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**High Technology Organizations:
Context, Organization and People**

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Abstract

Firms in global high technology industries face key challenges. This paper presents a preliminary framework that delineates aspects of their context, organization and human resources. It also identifies tensions within the firm that can only be resolved by increasing the capacity of the firm to deal with multiple and conflicting pressures. High technology firms must be adept at resolving tensions and learning in a very fast paced and changing world.

High Technology Organizations: Context, Organization and People*

INTRODUCTION

The high technology arena includes a critical portion of the economy of all developed and newly industrialized countries. The ultimate shape of the evolving global economy of the 1990's will most likely depend upon how the various pieces of high technology industries unfold. Who performs the research and development that create the knowledge that underlies the rapid growth of high technology industries and seemingly unlimited potential for spawning new products and capabilities? Who harnesses that knowledge in new product designs? Where are these products manufactured? How are they distributed and to what markets? Who services the customers and insures that they take advantage of the benefits offered by the latest generation of technology? The answers to these questions will depend to a large extent on the competencies that companies and societies develop to deal with the many and quickly changing facets of the world of high technology business.

A great deal of theoretical and empirical work has been stimulated by the relatively recent awareness of the significance of this vital segment of the economy. For example, an early 1988 conference on "Managing the High Technology Firm" at the University of Colorado in Boulder generated 75 written papers dealing with various aspects of the subject. Nevertheless, our understanding of high technology organizations remains somewhat rudimentary. Researchers have applied their theories and frameworks and in some cases found them inadequate for capturing the complexity of this arena. Descriptive work has in some cases identified patterns, practices, and problems, but prescriptions have not readily followed.

Although definitions vary, there is general consensus about what constitutes a high technology firm. Four criteria can be applied: 1) These firms employ a large portion of scientists, engineers, and technologists; 2) They have an unusually high percentage of R&D expenditures; 3) The emergence of new technology makes existing technology obsolete very quickly; and 4) High technology industries have the potential for extremely rapid growth, as the applications of new technology make possible the emergence of a stream of new products and processes. Other characteristics frequently mentioned include global markets, the existence of entrepreneurial firms that commercialize emergent technologies, complex products and uncertainty in the marketplace.

There is as yet no integrative model of the high technology firm. This paper begins to build toward such a model by pulling together into a framework diverse work that has examined various aspects of such firms. We deal with the context of the high technology firm, its organization, and its human resources. We then pull out some common themes and tensions that cut across these levels of analysis, and describe some of the challenges inherent in the high technology arena. Finally, we ask some basic questions which we feel ought to be in the forefront as a literature of the high technology firm emerges. Among these questions is a very fundamental one: Are high technology firms really different from their lower technology brethren?

THE HIGH TECHNOLOGY CONTEXT

The environment for high technology organizations is extraordinarily complex, and presents an unending series of challenges to the firm. Figure 1 illustrates the context in which a firm is embedded. Each of the ovals represents not only one aspect of the organization's context, but also a

perspective for analyzing and understanding the high technology firm. That is, the high tech firm can be viewed as a player in a global economy, an industry member, a firm in a local (community, regional or national) society, or an element in the international constellation of institutions and organizations that advance the development and application of technology. Obviously each perspective is intricate and the organization cannot remove itself from any of these relevant environments. Traditional notions of competitive strategy (e.g., Porter, 1980) have analyzed the position of the firm within its industry. Relevant elements are competitors and markets, whether regional, national or international. It is necessary to go beyond this "traditional" view of competitive strategies by noting that many high tech organizations are truly global firms. They are members of the global marketplace and the global economy; they are no longer domestic entities competing in foreign markets.

Forces such as the need to recover the high costs of R&D, and insistence by local governments on local content and control have pushed organizations to become truly "global" in their operations: manufacturing, marketing, sourcing of capital, technology and labor, and sales and distribution (Galbraith, 1989, Balakrishnan and Koza, 1988). Such an orientation in its extreme is blind to national boundaries. The world is viewed as a single market and a single economic arena. A country is important only for the barriers and facilitators that it presents, and for the particular requirements that are presented for doing business within its boundaries. Global financing and ownership and international management and careers are challenging the traditional ways of thinking about organizations and international competition.

From another perspective, local contexts are quite important, because

they provide the institutional mechanisms and the incentives and disincentives that influence competitive strategies and success. The institutional forces that result in technological diffusion and transfer, for example, reflect the broader aspects of the society, including the availability and mobility of skilled labor and the accepted role of government in encouraging research and its dissemination. Ungson (1988; 1989) has examined in detail the societal incentives and disincentives operating in Japan, Western Europe and the United States of America. He found that fundamental differences exist that directly relate to competitive strategy. A glaring example is the comparison of the incentive structures that existed in Japan and the U.S. during the downturn in the semi-conductor industry. The U.S. industry experienced a dramatic cutback in R&D and the development of manufacturing facilities while the Japanese industry, encouraged by local governmental and financial institutions to take a long term perspective, were expanding and developing. Societal laws, educational institutions, cultural values, and technical, political, and economic practices may result in a competitive "recipe" for a given country that consequently strengthens or weakens that country's firms in the global competitive arena.

The technological environment is perhaps the most interesting and complex of all, and certainly is the one that most distinguishes the high technology arena from lower technology settings. High technology organizations are fueled by the relentless march of technology--by the generation and communication of knowledge that can be utilized to solve a problem or accomplish a function. Each new breakthrough in basic scientific knowledge and in engineering and design capabilities can propel an entire industry to a new level of product or process. It can simultaneously create new opportunities for entry, bankrupt existing

companies, and render obsolete entire product lines and manufacturing and design processes overnight. The progress of technology is in diverse directions. No one firm has sufficient resources to keep up with all directions and aspects--from basic research to product development in multiple technical areas. Consequently firms must develop a technology strategy (Friar and Horwitch, 1986; Hamilton, 1986; Ottensmeyer and Snow, 1988) that enables them to focus their investment dollars and develop alliances necessary to obtain the knowledge that they cannot generate on their own, or competencies they cannot afford to develop (Galbraith, 1989; Pennings and Harianto, 1988).

Technology strategy locates the firm among elements in an interorganizational network that advances the generation and application of technical knowledge. This interorganizational network is critical because of the considerable evidence that major innovations frequently originate outside of the company and even the industry that commercializes them (eg., Scherer, 1982; Pavitt, 1984). Pennings and Harianto (1988) have postulated that firms located at the junction of interorganizational and inter-industry networks are more likely to innovate than those that are inward focussed.

Rogers and Chen (1989) and Rogers and Valente (1988) have described one manifestation of this network, the "technopolii". These are clusters of organizations that create both the critical mass and the diversity of elements necessary for technology advance to occur and for commercialization to result. The Silicon Valley in California is an example. The research university or research institute is the growth stimulus, providing the energy for technological innovations that can then be converted into products and processes. Financial elements such as

venture capitalists or banks are available to underwrite the costs of this conversion. The symbiotic nature of the relationship between the research organizations, financial organizations, and the entrepreneurial organizations that exist to commercialize the ideas is significant. Rogers and Chen have argued that there is a symbiosis among all elements of the technopolis that provide ideas, support, models and even manpower for one another, and that breed the entrepreneurs that spawn new organizations. One can argue that whether located in a technopolis or not, a high technology firm must find a way to link into the loosely coupled interorganizational network that enables high technology to advance.

These different perspectives on the context of high technology organization interact with one another. Technopolii, for example, enable a country to support and advance the development of an industry, and thus can be viewed as a domestic phenomenon. However, the presence in most technopolii of elements representing several countries makes them global. As companies enter global markets, they become subject to many different local contexts. Alliances with overseas competitors both magnify and erode the national identity of the firm (Von Glinow and Teagarden, 1988), by making clear the cultural differences and demanding a resolution of conflicting interests. National technology policy and the social and economic context provided by each unique national setting have strong implications for firm technology strategy, for the relative success of a country's firms in the various arenas of high technology, and consequently for their success in the world economy.

High technology managers must cope with the complexity of this environment. Two factors magnify this complexity. First is the rapid pace at which it changes. Rapid technological development results in an ever-changing combination of elements at local, national and global levels.

Figure 1 is deceptive in capturing that changing complexity. It does not portray the rapid churn that occurs in each of the ovals--the change in the elements that compose the industry, the local environment and the global economy. It does not depict the rapid technological development, the ongoing entry and exit of competitors, or the mergers and acquisitions that move competencies and resources from one competitor to another. The global economy assumes an ever changing form as newly developing countries emerge as fierce competitors, countries make forays and gain strongholds in new national markets and, governments pass protectionist or trade-enabling laws. This turbulence is the constant state of the high technology context.

Second, new entities such as joint ventures and other strategic alliances, consortia, and technopolii (Rogers and Valente, 1988) emerge which pool and magnify influence on the unfolding of the future. "Intermediate organizational strategies" (Balakrishnan and Koza, 1988) such as joint ventures, partial ownership, and various kinds of contracting and licensing arrangements have enabled firms to achieve some control over the various inputs to and stages of their products without having to be vertically integrated (Galbraith, 1989). New forms of social organization are being created to deal with the complexities of the high technology arena and the information age and with the enormity of the global economy. These forms present more strategic choices and more strategic uncertainty. They are neither well understood nor easily managed.

Thus, one can understand a certain preoccupation with strategy that is manifest in all high technology firms. A successful firm must keep its eye on and find a path through many layers of ever-changing complexity. While keeping an eye on the environment, however, the organization must also tend to its internal functioning. Designing, building and updating an

organization that can function well in these turbulent seas is an equally difficult challenge, one that will be discussed in more detail in the next section.

THE HIGH TECHNOLOGY ORGANIZATION

The nature of the high technology organization is a direct reflection of its environment and of the characteristics of the technology that it produces and utilizes. As described above, all aspects of the environment of high technology firms are changing rapidly. Complexity is increasing because of the increasing number of players in the arena and the proliferation of national laws, trade policies and cultures that are relevant to the global economy. In addition, diverse kinds of entities have emerged or proliferated, such as technopolii, consortia, and various strategic alliances. These new forms have blurred the traditional lines between competition and cooperation, increased the potential influence of any one entity, tied the fates of various entities in the system more closely to one another, and increased the options and the difficulty of strategic decision making (Bourgeois and Eisenhardt, 1987). At the same time that complexity has increased, so has the interdependence among elements in the high technology arena (Roberts and Gargano, 1989).

The rapidly developing global high technology arena provides a moving context and a more complex one to which the organization must adapt. It compresses the time frame within which the organization must accomplish its tasks. As more research institutions are formed and funded, technology progresses more rapidly and in many more directions. The life of a product, and indeed of whole generations of technology, has shrunk, resulting in less time for an organization to commercialize and reap the return from those products. The impact is magnified for high technology

firms that both utilize high technology as tools and produce high technology as their product. The life cycle of process technologies is similarly shrinking. Scientific and technical knowledge is becoming obsolete more quickly, placing a burden on organizations to more rapidly re-educate their employees (Kleingartner and Anderson, 1987). As more competitors enter the arena, each with special competencies, the time frame for each step in the sequence from research to the production and distribution of product has been truncated, and cutting edge product and process technologies are key competitive success factors (Birnbaum, 1988).

In addition to its rapid rate of development, certain characteristics of the technology itself have strong implications for the organization of high technology firms. All aspects of the technology sequence involve extremely complex technical problems (Riggs, 1983), as evidenced by both the depth and breadth of knowledge required to solve them. This is true not only of the research and development process, but also in the product design phase, the design and operation of manufacturing and test processes, and in the assessment of and application to customer needs.

The solution to these complex problems is to a greater or lesser extent a creative process: one that requires invention and innovation (Mohrman, Mohrman and Worley, 1989). As such, there is uncertainty and consequently risk involved at every step. In adopting a strategy, high technology firms are gambling that they can solve these complex puzzles fast enough to secure a position in the market (Ottensmeyer and Snow, 1988). In many cases, the costs of staying in the game are extremely high (Galbraith, 1989). The solution to technical puzzles frequently involves a number of distinct areas of expertise. The interdependence of individuals in research and development laboratories has long been acknowledged in the

literature (Allen, 1969; 1980), and labs have been organized to acknowledge it. As time frames are being compressed, organizations are coming to more fully understand the crucial reciprocal interdependencies between functions that once were handled sequentially and buffered from one another: design, manufacturing, test, marketing and field applications (Kosnik, 1989; Birnbaum, 1988; Morhman, Mohrman and Worley, 1989). Innovation involves the simultaneous coupling of all aspects of the organization--it is not a linear or sequential process (Galbraith, 1982; Van de Ven, 1986). Once treated as separate sequential technical puzzles, in today's environment the sequence of puzzles must be treated as an interconnected system, simultaneously solved, and with the solutions fitting together.

Figure 2 depicts the relationship of these aspects of high technology and its environment to their organizational implications. Each of these implications will be discussed below.

High Technology Organizations as Learning Systems

The discussion of the environment implies not only a rapid rate of change, but also a directionality. The rapid pace of technological change and the emergence of a global economy not only create new and different situations to which the organization must adapt, but also imply development in a distinct direction. Development enhances the performance capacity of the developing unit. Consequently, to secure their position in the constellation of organizations that constitute the high technology arena, firms must in an ongoing way develop their performance capabilities, i.e., they must learn to be more effective.

Clearly a major way in which they must develop is in their capacity to adjust to ongoing change. Eisenhardt and Bourgeois(1989), for example, have described strategic decision making in high technology firms as a

process that is characterized by continual monitoring of key information, rapid input from various individuals who have differing perspectives, and decisive but not always consensual decision making from the top. This ability to make quick but informed decisions is coupled with a posture toward action that maintains multiple options as long as possible, collecting additional information to test the appropriateness of the decision. This sequence describes a learning process.

A learning process is required to support the introduction and effective utilization of new process technologies. Leonard-Barton (1989) studied the implementation of process control technology and makes the case that effective implementation requires organizational learning. Adler (1989) found that the ultimate bounty to be gained from CAD/CAM systems is their ability to enable organizational learning; but to use these systems that way requires not only individual learning but also learning at the structural, strategic and cultural levels.

Not only must high technology organizations learn to do new things; they must also learn how to redesign themselves. Traditional organizational theory may be inadequate to prescribe organizational forms suitable for the rapid rate of change and persistent need to innovate (Jelinek and Schoonhoven, 1988). The new forms of organization that are developing to cope with the complexity of the global high technology marketplace are themselves innovations, demanding ongoing learning and redesigning by organizational members. The term "intermediate" that has been applied to these forms by Balakrishnan and Koza (1988) implies they are neither pure market nor pure bureaucratic. Rather, they exist somewhere in the middle, are established to meet the particular current needs of members, and can be altered as these interests change. The generation of

novel organizational forms clearly requires ongoing organizational learning. It also implies flexibility of design, which is the next characteristic of high technology organization discussed below.

The Use of Flexible and Temporary Designs

High technology organizations have to respond to rapid change in their environment with frequent changes in strategy and direction. Since design follows function and since function is a consequence of strategy (Galbraith, 1977), this means that these organizations must frequently change their design. For example, Schoonhoven and Jelinek (1989) found that successful high technology organizations are able to change their formal organizational structure rapidly and frequently. Kosnik (1989) reported a predilection for interfirm alliances that are flexible and temporary, and that can be changed as the strategic needs of the organization change. The importance of being able to change systems such as compensation and rewards to fit the current needs of the firm has been discussed (Gomez-Mejia and Wellbourne, 1989; Shuster, 1984; Von Glinow, 1988). This all implies that a high technology firm must become competent at the process of self-design (Weick, 1977; Mohrman and Cummings, 1989): redesigning themselves to adapt to a continually changing environment.

Permeable Boundaries

The complexity and rapid rate of change of the environment make boundary spanning activities extremely important in high technology organizations (Miller, 1986). They need diverse, timely and reliable ways to collect and process information from the environment. Several forces blur the boundaries of the organization and establish linkages with various aspects of the environment. Close coupling of the technical population of

the organization with the greater technical environment stems both from the professional orientation of technical employees and from the need of the firm to be well integrated into the technology advancement process. The clustering of high technology organizations in technopolii facilitates this process by creating close linkages between high technology firms and research generating institutions such as universities (Rogers and Valente, 1988). It also creates a critical mass of scientists and technologists who interact informally and share information and problem solving approaches (Rogers and Chen, 1989). The highly mobile career patterns in these areas further blur boundaries, as individuals carry with them information and skills that they gained from previous employers.

The high cost of the development of technical competencies and the need to share competencies and risk cause organizations to band together in alliances that create overlapping interests and involve and link members of multiple organizations in collaborative efforts. Becoming global competitors entails establishing operations in countries with many diverse patterns of laws and cultural expectations, and adapting organizational practices to very diverse workforces. This often requires sharing ownership and influence over decisions. These factors open the high tech organization to strong influence from other organizations--a practice which most traditional organizations seek to avoid.

High technology companies generally work hard to establish close relationships with other organizations such as suppliers and customers with whom they are highly interdependent. For example, locating field applications personnel in major customer facilities has been a long standing practice in many high technology firms. Many companies are now also involving suppliers and customers in the new product development

process (e.g., Heiko, 1988), a practice which further blurs boundaries.

Integration

The extreme interdependence of high technology work argues that integration of effort is a key challenge in these organizations. Kosnik (1989) has argued that integration is also demanded by the uncertainty of product and market, and the need for ongoing reciprocal modification, interdisciplinary cooperation, and cross training in multiple specialties. In meeting the dual competitive necessities of product innovation and low-cost, high quality manufacturing, close linkages are required between design and manufacturing (Birnbaum, 1988). Adler contends that the greatest benefit of CAD/CAM lies in its ability to integrate manufacturing and design; the faster the development of the technology, the greater the need for special integrating mechanisms to pull together the various CAD/CAM activities into a common framework and to provide an incentive for integrated effort. Schoonhoven and Jelinek (1989) have argued that "quasi-formal structure" (task forces, committees interdisciplinary teams, etc.) plays a large role in integrating efforts across organizational lines. Galbraith (1989) focuses on overlay organization, or matrix arrangements, that enable multiple foci on functional country and product requirements.

The culture also can serve as a facilitator or barrier to integration. For example, Adler (1989), Kosnick, (1989) and Resnick-West and Von Glinow (1989) point out that status differentials built into the fabric of the organization inhibit integration between individuals and groups who perceive themselves to be unequal. This is true not only between different functional areas with different training and focus, but also across hierarchical levels. Jelinek and Schoonhoven (1989), for example, have

argued that keeping pace with ongoing need for innovation can only occur if organizational strategic decision making is opened up to include input and influence from technical contributors throughout the organization.

Human resources practices can, if properly designed, be used to encourage integrative behavior (Cascio, 1988). Performance management practices such as reward and appraisal systems play a big role in promoting or discouraging teamwork and integration (Mohrman, Mohrman and Worley, 1989; Gomez-Mejia and Wellbourne, 1989). In addition, cross-functional career paths and cross training are ways to build integrative capability into individuals.

Differentiation

Although integration is a key concern in high technology organizations, differentiation is equally important (Lawrence and Lorsch, 1969). Rapid change in technology, uncertainty, and the proliferation of products and product lines contributes to the need to establish differentiated units.

An organization is likely to be involved simultaneously with multiple products that are in different growth stages and with technology lines in different stages of the technical cycle. In dealing with emergent technologies, exploration, invention and entrepreneurial behavior will be key performance values. Firms will tend to work more closely with one another in order to share the risk (Friar and Horwitch, 1986). As the technologies become better understood, commercialization and diffusion become key performance values. Cost reduction and niche marketing assume greater importance during the mature period. At these later stages, when firms are better able to focus their efforts, they tend to bring their operations inside in order to exploit the technology.

At these different technical stages, different performance values are

relevant, different kinds of people are required, and different organizational designs are appropriate. Furthermore, different phases in a product and industry life cycle entail their own sources of competitive advantages and lead to varying strategies. This argues for differentiating units that are engaged in significantly different kinds of businesses. For example, large mature organizations often establish units that are free from their bureaucratic constraints in order to elicit entrepreneurial behavior and invention (Schoonhoven, 1986; Schoonhoven and Eisenhardt, 1987; Von Glinow, 1988). Perhaps the most publicized successful example of this was IBM's development of the personal computer. IBM was able to enter this market only by creating a separate unit that was free from most of the traditional IBM requirements for structure, review and control (Davidson, 1988).

Ironically, even the need to integrate can contribute to differentiation. Roberts and Gargano (1989), in discussing the management of nuclear submarines (labeled as high reliability organizations), and Adler (1989), in describing the implementation of CAD/CAM systems, give examples of special differentiated units arising to provide systems integration for other parts of the organization. Systems integration units such as program management and business development departments have long been a part of the aerospace and defense industries.

Ongoing Resolution of Competing Tensions

The rapid pace of environmental change and technological development presents an organization with ongoing choices as to how to apply its scarce resources. Preferences often fall along functional or discipline-based lines. For example, technologists prefer investment of scarce resources in

activities that prepare the organization to be cutting edge with respect to developing technologies (investment activities); financial managers think about market position and cash flow (Mitchell, 1986). Kosnik (1989) describes a similar tension within the marketing area between the need to be creative and inventive and the need for ongoing business discipline. Such tension influences the daily interactions of managers and technologists, and can create frustration, ambiguity and confusion on all sides (Resnick West and Von Glinow, 1989; Badawy, 1988).

Even within the technical ranks there are tensions between the orientations of those dealing with the front end processes (development and design) and those dealing with the back end (manufacturing, test and assembly). The walls that develop between these groups can interfere with the learning, innovation and change that are the essence of the successful high technology firm. Adler emphasized the need for multiple input into such decisions as a CAD/CAM strategy, so that the needs of all groups are met, all groups are moving in the same direction, and the organization can take full advantage of the technology.

The resolution of these tensions requires structural mechanisms and processes for resolving conflicts between groups with conflicting interests and preferences. "Quasi-structure" (Schoonhoven and Jelinek) such as task teams and committees and various management groups such as the executive committee will need processes and schemata to help them surface information and make conscious trade-offs. Strategic decisions need to be made in a manner that takes multiple perspectives into account (Mitchell, 1986), enabling input from parties with different preferences and an agreed-upon process for considering and weighting information. Compressed time frames and potentially fundamental underlying value differences may combine to attenuate a consensus-building process. This combination of high input and

non-consensual decision making is the key to the decision making processes described by Eisenhardt and Bourgeois(1989).

Organizations that have the characteristics described above place extraordinary demands on their human resources. People are expected to learn, function within ongoing processes of renewal and reorganization, accomplish their highly specialized tasks and be part of an ongoing integration of very different parts of an organization and resolution of conflicting values and preferences. Once past the first entrepreneurial period of excitement and creation, organizations struggle to find human resource practices suitable for the long term. The next section deals with the people management issues and practices of the high technology world.

HIGH TECHNOLOGY HUMAN RESOURCES

A key factor differentiating high technology firms from firms not engaged in high technology outputs or processes, is its concentration of high technology human resources. Some have referred to these scientists and engineers as "gold collar" workers (Kelley, 1985); others have referred to them as knowledge workers (Drucker, 1988), and still others refer to them as, first and foremost, professionals (Kleingartner and Anderson, 1987; Von Glinow, 1988). Extraordinary pressures befall these people, requiring innovative human resource practices designed to attract and retain this talent, motivate it, develop a calculus for managing the diversity and finally emphasize a continued learning and development environment. Figure 3 maps some of these factors, and notes the dynamic nature of these relationships. Since these professionals are the high tech organization's life blood and among its most important assets, innovative strategies and practices have been developed to cultivate them. However

critical these people are, they must nevertheless operate within a business environment. Thus mediating the dynamic tensions between the human needs and the organizational goals must be achieved for the high technical organization to prosper.

Excellent high technology human resources are in scarce supply, and are difficult to attract and retain. Technopolis represent fluid job markets, where people can readily move from firm to firm, carrying with them ideas, experiences and learning from previous employers (Rogers and Chen, 1989). There is an active grape-vine of professionals and employees are reasonably adroit at determining if the grass is greener elsewhere. Since turnover tends to be fairly high for high tech professionals (Von Glinow, 1988), recruitment and retention strategies occupy a great deal of attention in high technology organizations. Frequent devices for recruitment include exposure to the project team prior to signing on, and front-end bonuses (Gomez-Meja and Welbourne 1989).

High technology workers are also difficult to maintain over the course of their organizational life. In some fields, for example, engineers become technically obsolete within three years of finishing their degrees (Miljus and Smith, 1987). Most organizations employ individuals in a wide variety of disciplines each of whom must develop in the same direction as their fields of expertise develop. Some fields diminish in importance as others emerge as preeminent. Implicit here is the constant vigilance that is required to create and maintain a learning environment. In electronics, for example, many firms are busy trying to transform "hardware people" into "software people". Ongoing development, retraining, and reskilling are continual imperatives in firms already burdened by the quick pace of strategic and organizational change and by the increasing tempo of the work.

Gold collar workers expect and demand careers, and yet the traditional organization as well as societal values reinforce linear hierarchical movement as the only desirable route. This is usually accomplished by having technical people move out of their technical specialty and into management (Raelin, 1987). Dual career ladders rarely have levels equivalent to that of top management. As a result, many fine technical employees shift to management jobs, often without training, aptitude or interest in managing people. They often take the interesting technical tasks with them, further diluting the technical ladder and the amount of interesting work that goes to individual contributors. The answer to this problem has yet to be fully resolved. Hierarchical promotion should not, however, be the primary means by which 'professionals' judge the success of their careers.

A key challenge, (Resnick-West and Von Glinow, 1989; Gomez-Mejia and Welbourne, 1989; Mohrman et al, 1989), is that a firm's human resource systems must have reflexive capabilities built into them in order to manage all the diversity. Reflexivity implies learning, and learning must occur at both the individual as well as the organizational level. There is constant and dynamic movement in most high tech organizations. As figure 3 depicts, the firm's human resource systems have the extremely complex task of matching the needs of the high technology organization with the needs of the high tech workers. Given the pace of change, the successful management of high technology workers must recognize that a certain amount of tension, dissent and conflict is not only inevitable, but necessary (Von Glinow, 1988). If we keep in mind that most prescriptions of the past for managing professionals attempted to lessen the frictions and tensions, we begin to realize that the human resource practices of the high technology firm are

at variance with most firm practices. For example, most organizational control systems are established to control the performances of people. Yet, in high tech organizations, considerable attention is devoted to buffering the high technology professionals from excessive controls. Not only are these workers given intellectual space (Von Glinow, 1988), but since the creative process is so difficult to manage, they are frequently given "controlled freedom" to do what they want to do. The concept of entrepreneurship captures this aspect of controlled freedom. Once again, we are struck by some of the dynamic aspects associated with human asset utilization.

Creative human resource practices of successful high tech firms recognize that what motivates technical professionals to perform is entirely different from traditional organizational incentives (Von Glinow, 1988). A key here is challenging work, and meaningful work accomplished through team efforts, or projects. Very few technical professionals work in isolation from one another, thus traditional methods of performance appraisal, evaluation, and rewards which focus on the individual as the unit of analysis and scrutiny, will not work for these team-oriented employees. Team-related human resource practices are critical for high technology organizations. However, technical employees are frequently trained to expect and inclined to prefer individual tasks and accomplishments (Adler, 1989). Thus, a trade off must be made between individual and team activities. To the extent that teamwork predominates most high tech firms, these teams must serve as sources of learning, development and motivation for all team members. Human Resource systems must recognize the dominance of the need for teamwork and refocus at that level--not at the individual level (Mohrman, Mohrman and Worley, 1989).

Traditional theories of organizational control (Eisenhardt, 1985;

Ouchi, 1979) suggest two underlying control strategies. Tasks that are easily programmed or measurable can be controlled through performance evaluation that focuses on behaviors or outcomes. The nature of high technology work is not highly programmable nor are the outcomes readily measurable. The second strategy minimizes the diversity of preference among organizational members through policies such as selection, training and socialization that lead to internalized goals and performance values. In high technology firms, the split in frame of reference between technical employees and business managers complicates the use of this second control strategy as well. It is far easier to get professional scientists and engineers to adhere to well-specified norms of their professional field than to the norms and values of the business world. Thus it is critical that a culture be established that supports high performance in both the technical and business arenas. This dynamic tension must be frequently adjusted to reflect performance changes.

Critical in addressing this issue is the matching of the firm's human resource practices with the organization's culture (Miller, 1986). If the culture of the firm supports strong performance values, then those must be communicated consistently through its human resource practices (Shuster, 1984). Similarly, in view of the constant changes occurring in the high technology organization's environment, technical professionals must be sensitized to the need or rationale for internal change to meet business demands. They must be linked to the business imperatives of the firm by the creation of open communication and meaningful technical input into business decisions. Even with this communication and input, tensions are bound to erupt due to the dynamic nature implicit here. It will be the high technology firms that can learn from and manage these tensions through

skillful human resource practices, that will successfully navigate the sea of technological change.

RECURRING THEMES

A number of words recur in almost any description or analysis of high technology organizations: complexity, invention, risk, change, uncertainty, learning, ambiguity and renewal. One might image these organizations as playing a game on a playing field that is both moving and changing shape, in which the players keep changing, the content of the game becomes more complex through time, and the rules are made up as the game progresses. The winners are those that can learn, invent, survive, and ultimately recognize that within any iterative process, beginnings and endings are difficult to pinpoint, and all aspects of the organization will forever be in transition.

Effective high technology organizations are able to deal with many conflicting demands. We have already described a number of them in some detail:

(1) The organization needs creativity and invention in the accomplishment of the technical task and the solution of organizational problems; it needs predictability, control and planning in order to remain viable as a business.

(2) In the rapidly changing environment, there is a tremendous amount of information that may be relevant to the organization's strategic decisions; however, decisions must be made very rapidly in order not to fall behind the swiftly moving environment.

(3) The organization simultaneously cooperates and competes with many other organizations in its environment.

(4) A clear, well-understood structure and disciplined procedures

facilitate efficient accomplishment of the complex high technology tasks; but it does not eliminate the need for informal and "quasi-formal" structure and communication to integrate the various parts and keep them working in the same direction. In addition, the structure must be changed frequently as the needs of the organization change.

(5) Good decisions require input from various stakeholders who hold relevant perspectives and information; yet strong directive leadership is required because there is rarely sufficient time for consensual decision making to occur.

(6) Integration between various disciplines, functions and components is key to the solution of complex problems; yet differentiated units that are able to operate with minimal constraints are best suited for the challenges of rapid change and the diverse environment.

In each of these areas a balance must be found. We do not think of balance as a trade-off, however; instead, an escalation of both kinds of activity may be required for the high technology organization to survive and excel. For example, increased differentiation brings with it requirements for increased integrating mechanisms (Lawrence and Lorsch, 1967). As the competitive environment becomes more intense, collaborative efforts are called for. Optimal use of CAD/CAM requires that formal procedures and communication and face-to-face and informal integration both increase. Hierarchical decision making is most likely to be accepted by professional employees (probably all employees) if time has been spent getting their input and making them feel as though they were a partner in the business.

High technology organizations exist in a high velocity environment, perform extremely complex tasks in a compressed time frame, and demand high

intensity from their employees. They utilize every possible uncertainty reduction mechanism (Galbraith, 1977). Traditional hierarchical mechanisms such as goal setting, rules, vertical information systems and hierarchical resolution of conflict are vital. In addition, the organization could not function without effective use of more organic approaches that involve lateral integration such as project teams, integrating roles, task teams and lateral information exchange.

Almost everyone in the organization is affected. All functions must change rapidly to keep up with the changing environment; consequently, most people find themselves learning, innovating and inventing in order to perform their jobs. Contact with the environment is not limited to a few specialized "boundary spanners" as we were traditionally taught to believe. On the contrary, all technical people span the boundary with the technical environment, and many functions relate directly to environmental entities such as customers, suppliers, competitors and allies. The resolution of conflicting perspectives occurs at all levels in the organization.

Certainly traditional bureaucratic representations of an organization as a carefully designed machine do not fit the organization. In high technology organizations, each job does not have well defined responsibilities and standards and a clear set of needed skills, and traditional hierarchical control cannot be achieved. A high technology organization is one in which hierarchy, structure and differentiation of tasks into jobs is just the skeleton. The flesh and blood are the processes that occur.

Communication, coordination, complex problem-solving under conditions of uncertainty, the introduction of change, redesigning, addressing multi-stakeholder perspectives, resolving conflicting preferences, and monitoring the environment are the substance of high technology organizations. These

processes must become routine: they must be built into the fabric of the organization. Structure and systems can support these processes by providing well understood and agreed-upon procedures, clarifying authority and responsibility, and providing incentives. However, they can only begin to make a dent in the uncertainty reduction that must occur.

Cybernetic technology such as integrated CAD/CAM systems, Electronic mail and other new communication technologies can greatly facilitate the flow of information, can introduce discipline into task accomplishment and communication, and can integrate the tasks of individuals and groups that are widely dispersed. Technology may provide the tools for organizations to be able to handle the extreme information processing demands of the high technology environment. But the processes that are so key to resolving the tensions and guiding the learning of the high technology firm depend on human behavior.

INTERESTING QUESTIONS

Research in high technology firms has just begun to scratch the surface of interesting issues in the management of high technology firms, and raises just as many questions as it answers. The questions that are raised now will most likely become the basis for testable propositions and future empirical research. Three of the more interesting of these questions are briefly discussed below.

Are high technology organizations qualitatively different than other organizations? Do they require new concepts and theories, or do they fall comfortably within the current ways of understanding organizations? Similar questions have been raised by Ungson (1988).

It can be argued that high technology organizations are simply extreme

examples of organic organizations (Burns and Stalker, 1961). Contingency theories of organization design (Lawrence and Lorsch, 1969; Lawrence, in press) have posited that a different profile of design characteristics is necessary for organizations trying to accomplish regular efficient performance than for those that require innovation and flexibility to introduce new products into a changing environment.

The answer to the question is complicated by the large amount of diversity among high technology firms. In electronics, for example, firms range from miniscule start-ups to large hierarchical behemoths, from components manufacturers who deal in commodities to value added resellers who do not manufacture at all. Davidson (1988) has pointed out that high technology firms with short-cycle products, such as personal computers, will differ in almost all aspects of their organization from firms with long-cycle products, such as drugs. So perhaps high technology firms are not easily described as a common set. Perhaps they run the full gamut of diversity that is already captured in existing organizational literature.

There does appear to be an aspect of high technology firms that is not adequately covered by traditional views of management and organization. The pace of technological advancement which fuels continual change and development provides an organizational challenge that is not easily dealt with using a static contingency model. These organizations must continually and quickly redesign themselves. They make decisions at a pace which prevents conventional strategic planning. They present an ever-changing set of tasks, responsibilities and jobs. They require continual learning and renewal at both the organizational and individual levels. A model of the learning organization is required to truly understand high technology organizations.

A case can be made that most organizations are dealing with many of

the same environmental requirements as high technology organizations. Most industries today are dealing in some ways with the unfolding of the global economy. They are confronting a different competitive environment, having to radically improve their efficiency and quality, and establishing closer ties with customers and suppliers. Most organizations are implementing cybernetic process technology that changes the nature of the work that is done and upgrades the skills that are required to do it. They are changing in ways that require individuals to learn new skills and knowledge bases, setting up continuous improvement processes, and redesigning to avoid some of the inefficiencies of their bureaucratic structure.

Considering this, it may be that high technology organizations are a laboratory for learning new organizational concepts that have broad application in this period of turbulence that accompanies the transition to the global economy and the emergence of the information society. The question still remains, do factors such as the pace of change, the risk, and the seeming unending potential for technological advance, and the need to be embedded in the larger technological environment create a context that requires a different kind of organization in the high technology world?

Is this period of extreme turbulence a temporary phenomenon or will it be the lasting context for high technology firms? If the generation of knowledge is the fuel that creates the growth and development in the high technology world, then it follows that a slow-down in such knowledge generation might result in the introduction of stability to technology based firms. As more products and technologies reach maturity, high technology firms may come to resemble more closely their lower technology counterparts. As the transition to the global economy proceeds, a new

status quo may emerge that will enable firms to better plan around their competition and the marketplace.

Perhaps this is a question that will have to await the unfolding of history for its answer. For now, it appears that a new generation of technology continues to become available to replace each previous one, and that new industries continue to be made possible by emergent technologies that can be harnessed for commercial application, and that more and more technopolii are emerging to continue to fuel the fire (Rogers and Valente, 1988). If this is so, then the world of high technology will continue to be one of risk, compressed time frames, and continual change (Schoonhoven and Eisenhardt, 1986).

Does cybernetic technology make possible organizational forms that are quite different from those that we have studied in the past? Perhaps a new logic of organization is embodied in these technologies and their information processing capabilities. Adler (1989) has begun to shed light on this issue in his insightful paper on CAD/CAM. In his words, the changes that are required to optimally use the integrative capabilities of CAD/CAM "go to the very core of our conception of the firm." Flat, flexible, collaborative, dynamic learning, and oriented toward capabilities are some of the organizational imperatives that emerge from the logic of the technology.

Information technology has made possible the integration of widely dispersed performers and units (c.f. telecommuting articles such as Metzger and Von Glinow, 1988; Olson, 1987). It enables information to be widely shared throughout the organization, theoretically providing the line worker with sufficient information to work without supervision and to make decisions from a perspective that goes well beyond the individual job. It enables organizations to intertwine their data bases, and to be able to

enter into much closer collaborative and market relationships based on full disclosure and sharing of information (Miles and Snow, 1986). It provides the basis for simultaneous accomplishment of the many pieces of the puzzle that have in the end to fit together to create and deliver the technological product.

It is possible that even without the rapid pace of development of new technology, an organization designed to fully use cybernetic technology would look quite different from the traditional organization. This process technology may be a force that is pushing all organizations, high and low technology, toward a similar design.

Conclusion

Firms in global high technology industries face key challenges. This paper has presented a preliminary framework that delineates aspects of their context, organization and human resources. It has also identified tensions within the firm that can only be resolved by increasing the capacity of the firm to deal with multiple and conflicting pressures. High technology firms must be adept at resolving tensions and learning in a very fast paced and changing world.

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Footnotes

*This paper is an expanded version of the final chapter of: Managing Complexity in High Technology Organizations, Mary Ann Von Glinow and Susan A. Mohrman, (editors), New York: Oxford University Press (in press, 1989).

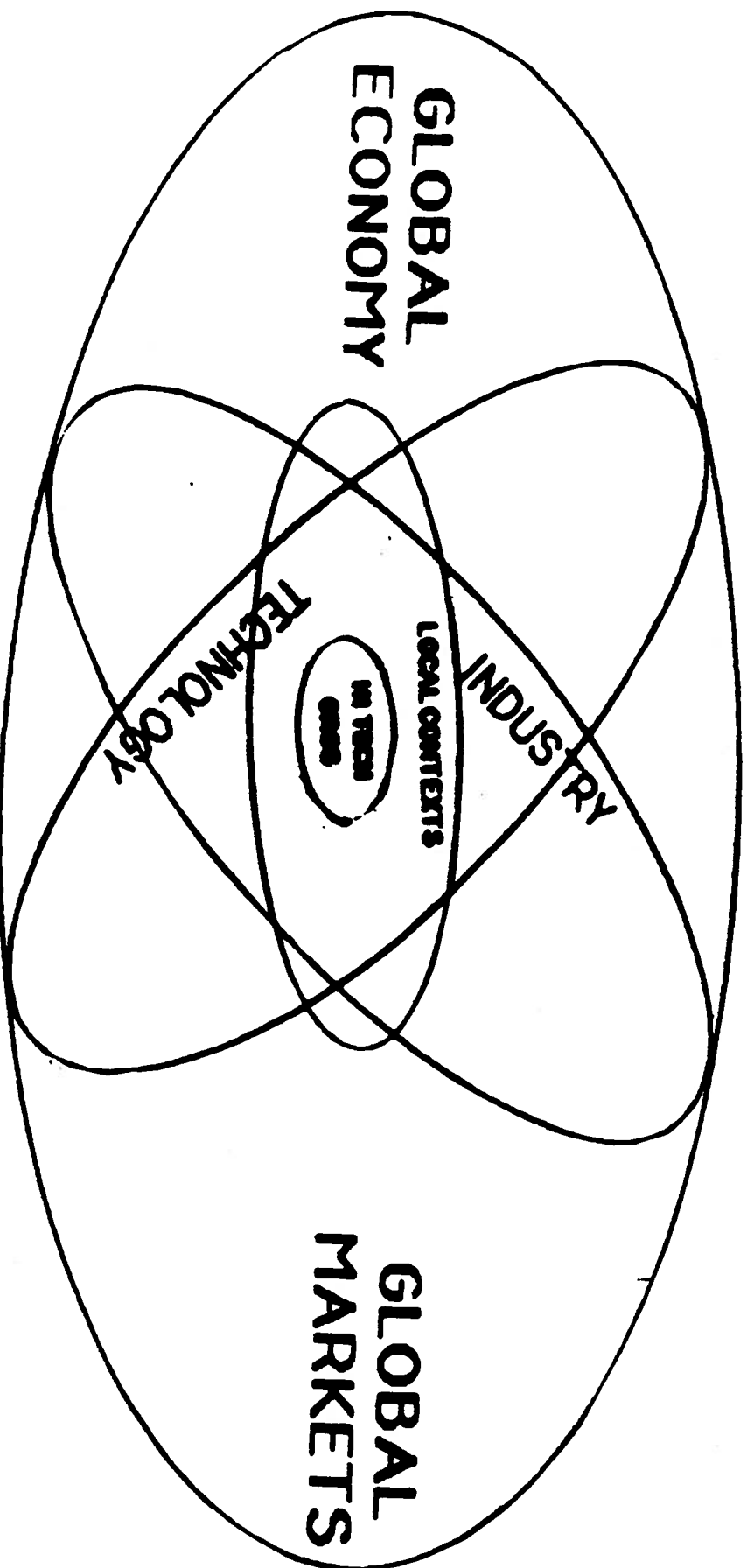
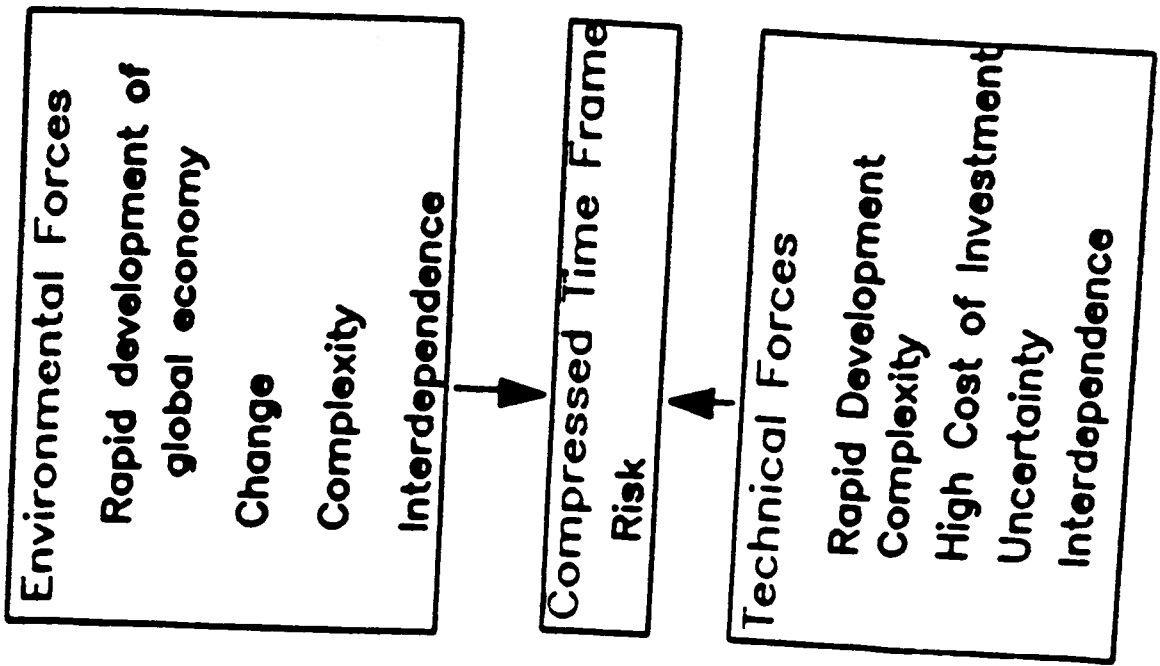


FIGURE 1

The High Technology Context

Figure 2
Organizational Imperatives in
High Technology Firms



- Organizational Characteristics**
- Learning System**
 - Flexible (Temporary) Structures**
 - Blurred Boundaries**
 - Integration**
 - Differentiation**
 - Ongoing Need To Resolve Competing Values**

Figure 3
Dynamic
Human Asset
Utilization

