Organizational Issues in the Introduction of New Technologies

Ralph Katz and Thomas J. Allen

June 1984 1582-84

Organizational Issues in the Introduction of New Technologies

by

Professor(s) Ralph Katz and Thomas J. Allen

More than ever before, organizations competing in today's world of high technology are faced with the challenges of "dualism", that is, functioning efficiently today while planning and innovating effectively for tomorrow. Not only must these organizations be concerned with the success and market penetration of their current product mix, but they must also be concerned with their long run capability to develop and incorporate in a timely manner the most appropriate technical advancements into future product offerings. Research and development-based corporations, no matter how they are organized, must find ways to internalize both sets of concerns.

Now it would be nice if everyone in an organization agreed on how to carry out this dualism or even agreed on its relative merits. This is rarely the case, however, even though such decisions are critically important to a firm competing in markets strongly affected by changing technology (Allen, 1977; Roberts, 1974). Amidst the pressures of everyday requirements, decision-makers representing different parts of the organization usually disagree on the relative wisdom of allocating resources or particular RD&E talents among the span of technical activities that might be of benefit to today's versus tomorrow's organization. Moreover, there are essentially no well-defined principles within management theory on how to structure organizations to accommodate these two sets of conflicting challenges. Classical management theory with its focus on scientific principles deals only with the efficient production and utilization of today's goods and services. The principles of high task specialization, unity of command and direction, high division of labor, and the equality of authority and responsibility all deal with the problems of structuring work and information flows in routine, predictable ways to facilitate production and control through formal lines of authority and job standardization. What is missing is some comparable theory that would also explain how to organize innovative activities within this operating environment such that creative, developmental efforts will not only take place but will also become more accepted and unbiasedly reviewed, especially as these new and different ideas begin to "disrupt" the smooth functioning organization. More specifically, how can one structure an organization to promote the introduction of new technologies and, in general, enhance its longer term innovation process; yet at the same time, satisfy the plethora of technical demands and accomplishments needed to support and improve the efficiency and competitiveness of today's producing organization.

Implicit in this discussion, then, is the need for managers to learn how to build parallel structures and activities that would not only permit these two opposing forces to coexist but would also balance them in some integrative, meaningful way. Within the RD&E environment, the operating organization can best be described as an "output-oriented" or "downstream" set of forces directed towards the technical support of the organization's current products and towards getting new products out of development and into manufacturing or into the marketplace. Typically, such pressures are controlled through formal structures and through formal job assignments to project managers who are then held accountable for the successful completion of product outputs within established schedules and budget constraints.

At the same time, there must be an "upstream" set of forces that are less concerned with the specific architectures and functionalities of today's products but are more concerned with the various core technologies that might underly the industry or business environment not only today but also tomorrow. They are, essentially, responsible for the technical health and excellence of the corporation, keeping the company up-to-date and technically competitive in their future business areas.

In every technology-based organization, as discussed by Katz and Allen (1985), the forces that represent this dualism compete with one another for recognition and resources. The conflicts produced by this competition are not necessarily harmful; in fact, they can be very beneficial to the organization in sorting out project priorities and the particular technologies that need to be monitored and pursued, provided there are mechanisms in place to both support and balance these two forces.

If the product-output or downstream set of forces becomes dominant, then there is the likelihood that sacrifices in using the latest technical advancements may be made in order to meet budget, schedule, and immediate market demands. Given these pressures, there are strong tendencies to strip the organization of its research activities and to deemphasize longer-term, forward-looking technological efforts and investigations in order to meet current short-term goals which could, thereby, mortgage future technical capabilities. Under these conditions, requirements for the next generation of new product developments begin to exceed the organization's in-house expertise, and product potentials are then oversold beyond the organization's technical capability.

At the other extreme, if the research or upstream technology component of the organization is allowed to dominate development work within R&D, then the danger is that products may include not only more sophisticated but also perhaps less proven, more risky, or even less marketable technologies. This desire to be technologically aggressive -- to develop and use the most attractive, most advanced technology -- must be countered by forces that are more sensitive to the operational environments and more concerned with moving research efforts into some final physical reality. Technology is not an autonomous system that determines its own priorities and sets its own standards of performance. To the contrary, market, social, and economic considerations eventually determine priorities as well as the dimensions and levels of performance necessary for successful commercial application (Utterback, 1974).

To balance this dualism -- to be able to introduce the new technologies needed for tomorrow's products while functioning efficiently under today's current technological base, is a very difficult task. Generally speaking, the more the organization tries to operate only through formal mechanisms of organizational procedures, structures, and controls, the more the organization will move towards a functioning organization that drives out its ability to experiment and work with new technological concepts and ideas. More informal organizational designs and processes are therefore needed to influence and support true innovative activity, countering the organization's natural movement towards more efficient production and bureaucratic control. These informal mechanisms are also needed to compensate for the many limitations inherent within formal organizational structures and formal task definitions. In the rest of this paper, we will describe three general areas of informal activity that need to take place within an RD&E environment (in parallel with the formal, functioning organization) in order to enhance the innovaton process for the more timely introduction of new technologies into the corporation's product portfolio. The general proposition is that these areas of informal activity need to be managed within the RD&E setting, strengthening and protecting them from the pressures of the "productive" organization in order to increase the organization's willingness and ability to deal with the many advancements that come along, especially with respect to new areas of technology.

PROBLEM-SOLVING, COMMUNICATIONS, AND THE MOBILITY OF PEOPLE

To keep informed about relevant developments outside the organization as well as new requirements within the organization, R&D professionals must collect and process information from a large variety of outside sources. Project members rarely have all the requisite knowledge and expertise to complete successfully all of the tasks involved in new technical innovations; information and assistance must be drawn from many sources beyond the project both within and outside the organization. Furthermore, if one assumes that the world of technology outside the organization is larger than the world of technology inside the organization, then one should also expect a great deal of emphasis within R&D on keeping in touch with the many advancements in this larger external world. Allen's (1977) 20 years of research work on technical communications and information flows clearly demonstrates just how important this outside contact can be in generating many of the critical ideas and inputs for more successful Research and Development activity.

At the same time, the research findings of many studies, including Katz and Tushman (1981), Allen (1977), and Pelz and Andrews (1966), have consistently shown that the bulk of these critical outside contacts comes from face-to-face interactions among individuals. Interpersonal communications rather than formal technical reports, publications, or other written documentation are the primary means by which engineering professionals collect and transfer important new ideas and information into their organizations and project groups. In his study of engineering project teams, for example, Allen (1977) carefully demonstrated that only 11 percent of the sources of new ideas and information could be attributed to written media; the rest occurred through interpersonal communications. Many of these "creative" exchanges, moreover, were of a more spontaneous nature in that they arose not so much out of formal project requirements and interdependencies but out of factors relating to past project experiences and working relationships, the geographical layouts of office locations and laboratory facilities, attendances at special organizational events and social functions, chance conversations with external professionals and vendors at conferences and trade shows, and so on. Anything that can be done to stimulate informal contacts among the many parts of the organization and between the organization's R&D professionals and their outside technology and customer environments is likely to be helpful in terms of both technology development and technology transfer.

Since communication processes play such an important role in fostering the creative work activities of R&D members, it would be nice if each individual or project team were naturally willing or always motivated to expose themselves to fresh ideas and new points of view. Unfortunately, this is usually not the case as engineering individuals continue to work in a particular project area or in a given area of technology. In fact, one of the more important assumptions underlying human behavior within organizations is that people are strongly motivated to reduce uncertainty (Katz, 1982). As part of this process, individuals, groups, and even organizations strive to structure their work environments to reduce the amount of stress they must face by directing their activities and interactions toward a more predictable level of certainty and clarity. Over time, then, engineers and scientists are not only functioning to reduce technical uncertainty, they are also functioning to reduce their "personal and situational" uncertainty within the organization (Katz, 1980). In the process of gaining increasing control over their task activities and work demands, three broad areas of biases and behavioral responses begin to emerge. And the more these trends are allowed to take place and become reinforced, the more difficult it will be for the organization to consider seriously the potential, long-term advantages of the many new and different technologies that are slowly being developed and worked on by the larger outside R&D community.

Problem-Solving Processes

As R&D professionals work together in a given area for a long period of time and become increasingly familiar with their work surroundings, they become less receptive toward any change or innovation that threatens to disrupt significantly their comfortable and predictable work patterns of behavior. In the process of reducing more and more uncertainty, these individuals are likely to develop routine responses for dealing with their frequently encountered tasks in order to ensure predictability, coordination, and economical information processing. As a result, there develops over time increasing rigidity in their problem-solving activities--a kind of functional stability that reduces their capacity for flexibility and openness to change. Behavioral responses and technical decisions are made in fixed, normal patterns; and consequently, new or changing situations that may require technical strategies that do not fit prior problem-solving molds are either ignored or forced into these established molds. R&D professionals interacting over a long period, therefore, develop work patterns that are secure and comfortable, patterns in which routine and precedent play a relatively large part. They come, essentially, to rely more and more on their customary ways of doing things to complete project requirements. In their studies of problem-solving strategies, for example, Allen and Marquis (1963) show that within R&D there can be a very strong bias for choosing those technical strategies and approaches that have worked in the past and with which people have gained common experience, familiarity, and confidence; all of which inhibit the entry of competing tactics involving new technologies, new ideas, or new competencies

What also seems to be true is that as engineers continue to work in their well-established areas of technology and develop particular problem-solving procedures, they become increasingly committed to these existing methods. Commitment is a function of time, and the longer individuals are asked to work on and extend the capabilities of certain technical approaches, the greater their commitment becomes toward these approaches. Furthermore, in accumulating experience and knowledge in these technical areas, R&D has often had to make clear presentations, showing progress and justifying the allocation of important organizational resources. As part of these review processes, alternative or competing ideas and approaches were probably considered and discarded and with such public refutation, commitments to the selected courses of action become even stronger. Individuals become known for working and building capability in certain technical areas, both their personal and organizational identities become deeply ensconced in these efforts; and as a result, they may become overly preoccupied with the survival of their particular technical approaches, protecting them against new technical alternatives or negative evaluations. All of the studies that have retrospectively examined the impact of major new technologies on existing organizational decisions and commitments arrive at the same general conclusion: those working on and committed to the old, invaded technology fail to support the radical new technology; instead, they fight back vigorously to defend and improve the old technology (e.g., Cooper and Schendel, 1976; Schon, 1963). And yet, it is often these same experienced technologists who are primarily asked to evaluate the potential effects of these emerging new technologies on the future of the organization's businesses. It's no wonder, therefore, that in the majority of cases studied, the first commercial introduction of a radical new technology has come from outside the industry's traditional competitors.

Communication and Information Processing

One of the consequences of increased behavioral and technical stability is that R&D groups also become increasingly isolated from outside sources of relevant information and important new ideas. As engineers become more attached to their current work habits and areas of technical expertise, the extent to which they are willing or even feel they need to expose themselves to new ideas, approaches, or technologies becomes progressively less and less. Instead of being vigilant in seeking information from the outside world of technology or from the marketplace, they become increasingly complacent about external events and new technological developments. After studying the actual communication behaviors of some 350 engineering professionals in a major R&D facility, Katz and Allen (1982) found that as members of project teams worked together, gained experience with one another, and developed more stable role assignments and areas of individual contribution, the groups also communicated less frequently with key sources of outside information. Research groups, for example, failed to pay sufficient attention to events and information in their external R&D community while product development and technical support groups had reduced levels of communication with their internal engineering colleagues and with their downstream client groups from marketing and manufacturing. Such low levels of outside interaction also result in stronger group boundaries, creating tougher barriers to effective communication and more difficult information flows not only among R&D groups but also to other organizational divisions and to other areas outside the organization.

Another set of forces that affects the amount and variety of outside contact that R&D employees may have is the tendency for individuals to want to communicate only with those who are most like themselves, who are most likely to agree with them, or whose ideas and viewpoints are most likely to be in accord with ther own interests and established perspectives. Over time, R&D project members learn to interact selectively to avoid messages and information that might conflict with their current dispositions toward particular technologies or technical approaches, thereby, restricting their overall exposure to outside views and allowing themselves to bias the interpretation of their limited outside data to terms more favorable to their existing attitudes and beliefs. Thus, the organization ends up getting its critical and evaluative information and feedback not from those most likely to challenge or stretch their thinking but from those with whom they have developed comfortable and secure relationships, i.e., friends, peers, long-term suppliers and customers, etc. And it is precisely these latter kinds of relationships that are least likely to provide the inputs and thinking necessary to stimulate the organization's movement into new technical areas.

Cognitive Processes

One of the dilemmas of building in-house capability in particular areas of technology is that engineers responsible for the success of these technical areas become less willing to accept or seek the advice and ideas of other outside experts. Over time, these engineers may even begin to believe that they possess a monopoly on knowledge in their specialized areas of technology, seriously discounting the possibility that outsiders might be producing important new ideas or advances that might be of use to them. And if this kind of outlook becomes mutually reinforced within a given R&D area or project group, then these individuals often end up relying primarily on their own technical experiences and know-how, and consequently, are more apt to dismiss the critical importance of outside contacts and pay less attention to the many technical advances and achievements in the larger external world. It is precisely this attitude, coupled with the communication and problem-solving trends previously described, that helps explain why most of the successful firms in a very new area of technology had never participated in the old or substituted area of technology.

This rather myopic outlook within R&D is also encouraged as technologists become increasingly specialized, that is, moving from broadly defined capabilities and solution approaches to more narrowly defined interests and specialities. Pelz and Andrews (1966) argue from their study of scientists and engineers that with increasing group stability, project member preferences for probing deeper and deeper into a particular technological area becomes greater and greater while their preferences for maintaining technical breadth and flexibility gradually decreases. Without new challenges and opportunities, the diversity of skills and of ideas generated are likely to become progressively more narrow. They are, essentially, learning more and more about less and less. And as engineers welcome information from fewer sources and are exposed to fewer alternative points of view, the more constricted their cognitive abilities become, resulting in a more restricted perspective of their situation and a more limited set of technological responses from which to cope. One of the many signs of obsolescence occurs when engineers retreat to their areas of specialization as they feel insecure addressing technologies and problems outside their direct fields of expertise and experience. They simply feel more comfortable and creative when they can see their organizational contributions in terms of their past performance standards rather than on the basis of future needs and requirements.

Finally, there is not only a strong tendency for technologists to communicate with those who are most like themselves, but it is just as likely that continued interaction among members of an R&D project team will lead to greater homogeneity in knowledge and problem-solving behaviors and perceptions. The well-known proverb "birds of a feather flock together" makes a great deal of sense, but it is just as accurate to say that "the longer birds flock together, the more of a feather they become." One can argue, therefore, that as R&D project members work together over a long period, they will reinforce their common views and commitments to their current technologies and problem-solving approaches. The group not only tries to hire or recruit new members like themselves but they also begin to attract people like themselves, thereby, exacerbating the trend towards greater homogeneity and consensus and less diversity. Such shared values and perceptions, created through group interactions, act as powerful constraints on individual attitudes and behaviors and provides group members with a strong sense of identity and a great deal of assurance and confidence in their traditional activities. At the same time, however, these shared systems of meaning and beliefs restrict individual creativity into new areas and isolates the group even further from important outside contacts and technical developments, thereby, causing the old technologies to become even more deeply entrenched.

Mobility of People and the Not Invented Here Syndrome

What is implied by all of this discussion is that R&D managers need to learn to observe the strong biases that can naturally develop in the way engineers select and interpret information, in their willingness to innovate or implement radically new technological approaches, or in their cognitive abilities to generate or work with new technical options so that appropriate actions can be undertaken to encourage R&D to become more receptive and responsive to new ideas and emerging technological opportunities. The trends described here are observable; one can determine the extent to which project groups are communicating and interacting effectively with outside information sources, whether project groups are exposing themselves to new ideas and more critical kinds of reviews, or whether a project group is becoming too narrow and homogeneous through its hiring practices.

In the best-selling book, In Search of Excellence, organizations are encouraged by Peters and Waterman to practice the Hewlett Packard philosophy of MBWA (Management by Wandering Around). But managers have to know what to look for as they wander around. In particular, technical managers can try to detect the degree to which these different trends are materializing, for the way engineering groups come to view their work environments will be very critical to the organization's ability to introduce and work with new technologies. The more the perceptual outlook of an R&D area can be characterized by the problem-solving, informational, and cognitive trends previously described, the more likely it has internalized what has become known in the R&D community as the "Not Invented Here" (NIH) or the "Nothing New Here" (NNH) syndrome. According to this syndrome, project members are more likely to see only the virtue and superiority of their own ideas and technical activities while dismissing the potential contributions and benefits of new technologies and competitive ideas and accomplishments as inferior and weak.

It is also argued here that the most effective way to prevent R&D groups from developing behaviors and attitudes that coincide with this NIH syndrome is through the judicious movement of engineering personnel among project groups and organizational areas, keeping teams energized and destabilized. Based on the findings of Katz and Allen (1982), Smith (1970), and several other studies, new group members not only have a relative advantage in generating fresh ideas and approaches, but through their active participation, project veterans might consider more carefully ideas and technological alternatives they might otherwise have ignored. In short, project newcomers represent a novelty-enhancing condition, challenging and improving the scope of existing methods and accumulated knowledge.

The mobility of people within the organization is a most fruitful approach for keeping ideas fresh, building insights, and maintaining innovative flexibility. Japanese organizations, for example, assume that the best course of development for capable individuals is lateral rotation across major functional areas of the firm before upward advancement takes place. In a Japanese company, an engineer progressing well may move from R&D into marketing, then into manufacturing, and perhaps back into R&D at a higher level. This is seldom the kind of career track that American firms find appropriate; yet, we all know for sure the kinds of problems one is avoiding as well as the benefits that would accrue over the long-run through the greater use of rotation programs even if rotation were limited to between Research and Development and Engineering groups.

In an additional attempt to foster new thinking and to build stronger intraorganizational bridges and communication networks, some companies hold special meetings in which organizational areas report on what they have been doing and on the kind of capability they have. The 3M Corporation, for example, holds a proprietary company fair at which there are presentations of technical papers, exhibits, and demonstrations of projects and prototypes. The fair enables the rest of the people in the company to begin to learn about what is taking place in other divisions or laboratories. The Monsanto Company uses what it calls the Monsanto technical community to bring together technical people, trained in similar disciplines but employed in different divisions of the firm, and it convenes these people in different workshops and groups, encouraging them to exchange ideas and information. These kinds of programs can be very helpful in fostering communication and in stimulating the identification of new technical capabilities as well as the identification of new market and technical needs throughout the firm.

ORGANIZATIONAL STRUCTURES

Unlike productivity, which is the efficient application of current solutions, innovation usually connotes the first utilization of a new or improved product, process, or practice. Innovation, as a result, requires both the generation or recognition of a new idea followed by the implementation or exploitation of that idea into a new or better solution. So far, we have discussed organizational processes to the extent that they primarily affect the idea-generation phase of the innovation process. It is just as important, of course, for an organization to plan for the idea-exploitation phase where exploitation includes the appraisal, focusing, and transferring of research ideas and results for their eventual utilization and application. To say that one is managing or organizing for the introduction of new technologies within the innovation process implies that one is "pushing" the development and movement of new technical ideas and capabilities downstream through the organization from Research to Development to Engineering and even into manufacturing and perhaps some phase of customer distribution.

Innovation, then, is a dynamic process involving the movement and transfer of technologies across internal organizational boundaries. Formal organizational design, on the other hand, is a static concept, describing how to organize collections of activities within well-defined units and reporting relationships, e.g., Research, Advanced Development, Product Development, Engineering, Quality Assurance, etc. Formal organizational structures tell us what to manage and with whom to interact within certain areas of interdependent activity; they tell us little about how to move information, ideas, and in particular technologies across different organizational areas, divisions, or formal lines of authority. In fact, formal structures tend to separate and differentiate the various organizational groupings, making the movement of ideas and technologies particularly difficult across these groupings especially if there are no compensating integrating mechanisms in place. And it is in the movement of new technological concepts from Research to Advanced Development to successful Product Development that we are particularly interested.

The effective organization, therefore, needs to cause the results of R&D to be appropriately transferred. Technically successful R&D, especially if it embraces new radical technologies, is very likely to pose major problems of linkages with the rest of the firm, particularly product development, engineering, manufacturing, marketing, sales, field-service, and so on. A company can do a terrific job of R&D and a terrible job of managing the innovating process overall simply because the results of R&D have never been fully exploited and successfully moved downstream. Witness, for example, the problems of Xerox where the R&D labs have generated and surfaced many major new advances and approaches only to discover that the company has failed to fully exploit and capture benefit from many of them. Other corporations, on the other hand, have benefited extremely well from Xerox's research activities -- so many in fact that some have quipped that Xerox's research facilities should be declared a National resource instead of a resource for Xerox (see Fortune Magazine, September, 1983).

Over the past decade or so, Roberts (1979) has been studying the problems of moving R&D results through the organization. From carrying out these studies, he has found that most large organizations have been dissatisified with the degree of transfer of their own R&D results and feel very uncomfortable about how little of their good technical outcomes ever reach the marketplace and generate profitable pay-back for the firm. The R&D labs he studied seemed to have broad enough charters to do almost anything they chose but ended up being quite narrow as to what they in fact implemented within their own organizations. To enhance the transfer of R&D results across the barriers of organizational structures, Roberts (1979) advocates the building of bridges; and in particular, he recommends three different groups of bridges: procedural, human, and organizational.

The procedural approaches, according to Roberts, try to tie together both the R&D unit and the appropriate receiving units by joint efforts. In the case of new technological concepts, the most immediate receiving unit is typically some Advanced Development group or some divisional Product Development organization that receives the output from a centralized Research and Development lab. The kinds of procedural bridges that have been suggested include joint planning of R&D programs and joint staffing of projects, especially immediately before and after transfer for those are the most critical phases of the process in which key know-how and information can easily slip through the cracks.

Joint appraisal of results by Research, Development, and any other appropriate downstream unit or customer is also employed in some labs. From the viewpoint of generating useful information, the best time to carry out joint appraisal of results is when failure has occurred, for there is usually something objective to look at from which one might be able to learn and improve. At the same time, however, this exercise must be done carefully and sensitively to prevent this opportunity from becoming a situation of mutual fingerpointing, showing why the other group is really at fault and how those people caused the failure. In these joint appraisals, the attributions of failure should be centered around substantive issues that can be dealt with behaviorally, structurally, or procedurally; otherwise, intergroup conflicts and differences will be strengthened which is likely to cause even greater difficulty in future technological handoffs. Joint appraisal of successes should also not be overlooked for they can be very helpful in generating the goodwill and trust necessary to strengthen organizational linkages, especially after a history of prior difficulty or failure.

The establishment of human bridges also helps to cope with transfer issues. Interpersonal alliances and informal contacts inevitably turn out to be the basis of integration and intraorganizational cooperation that really matter. The human approaches focus on the relationships that convey information between people, that convey the shift of responsibility from one person to another, and that convey enthusiasm for the project. Roberts argues strongly, in fact, that the building of human bridges is by far the best way to transfer this vital enthusiasm and commitment.

Technology moves through people and the most effective of these human bridges is the actual movement of people in two directions. Upstream movement of development engineers to join the R&D effort well in advance of the intended transfer is a very important step. This transfers information from the Product Development areas into the Research process, creates an advocate to bring the research results downstream, and builds interpersonal ties for the later assistance that will inevitably be needed as the technology encounters problems. Downstream movement of Research individuals will also be helpful in providing the technical expertise necesary for Development to build up its own understanding and capability.

In addition to the specific movement of people, human bridges are also built through the interpersonal communication systems that have developed over time through the history of working relationships, rotation programs, task force participation, and other organizational events and activities. Another important device to be considered is the joint problem-solving meeting in which development individuals are asked to sit down with research colleagues to let them explain their difficulties and initial problem-solving thinking. Such meetings are not only helpful in dealing with specific project problems but will also be useful in building stronger human bridges between the related

R&D areas and may even be helpful in solving additional related problems that were not initially put forth.

The final area for considering the movement of R&D results towards development and eventual commercialization consists of organizational changes and organizational bridges. According to Roberts, these are the toughest kinds to create and implement effectively in an organization. It is far easier to alter procedures or to try to build human bridges across groups than it is to change organizational arrangements and relationships. Nevertheless, several different structural approaches can be effective under different organizational conditions. Some organizations have developed specialized transfer groups, created solely for the purpose of transferring important technical advances or important new processes. Under this approach, the transfer group is like the licensor of a technology who is not just sending equipment and documentation but who is also responsible for training others to work with the technology, for installing the equipment, etc. If used, the specialized transfer group should consist of at least a few of the key technical players. Senior management should not be allowed to argue that they can't spare the superstars of the Research organization to support development or manufacturing engineering.

Another organizational approach is to employ integrators or integrating groups that are given responsibility for straddling the various parts of the RD&E organization. This is a very uncomfortable and a very difficult job to assume because it is extremely difficult to ask someone to take care of an integrating function across two separate suborganizations when he or she does not have responsibility for either the sending or the receiving organization. To perform this function successfully requires someone who can cope with the political sensitivities of multiple groups and who has built substantial informal influence and credibility within the organization.

Finally, a variety of corporate venture strategies can be considered by companies that are concerned with developing new technical approaches, new product lines, or want a stronger emphasis on technical entrepreneurship. Roberts (1980) suggests a large variety of possible venture strategies, ranging from the high corporate involvement of internal venturing to low corporate involvement through venture capital investments in outside firms for the purpose of gaining windows on technology and new market opportunities. Additional venture strategies are also described by Roberts, including the coupling of R&D efforts from both the large corporation and the small independent firm. In general, there is no single best way to organize for the effective introduction of new technologies; but the more informal mechanisms one puts in place to foster both the idea generation and the idea exploitation phases, the more one is likely to be successful at managing the innovation process.

ORGANIZATIONAL CONTROLS

All of these organizational attempts at stimulating new technological innovation will fall flat, of course, if organizational controls are not consistent with the innovation process. In looking at many case histories of successful versus unsuccessful innovations based on radical new technologies, Cohen, et. al. (1979) and several other studies have identified a number of factors as being critically important for trying to influence the generation and successful movement of new technologies through the organization.

Technical Understanding: One of the most important issues in working with new technologies is that the Research function must fully understand the main technical issues of the technology before passing it on. Although this point seems obvious, it is often overlooked. The Research function must focus not only on the benefit of the new technology in and of itself; it must also deal with the technology's limitations relative to conventional technologies and to other new technological approaches. In the early days of transistors, for example, one large electronics company spent a great deal of money and many years of research effort on understanding the materials and processing problems of germanium for point contacts and junction transistors. Unfortunately, the Research organization failed to compare the use of germanium to silicon whose own development was continuing to make a great deal of progress. Only after many years did the organization finally realize the limitations in the advantages of germanium over silicon and these limitations had less to do with the devices themselves and more to do with device implementation in packaging and circuitry.

It is also important, therefore, to make sure that Research understands where the new technology might fit in with respect to the product line or at least what requirements must be met to reach this fit. Research should not waste its time solving problems that don't exist or producing technologies that can't be sold. Whirlpool, for example, invested substantial research resources in making appliance motors more energy efficient long before the oil crisis, but of course, the marketplace was not yet interested in these kinds of advances. Similarly, GE conducted a great deal of research in environmental concerns in the 1940's but at that time there was very little interest in improving the ecology of our environment. As a last example, DuPont developed Corfam as a synthetic substitute for leather, but unfortunately for DuPont, the public was perfectly satisfied with leather and saw no need for the man-made substitute.

Full understanding also means that Research must begin to examine the means of manufacturing, the availability of key materials and technical talents, the ease of use, and so on. Air Products and Chemicals, for example, spent millions of dollars to develop a fluorination process so that textile manufacturers could make fabrics, especially polyesters, more resistant to oil and grease. Unfortunately, textile manufacturers didn't want flourine -- a poisonous and corrosive gas -- anywhere near their plants and refused to buy the system. Research should also be able to make, at the very least, preliminary cost estimates. One of the most basic elements of a technology is its cost. In fact, a study of technology programs at GE concluded that most of the barriers to the introduction of new technologies (even hardware and software) were cost constraints and not technical feasibility; it was getting the technology to perform capably at a marketable cost.

To help ensure these kinds of requirements, some labs have begun to hire full time marketing representatives and cost estimators as a regular part of the R&D organization. Previously, corporate R&D

organizations were completely dependent on product line divisions for both marketing and sales effort and for business and economic analysis as well. These dependencies, especially the latter, were harmful in getting research projects justified, supported, and accepted by the divisions who were suppose to be the eventual customer of the research results.

Technical Feasibility: All too often, a technology is transferred before there has been sufficient time within Research to demonstrate true feasibility. Such pressures can come from the downstream organization or they can arise from the "unbridled enthusiasm" of the researchers themselves. In either case, it would be more beneficial to discuss what constitutes feasibility and for Research to strive to achieve it.

Most new technical concepts don't succeed simply because they must run a guantlet of barriers as they enter the main part of the functioning organization. In many cases, the new technology is embedded within a system of established technologies. The question then is will the new technology offer a sufficient competitive advantage to warrant its incorporation into this interdependent system, perhaps changing drastically the tooling and the overall manufacturing process. Experienced technologists will typically warn you that what you don't yet know about the workings of a new technial advance will probably come back to haunt you. What often appears to be a simple technical issue turns out to be more complicated than we realize. GE discovered a fiber, for example, that looked and behaved more like wool than any synthetic yet known. Unfortunately, the fiber disintegrates in today's cleaning solvents and the problem has yet to be solved.

Research and Development Overlap: As previously discussed, it is very helpful to the movement of a new technology if Development, or some other appropriate receiving organization, also has a group of technical people who have been getting up to speed on the technology before the actual transfer, e.g., the presence of "ad tech" groups. Such advanced technical activities within Development can greatly aid the movement of technology and the smoothing of conflicts.

In a similar fashion, it is also important for Research to maintain some activity to support and defend the new technology or to find new ways to extend the technology. Research must not be allowed to feel that it is "finished" at the time of transfer for if this feeling is present, their willingness and enthusiasm to support the technology will be minimal. Most new technologies are relatively crude at first. Ball-point pens, for example, blotted, skipped, stopped writing all together, and even leaked in consumers' pockets when they first appeared on the market. The first transistors were expensive and had sharply limited frequencies, power capabilities, and temperature tolerances. Such experiences are very typical of new technologies, especially radical new technologies. And the more prepared Research is to help "push" the technology, the less likely it will be for the new technology to be dismissed prematurely as a "fad" or as a technology with very limited application.

Growth Potential: As a related point, all too often a research program sells itself short by being too narrow and not showing a clear path towards technical growth and growth in product applicability. In almost every instance, when the new technology appears on the scene, the old technology is forced to "stretch" itself, often with major advances being achieved in the threatened technology. Under these circumstances, the new technology is in the position of trying to chase or catch a "changing target". Moreover, this new potential in the old technology often holds back the entry of the new technology. Advances in flash bulbs, for example, held off the widespread use of electronic flash for quite some time while advances in magnetic tape audio and video recording have prevented the emergence of thermoplastic recording. In their well-known study of strategic responses to technological threats, Cooper and Schendel (1976) indicate that in the majority of cases, sales of the old technology did not decline after the introduction of a new technology. To the contrary, sales of the old technology expanded even further. It is for these reasons that the diffusion and substitution of a radical new technology must be viewed as a long-term process and Research and Development must carefully prepare to argue and demonstrate why the pressured organization should be patient during this time period.

Organizational Slack and Sponsorship: When an organization pushes too hard for productivity within the RD&E environment, trying to measure and control all aspects of the innovation process, there is little room or slack for experimenting or pursuing novel ideas and concepts. The environment is simply too tightly run and the climate becomes unfavorable for very new or long-term innovation. Engineers and scientists become anxious, restrict the depth of exploration along new paths, and center their attention upon issues closely related to the company's immediate output. Creative innovation, on the other hand, is harder to measure and takes a longer period to assess. It requires speculative investments on the part of the firm that wants to nurture the ideas and the experimenting activities that will eventually be worth it.

Given all of the resistance and testing that a new technological idea will eventually encounter from the functioning organization and from operational review committees, strong corporate sponsorship is needed to protect new technological innovations. And the more radical the new technology, the stronger the corporate sponsorship has to be. One of the observations we have made from working and consulting with many technology companies is that most (and in some high technology companies "all") radical new technologies have had to have well-identified sponsorship at the corporate level in order to succeed.

Another important finding from retrospective studies of radical innovation is that new technologies are not really new! By this, we mean that technological change is a relatively continuous and incremental process which casts shadows far ahead. According to Utterback and Brown (1972), the information incorporated in successful new innovations has been around for roughly five to thirty years prior to its use. They further argue that there are many multiple signals within the external environment that can be used to predict the direction and impact of future technological changes and development. von Hippel (1983), on the other hand, argues that one can often anticipate future innovations by identifying what he calls "lead users", that is, users whose needs today foreshadow the needs of the general marketplace tomorrow. Nevertheless, even if particular areas of new technology were identified as extremely important, without strong sponsorship it is unlikely that sufficient resources would be diverted to it, that engineers would be isolated from other pressures or tasks to work on it, or that they would be given sufficient uninterrupted time to complete it. One of the reasons why so many new technologies are introduced through the emergence or spin-offs of new firms is that in these situations, the new technology does not encounter resistance from or have to fight against already existing businesses and entrenched technical approaches.

Another benefit of strong sponsorship is that it helps protect the individual risk-taker who is willing to take on the entrepreneurial burden of moving the new technology through the organization. No matter how beneficial the new technology appears to be, someone must be willing to sell the effort and make it happen. Schon's (1963) analysis of successful radical innovation is quite clear. At the outset, the new technological concept encounters sharp resistance which is usually overcome through vigorous promotions by one emerging champion. What is important to recognize here is that these champions are typically self-selected; it is extremely difficult to appoint someone to withstand all of the pressures, hassles, and risks associated with being an idea champion and then to expect him or her to do it excitedly for a long period.

Finally, we also know from research studies that the ultimate use of a new technology is often not known or may change dramatically as the technology becomes further developed. The new technology, moreover, often invades traditional industry by capturing a series of submarkets, many of which are insulated from competition for some extended period. The earliest application of the transistor, for example, was in hearing aids but its use was not immediately transferred to the organization's missile divisions. Because of these more limited niche markets (and consequently, relatively low sales volume), R&D often concludes that it does not have to work closely with marketing; nor does it want to subject its technological concept to the typical market screens of revenue and volume. Such a conclusion, however, does not help to build the strong harmonious relationship between marketing and R&D that has been shown to be so important for successful commercialization of new innovations (Souder, 1978). The key to success in these kinds of situations may be to find a pioneering application where the advantages of the new capability are so high that it is worth the risks. This would require the coupling of technical perspective with creative marketing development to identify such pioneering applications. On this basis, early involvement of marketing could be very helpful in providing inputs and market perspective (but not market screens) to the new technological effort.

<u>Organizational Rewards</u>: Ultimately, we all know that those activities which are measured or get rewarded are those which get done. If the managerial and organizational recommendations and suggestions discussed in this paper are to be effectively implemented, then the reward systems must be consistent and commensurate with the

hoped for behaviors. One of the most important of these is that research engineers and scientists must come to see that part of their reward system is not just the generation or publication of new technological concepts and advances, but that part of their responsibilities is also the successful transfer of their work. A few high technology companies we know have been making such reward systems explicit within their corporate labs, and although it has taken some time to take hold, it has been quite effective in moving technology through the development cycle. It has also resulted in Research seeking more joint sponsorship of its activities, especially with the Development divisions -- all of which has helped to strengthen the communication and bridging mechanisms within the corporation.

Finally, in most areas of day-to-day functioning, productivity rather than creativity is and should be the principal objective. Even where innovation and creativity are truly desired and encouraged, activities that are potentially more creative may be subordinated to those activities of higher organizational priority or more closely tied to identified organizational needs. Nevertheless, organizations exhibit simultaneous demands for routinization and for innovation. And it is in the balance of these countervailing pressures that one determines the organization's true climate for managing and encouraging the introduction of new technological opportunities.

REFERENCES

Allen, T.J. and Marquis, D.G. "Positive and negative biasing sets: The effect of prior experience on research performance." IEEE Transactions on Engineering Management, 1963, 11, 158-162.

Allen, T.J. Managing the Flow of Technology. Cambridge: MA, MIT Press, 1977.

Cooper, A.C. and Schendel, D. "Strategic responses to technological threats." Business Horizons, 1976, February, 61-69.

Cohen, H., Keller, S., and Streeter, D. "The transfer of technology from research to development." Research Management, 1979, May, 11-17.

Katz, R. "Time and work: Toward an integrative perspective." Research in Organizational Behavior, 1980, 2, JAI Press, 81-127.

Katz, R. "The effects of group longevity on project communication and performance." Administrative Science Quarterly, 1982, 27, 81-104.

Katz, R. and Allen, T.J. "Investigating the not invented here (NIH) syndrome." R&D Management, 1982, 12, 7-19.

Katz, R. and Allen, T.J. "Project performance and the locus of influence in the R&D matrix." Academy of Management Journal, 1985, March, In press.

Katz, R. and Tushman, M. "An investigation into the managerial roles and career paths of gatekeepers and project supervisors in a major R&D facility." R&D Management, 1981, 11, 103-110.

Pelz, D.C. and Andrews, F.M. Scientists in Organizations. New York: Wiley, 1966.

Roberts, E.B. "A simple model of R&D project dynamics." R&D Management, 1974, 5, 1-15.

Roberts, E.B. "Stimulating technological innovation: Organizational approaches." Research Management, 1979, 22, 26-30.

Roberts, E.B. "New ventures for corporate growth." Harvard Business Review, 1980, July-August, 134-142.

Schon, D.D. "Champions for radical new inventions." Harvard Business Review, 1963, March-April, pp. 76-84.

Souder, W.E. "Effectiveness of product development methods." Industrial Marketing Management, 1978, 7, 299-307.

Utterback, J.M. "Innovation in industry and the diffusion of technology." Science, 1974, 183, 620-626.

Utterback, J.M. and Brown, J.W. "Monitoring for technological opportunities." Business Horizons, 1972, 15, 5-15.

von Hippel, E. "Novel product concept from lead users: Segmenting users by experience." M.I.T. Working Paper #1476-83, 1983.