding types of work teams perform and how they approach the task, Hackman classifies teams with regard to their governance processes. (Hackman, 1986, 1987). Of these, only the most autonomous group, the self-governing work team, selects their own membership. Hackman (1987) notes that such teams are highly atypical in organizations (Boards of Directors are one example). Typically, new product development teams, as task teams, are created in a formal way, with individuals assigned to the team, either as their sole project or as one of several projects, until the project is completed.

In contrast to the literature and empirical work on NPD teams, we observed that RI team formation is not based on formal assignment, but rather on volunteerism and informal recruitment through the champion's personal networks. People volunteer because they want to be involved in something that's 'truly important,' as the following quotes demonstrate.

"A lot of people worked for us as volunteers under the table."

"The project started with an informal team. It's a self-selecting process. . . . When enough people come together we organize a formal meeting time."

The implication of this team volunteerism is that there is energy and orientation toward RI in some people and not others. As such, mechanisms that identify those people who are predisposed to high risk but potentially high impact projects would seem useful. Career development paths can then be structured to enable these individuals to flourish and to be leveraged in the organization's best interest.

A final point regarding team composition is our observation that project overseers are reluctant to seriously analyze the changing leadership needs of the team as the project matures. Whereas in the venture capital world, team leaders and core team members are replaced as the business needs require, we did not observe that happening in the large established company environment as readily. In one of the cases, for example, the project had foundered for years because its leader, while an extraordinary scientist, was doing an abysmal job managing the project. Finally, after increasing levels of inter-team conflict, frustration, and inability to accept key technical learning and make key decisions that guided technical and business direction, as well as turnover on the team, a leadership change was made. According to one of the team members we interviewed, the change was 2 years overdue.

Venture capitalists recognize when it is time to replace the entrepreneur with the seasoned business manager, yet the large firms we observed often appeared unable to recognize it was time to replace the scientist with someone with business development expertise. Though Eisenhardt and Martin (2000) describe this issue in the context of evolving dynamic capabilities, we see a direct parallel in terms of the nature of project management in radical

versus incremental innovation. The project manager in the RI scenario, as exemplified by the situation described above, must face the task of monitoring uncertainties, determining which to attend to at any point in time, and making decisions regarding which direction to take among a multitude of possibilities. In contrast, the project manager of a more conventional NPD project is tasked with the responsibility of developing a clear plan and ensuring it is executed in accordance with the approved budget and schedule. The underlying premise is that the project manager can extrapolate future results based on a wealth of past experience, and can therefore be more accurate in his predictions of the outcomes of sets of activities because they've been undertaken before (McGrath and MacMillan, 1995; Sykes and Dunham, 1995). In summary, we observe that, as the RI project is initiated, the team leader and core team players are self selected based on networks of personal relationships and volunteerism as described above, and that team composition is not subject to the intense scrutiny that small start-ups seeking VC funding receive as the project matures. While the role of champion is extremely important in the large established organization, one must also attend to requisite leadership skills required for the project's efficient maturation at its current state of development.

3.3. Observation 3: RI's thrive on informal networks, both internal to and external to the company

"Our approach to creating really new innovations is to take our best and brightest people, lock them in a room, and slide food under the door." We were told this by a CTO in one of the sample companies. Clearly, the balance between incubating radical innovation projects from the distractions of the outside world or the bureaucracies of the mainstream organization and encouraging them to interact with internal and external constituencies is not straightforward. The concept of the skunkworks organization is based on removing the team from the mainstream and allowing them to focus intensely on the projects at hand. We observed three projects that operated in this way. One was eventually spun out of the organization as a non-strategic business, and the remaining two were built into completely new divisions of their companies. But the remaining projects all operated within Central R&D and faced the task of balancing the incubate/interact challenge, both with respect to external constituencies as well as internal ones.

3.3.1. External networks

A common feature in a number of studies of R&D and other knowledge creation processes is the need for explicit linkages between the focal firm and knowledge sources outside the firm. Cockburn et al. (2000) show that building new knowledge requires exchanges with external sources of information in terms of publication in the profession. They document that, where publications are used as a criteria for promotion, these linkages are more likely to occur and information flows are enhanced. Powell et al. (1996) found that significant formal alliance relationships lead to superior R&D performance in biotech firms.

These are two examples of formal mechanisms to enhance information exchange, but we saw much more activity in the human-to-human interface. In one of our IBM cases, the lead scientist presented his research on the properties of silicon germanium at a professional

conference. He was met with many questions by several members of the audience. Once the session was over, the most vocal audience member approached the presenter, and told him that the discovery could mean enormous leaps forward in some of the problems he was working on in his lab at analog devices. The IBM scientist invited the analog scientist to come and meet with his own senior management, who, at the time, were having trouble seeing the promise of the SiGe discovery. Once the visit occurred, the project was funded. In another case the team sent one of their members "outbound" regularly to investigate potential application markets that the firm did not participate in; those with whom they had no contacts. The team member's role was simply to establish those contacts so that more could be learned about the technology's potential in that environment. Other teams did this more formally. In three other projects, they did so by advertising their invention in various professional journals and trade magazines and inviting interested readers to contact them with application ideas. In two of those projects, so many inquiries were made that the team did not feel that it could follow up on all of them. So we witnessed team members proactively building new networks in a handful of our cases.

In others, we observed them relying on current networks. In one example, the team used a focus group session of current mainstream customers to test out their radical innovation concept. In a second instance, the team was looking for a beta test site and leveraged a strategic relationship with a firm that the company had just formalized. In both these instances, the results of the learning were disappointing. Not only are external networks important, then, but in fact, reaching out beyond current relationships seems critical for the case of radical innovation. Given that most current relationships are based on current technologies, markets needs, and platforms, and the scope of the radical innovation typically differs from those, the need to think beyond current markets appears highly important. Other researchers have substantiated this observation as well (Christensen, 1997).

3.3.2. Internal networks

The power and importance of informal internal networks for radical innovation success cannot be underestimated. As mentioned earlier, RI does not have the luxury of following processes that are clear or codified in the organization. Since radical innovation stretches the organization beyond it current domains, there is a constant need to draw on every aspect of the organization's knowledge and skill base as needed. Wide-ranging informal networks are one mechanism used to obtain rich information, which is needed for higher uncertainty environments (Daft and Lengle, 1986). In virtually every project in the study, informal networks of people within the company were critical for obtaining information, skills and other resources to help solve problems, identify or validate potential applications and to bring interested parties together. It appears that informal networks function as a way to manage uncertainty associated with RI, as noted in the quotes offered in Table 2.

One reason these informal networks play such an important role for RI projects is because of the presence of extensive sets of 'project alumni,' as we mentioned earlier. In addition, many of the projects in our sample moved from place to place in the organization over time. The project at air products began in the Gasses group, but subsequently transferred between Central R&D and Gasses four additional times. The Dupont Biodegradable polyester project began in one business unit, then transferred between R&D and a

Table 2
The power of informal networks case evidence

It's very important to know who the right people are in the company to get assistance and support.
The informal system is very strong here in terms of the links and integration.
The network of communication is very open. It can be horizontal or vertical.
How do you notice a new technology? I know all these people. There are informal networks for transmitting information. Not everything goes through the formal process.
It is the accessibility that is absolutely critical for survival.
I can actually go to the Mafia that exists in our company to get what I want. The Mafia is my personal network of people who I've done favors for. It's highly informal but effective.
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. It really does.
I wanted to know more about the XXXX market and who the major players were. . . I sent a note (e-mail) out, and there's a whole network of people inside that identified the (leaders in this technology). They're plugged in all over the world. . . so that makes you feel comfortable.

different business unit three times before ultimately ending up in a newly created division. At General Motors, the hybrid vehicle project moved from Central Engineering into R&D, but then moved to several different vice presidents' responsibilities within the technology group.

Several proactive mechanisms that we saw put in place to create and build networks were quite impressive. In terms of building senior management credibility, we observed one project manager, upon assuming a leadership role on the project team, work to establish a board of senior advisors who would formally accept responsibility for helping move the project along as needed in the division that would ultimately house the project. The board was comprised of key leadership in that BU along with senior corporate technical leadership, all of whom the project leader already had credibility with. He told us:

> The amount of involvement that we've traditionally had with the senior levels of the company had been very limited. We need to start managing up more than we have before. And so we have established a Steering Committee, comprised of the senior technical leadership of the company (Corp VP of R&D, Corp VP engineering and the VP of technology for the division). My intent is to use that group as a sounding board to develop broader based of support for this effort. (The VP of technology for the division) has responsibility for engineering, marketing and technology with the division, and his buy in to our strategy is absolutely critical for the success of this venture. I want to get him to start funding the application development work and have central R&D to continue to fund the more fundamental work. We've got to nurture that relationship with him and make sure he's a supporter, or this project will wither on the vine.

Finally, team members sometimes indicated surprise at how far-reaching their networks had to become to get the information or access they required. They had to go beyond their immediate contacts to their contacts' contacts, just as in the case of external networks needing to stretch beyond familiar customers and existing partners.

> We don't have a financial analyst in our group. I know, through my previous experience, who to work with. . . who might have the right skills. It's not a formal part of my job description, but it's a very important part of my job. Now we're going to do an economic

evaluation for a conceptual product that we've identified for (an application) in Spain and England, and there's no financial model for Spain and England here. So, working through my contacts here that have contacts there, we're getting those models prepared. It's a very interesting network of contacts that I'm using to get those things accomplished.

The R&D literature has focused on the importance of building rich information networks to access leading edge technical information. But radical innovation goes beyond that to creating markets, infrastructures within the market, and infrastructure within the firm. Therefore, network expansion both into downstream parts of the value chain and outward into the organization is an extremely critical aspect of project success. The implication is that, in this environment of downsizing and reliance on early junior talent, mechanisms to counteract the breakdown of networks are extremely important. Rotation of scientists through business units is one extremely important tool for developing them cross functionally and ensuring they form relationships with downstream players. In only three cases did we see significant attention paid to these rotations, but in each of those cases, that individual's experience greatly enhanced the internal networks that he drew upon.

3.4. Observation 4: there is a mismatch in risks required of RI team members and reward mechanisms currently in place

We were told, "The origin of the breakthrough success is often forgotten, but an R&D effort that does not succeed is never forgotten." The pervasive myth is that everybody wants to be on the big glamour project. Our observation is that some really do, and others do not. It's hard work requiring, in the observation of one of our interviewees, adding 40 pounds, working weekends, and going bald. It's also an enormous career risk. In that particular instance, the individual transferred with the project from R&D into a line of business, and wanted to manage the program's commercial launch. He was offered a small piece of it, even though he had the business acumen necessary for a high uncertainty environment. But his skills did not match those of a typical program manager in the operating unit, and so he was refused the program manger position. When asked for his quarter-by-quarter sales forecasts for the first year, he declined to provide them, since no qualified customers had yet been identified due to the very high levels of residual uncertainty associated with the market. When forced to provide numbers, he offered a conservative estimate. These were augmented by his director, to meet expectations for the operating unit's budget review. When the sales forecasts were not met, he was demoted from the position. As the R&D leader for the effort told us, this key team member of his, who'd devoted so much to the project, was "put in the penalty box." Ultimately, he quit the company. Table 3 demonstrates this high rate of frustration across the project teams. It shows that the most extreme actions possible, those of quitting the company completely and/or being fired, were experienced by the vast majority of the sample teams. Key team members were alienated and left the company, some under duress.

In most cases, team members viewed these projects as career risks, given that the likelihood of their success is so small. (A parallel can be drawn to the Venture Capital world, in which it is widely understood that a ratio of 1000 ideas to 100 projects funded to 10 commercially successful ventures exists.) Even though our sample projects had all already

Table 3
Key team members' disposition during and subsequent to project completion

Company (coded for anonymity)	Threatened to quit during project	Quit during project	Fired during project	Quit subsequent to project	Reason given[a]
1					
2		✓			Too much bureaucracy. Went to start new company.
3				✓	Sr. sponsor left; protection from others' jealousies no longer available
4		✓			N.A.
5	✓	✓			Person who quit did so because he felt his contribution was not recognized.
6					
7				✓	N.A.
8				✓	Forced out when senior sponsor left; negotiated to take IP and start his own venture. Negotiation failed when company realized venture potential.
9		✓			Quit to start own venture.
10		✓		✓	Started own venture within the firm and spun it out.
11			✓		N.A.
12			✓		When initial market failed to develop, and senior leadership retired, strategic change away from RI forced him into retirement.

[a] N.A. indicates information not available.

been recognized as legitimate projects via formal funding when the study period began, only eight of the 12 have been introduced to the marketplace. Of those eight, four are considered major commercial successes. So, of 12 funded, approved projects, only 1/3 might be considered radical innovation successes.

One specific detractor with regard to the human interface that we observed is the reward/compensation model used to encourage radical innovation. In all but one firm, RI teams were compensated no differently from anyone else in the firm. Careers were sidelined by unsuccessful projects in some cases. Bonuses and promotions were dependent on project success. Given the low likelihood of success, the downside risk for engaging in radical innovation is very high.

At the same time, in only one instance was there an upside reward in terms of shared equity in the venture. At Nortel Networks, radical innovation teams were offered equity, and were also allowed to remain salaried employees for as long as they felt necessary. If the project foundered, they could recycle back in to the company on other projects. So in that case, there was no downside risk and extreme upside potential for reward. Thus the established company environment offers two extreme approaches in the matter of compensation for risk taking (no risk sharing and no reward sharing), whereas, in the Venture Capital world, start up companies receive investments that they could lose if the initiative fails (appropriate risk), and retain substantial equity that can be enjoyed should the initiative succeed

(appropriate reward). This balance, it appears, is not paralleled in the established company environment.

4. Discussion and conclusions

The downside of attempting breakthrough innovation in large, ponderous organizations is well documented (Lynn et al., 1996; Eisenhardt and Martin, 2000; Leifer et al., 2001). Numerous antibody mechanisms are embedded in the organization that constantly block and thwart the advancement of fundamentally new ideas, and sometimes, view maverick individuals as too painful to tolerate.

It is assumed that entrepreneurial people, the type that thrive in high uncertainty domains, are typically driven from the large established corporate environment. The slow-moving, hierarchical decision making processes, the bureaucratic mindset and the numerous formal channels through which employees are required to report are too burdensome for the entrepreneurial type to handle. And to a large extent, that may be true. Many of the interviewees in our study echoed the frustrations associated with the large corporate environment.

But we also found evidence to the contrary. There are aspects of large corporations that some very action-oriented, entrepreneurial, visionary people thrive on. They simply know how to work the system, and that system is based largely on human connections of immensely capable people. In half of our sample cases we identified individuals, key leaders in the radical innovation projects we studied, who not only survived, but also thrived in these environments. Granted, the companies themselves varied with respect to their tolerance for radical innovation, and company cultures made a difference in how satisfied these people were. Across the 6-year study period, moreover, the context for innovation changed within individual companies as senior management turned over, or industry or competitive pressures warranted, and individuals that were happy in their companies at one point in time grew frustrated in these stricter environments. Still, radical innovators can and do thrive in large established company settings.

The reasons our respondents cited for appreciating the large established company environment included the rich networks available to them, with access to fine minds, an abundance of new ideas, and a rich talent pool to leverage. In addition, access to physical and financial resources were mentioned along with the heritage of innovation that preceded them in most cases. Finally the legitimacy associated with the company name and reputation opened many doors for them, particularly among new markets and new potential partners, financing sources, and governmental agencies that had not previously been associated with the firm. The prestige connected with the large company carried the project teams a long way as they worked to make new contacts, and was appreciated.

> I have standing job offers for ten times my present salary and the majority of the people on the team have the same situation. The reason we are here is that this is a terribly good organization. At its core, the premise of this company is fabulous. We are still technologically unequaled.

Despite the lack of established processes in place for the management of radical innovation, the innovative spirit of individuals within these large firms persevered. Few firms

demonstrated proactive mechanisms to connect idea generators with opportunity recognizers in most of our sample. And there was little in the way of coaching project teams on how to operate in domains of high market, resource and organizational uncertainty. Yet we did see elements of activities that were created, on a firm-by-firm basis which served to push these projects forward within their respective organizations. Project alumni and opportunity recognizers did exist and served significant roles in their organizations. RI teams were created, albeit in non-traditional, self-directed, ways, that seemed to be effective given the inherent uncertainty of the RI projects. Finally, we observed teams in these large firms leveraging their internal and external networks to extremes in order to push their project forward.

High velocity, or high uncertainty environments require simple routines, and a dependence on people over process (Eisenhardt and Martin, 2000). But, the problem with simple routines is that they are easily forgotten. So firms need a way of ensuring that, because of the limited frequency with which RI occurs, the same set of people are engaged in it over and over so that they build an intuition regarding the semi-structured routines that are necessary. Further, career development paths are needed to pass this learning on from over time.

It is clear from the data presented and the discussion above that there is plenty of room for improvement with regard to the people side of radical innovation in large established firms today. We expect that, by understanding the mechanisms by which RI does thrive, and by gaining insight into what prevents radical innovation from happening more effectively, firms can capitalize on the successful practices and enhance their RI capability. We clearly observed that individuals and individual initiative drive radical innovation, and that there are structures, mechanisms and management systems beginning to emerge that complement this individual action. These are not strict processes. Firms seek systematic, repeatable processes to bring order to the chaos of radical innovation, but underestimate the importance of individual action. By seeking to codify RI, firms may not allow for the situation specific trial and exploratory learning that is necessary in highly uncertain environments to occur (March, 1991; Van de Ven and Pollay, 1992).

But firms can move forward to build infrastructural support mechanisms to help these entrepreneurial individuals. In this way, an organization can develop a competence to engage in radical innovation over and over, by harnessing and leveraging individual experience and expertise. We define radical innovation maturity as the degree to which the organization has systematically implemented processes for initiating, supporting, and rewarding radical innovation activities. Moving from lower to higher maturity is not easy. However, remaining at a low level of maturity means the firm must rely on a combination of serendipity and extraordinary individual effort. In firms with a mature radical innovation capability, a supportive infrastructure can oversee the portfolio of RI projects, and can play a role in linking them to the strategic intent of the organization. It can coach and mentor new project teams regarding managing under high degrees of uncertainty. And, most importantly, it can provide a key boundary-spanning link between the RI project teams and the rest of the firm. Organizations can help themselves by instituting new roles, career paths, structures and mechanisms that support the creative persistence of people engaging in RI.

In this paper, we have examined the development of radical innovations in large established firms, with a specific focus on the corporate/human interface. The observations emanating from the 12 radical innovation projects we studied follow from our inquiry into

the factors that enable and those that inhibit entrepreneurial people in their efforts to successfully commercialize radical innovations in large established organizations. A number of interesting findings resulted from our analysis that enrich the literature on innovation. First, we observed and documented a large number of distinct roles that are filled in these projects, as well as the relative lack of coordination and connection that occurs among these positions within the firms we studied. Similarly, we noted that the composition of teams in these projects differs significantly from the composition of incremental teams both at their initiation as well as while maturing and moving toward the market. We also documented the criticality of nurturing and utilizing both internal and external informal networks in order for these projects to move forward within their firms. Finally, we observed and documented the strong mismatch that occurs between risks and rewards for radical innovation team members.

Taken together, these findings point to a fundamental challenge large mature firms face as they encourage their employees to work toward radical innovations. The roles, tasks and even the sources of answers (e.g. informal, often external) team members must negotiate in this arena are quite distinct from what is encountered in more incremental projects. Yet, at the same time managers ask team members to face these high risks, there is often little "upside" for the team members. There is a lot of career risk and little reward. Managerial attention to building supportive governance systems and infrastructural support for managing RI projects is a critical first step (Leifer et al., 2001).

It is our hope that future research in this area can help to reconcile this fundamental split. The aim of this paper was to highlight both the challenges and organizational response mechanisms that firms utilize to help move these projects forward in this turbulent environment. While our current research documents many of the key challenges and disconnects, and we did observe individual successful mechanisms firms were attempting to use to overcome these issues, more research is clearly needed to explore and document the specific mechanisms that can be successful in directly addressing these and other challenges in this arena. We would hope that each of the four key observations we outlined in this research could serve as pieces that can help to focus future research, and that further research on these and other key questions can build a better understanding of this important, yet clearly poorly understood phenomenon.

References

Amabile, R.M., 1988. A model of creativity and innovation in organizations, In: Staw, B.M., Cummings, L.L. (Eds.), Research in Organizational Behavior, vol. 19. JAI Press, Greenwich, CT.

Angle, H.L., 1989. Psychology and organizational innovation, In: Van de Ven, A.H., Angle, H.L., Poole, M.S. (Eds.), Research on the Management of Innovation: The Minnesota Studies. Ballinger, New York, NY, pp. 135–170.

Bacon, G., Beckman, S., Mowery, D., Wilson, E., 1994. Managing product definition in high-technology industries: a pilot study. California Management Review 36 (3), 32–57.

Burgelman, R.A., 1985. Managing the new venture decision: research findings and implications for strategic management. Strategic Management Journal 6 (1), 39–54.

Crawford, C.M., Di Benedetto, C.A., New Products Management, sixth ed. Irwin/McGraw-Hill, Boston, 2000.

Christensen, C., 1997. The Innovator's Dilemma. Harvard Business School Press, Boston.

Cockburn, I.M., Henderson, R.M., Stern, S., 2000. Untangling the origins of competitive advantage. Strategic Management Journal 21, 1123–1145.

Cooper, R.G., 1989. The new product process: a decision guide for management, IEEE Engineering-Management Review, June. pp. 19–33.
Cooper, R.G., 1990. Stage-gate systems: a new tool for managing new products, Business Horizons, May–June. pp. 44–54.
Cooper, R.G., Kleinschmidt, E.J., 1986. An investigation into the new product process: steps, deficiencies and impact. Journal of Product Innovation Management 3 (2), 71–85.
Daft, R., Lengle, R., 1986. Organizational information requirements, media richness and structural design. Management Science 32 (5), 554–572.
Damanpour, F., 1991. Organizational innovation: a meta-analysis of effects of determinants and moderators. Academy of Management Journal 34 (3), 555–590.
Damanpour, F., 1988. Innovation type, radicalness, and the adoption process. Communication Research 15 (5), 545–567.
Dougherty, D., Heller, T., 1994. The illegitimacy of successful product innovations in established firms. Organizational Science 5 (2), 200–218.
Eisenhardt, K.M., 1989. Building theories from case study research. Academy of Management Review 14 (4), 532–550.
Eisenhardt, K.M., Martin, J.A., 2000. Dynamic capabilities: what are they? Strategic Management Journal 21, 1105–1121.
Ettlie, J.E., Bridges, W.P., O'Keefe, R.D., 1984. Organization strategy and structural differences for radical versus incremental innovation. Management Science 30 (6), 682–695.
Garcia, R., Calantone, R., 2002. A critical look at technological innovation typology and innovativeness terminology: a literature review. Journal of Product Innovation Management 19, 110–132.
Gersick, C.J.G., 1989. Marking time: predictable transitions in task groups. Academy of Management Journal 32 (2), 274–309.
Gersick, C.J.G., Davis-Sacks, M.L., 1990. Summary: task forces, In: Hackman, J.R. (Ed.), Groups that Work (and Those that Don't): Creating Conditions for Effective Teamwork. Jossey-Bass, San Francisco.
Guilford, J.P., 1959. Three faces of intellect. The American Psychologist 14 (8), 469–479.
Hackman, J.R., 1986. The psychology of self-management in organizations, In: Pallak, M.S., Perloff, R.O. (Eds.), Psychology and Work: Productivity, Change and Employment. American Psychological Association, Washington, DC.
Hackman, J.R., 1987. The design of work teams, In: Lorsch, J.W. (Ed.), Handbook of Organizational Behavior. Prentice-Hall, Englewood Cliffs, New Jersey.
Hackman, J.R., 1990. Groups that Work (and Those that Don't): Creating Conditions for Effective Teamwork. Jossey-Bass, San Francisco.
Hollahan, P., Markham, S.K., 1996. Factors affecting multifunctional team effectiveness, In: Rosenau, Jr., M.D. (Ed.), The PDMA Handbook of New Product Development. Wiley, New York, pp. 119–135.
Kanter, R.M., North, J., Richardson, L., Ingols, C., Zolner, J., 1991. Engines of progress: designing and running entrepreneurial vehicles in established companies Raytheon's new product center, 1969–1989. Journal of Business Venturing 6, 145–163.
Katz, R., 1997. Managing creative performance in R&D teams, In: Katz, Ralph (Ed.), The Human Sides of Managing Technological Innovation: A Collection of Readings. Oxford University Press, New York, pp. 177–186.
Kotler, P., 1994. Marketing Management, eighth ed. Prentice-Hall, Englewood Cliffs, NJ.
Leifer, R., McDermott, C.M., O'Connor, G.C., Peters, L.S., Rice, M.P., Veryzer, R.W., 2000. Radical Innovation: How Mature Companies can Outsmart Upstarts. Harvard Business School Press, Boston.
Leifer, R., O'Connor, G.C., Rice, M.P., 2001. Creating gamechangers in mature firms: the role of radical innovation hubs. Academy of Management Executive, August. pp. 102–113.
Lynn, G.S., Morone, J.G., Paulson, A.S., 1996. Marketing and discontinuous innovation: the probe and learn process. California Management Review 38 (Spring), 8–37.
March, J.G., 1991. Exploration and exploitation in organizational learning. Organization Science 2 (1), 71–87.
Markham, S., Aiman-Smith, L., 2001. Product champions: truths, myths and management. Research Technology Management 44 (3), 44–50.
McDermott, C.M., 1999. Managing breakthrough new product development in large firms: a longitudinal study. The Journal of Operations Management 17 (6), 631–644.

McDermott, C.M., O'Connor, G.C., 2002. Managing radical innovation: an overview of emergent strategy issues. Journal of Product Innovation Management 19 (2), 424–438.

Miles, M.B., Huberman, A.M., 1994. Qualitative Data Analysis, second ed. Sage Publications, Thousand Oaks, CA.

McGrath, R.G., MacMillan, I.C., 1995. Discovery-driven planning. Harvard Business Review, July–August. pp. 4–12.

Morone, J.G., 1993. Winning in High-Tech Markets. Harvard Business School Press, Boston.

Nord, W.R., Tucker, S., 1987. Implementing Routine and Radical Innovations. Lexington Books, Lexington, MA.

O'Connor, G.C., Rice, M.P., 2001. Opportunity recognition and breakthrough innovation in large established firms. California Management Review 43 (2 Winter), 95–116.

Powell, W.W., Koput, K.W., Smith-Doerr, L., 1996. Interorganizational collaboration ad the Locus of Innovation. Administrative Science Quarterly 41 (1), 116–145.

Rice, M.P., Kelley, D., Peters, L.S., O'Connor, G.C., 2001. Radical innovation: triggering initiation of opportunity recognition and evaluation. R&D Management 31 (4), 409–420.

Roberts, E.B., Fusfeld, A.R., 1982. Critical functions: needed roles in the innovation process, In: Katz, R. (Ed.), Career Issues in Human Resource Management. Prentice Hall, Englewood Cliffs, NJ, pp. 182–207.

Sykes, H.B., Dunham, D., 1995. Critical assumption planning: a practical tool for managing business development risk. Journal of Business Venturing 10 (6), 413–424.

Tushman, M.L., O'Reilly, C.A., III. 1997. Winning Through Innovation: A Practical Guide to Leading Organizational Change and Renewal. Harvard Business School Press, Boston.

Van de Ven, A.H., Pollay, D., 1992. Learning while innovating. Organization Science 3 (1), 92–116.

Van de Ven, A.H., Angle, H.L., Poole, M.S. (Eds.), 1989. Research on the Management of Innovation: The Minnesota Studies. Ballinger, New York, NY, pp. 135–170.

Von Hippel, E., 1986. Lead Users: A source of novel product concepts. Management Science 32, 791–805.

Yin, R.K., 1994. Case Study Research. Sage Publications, Thousand Oaks, CA.