ENVIRONMENT, ORGANIZATION AND INNOVATION

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September 1980
WP-80-137

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PREFACE

Professor Daniel Roman is from the George Washington University, Washington, D.C., U.S.A. He is a well-known expert in the field of innovation research and was invited to spend two months with the Innovation Task Group of IIASA. The innovation task group "Management of Innovation" at IIASA includes researchers from market and planned economies and is especially interested in investigating the critical problems facing the management of innovation on the national and firm level within the different stages of the innovation cycle: take-off, rapid growth, maturation, saturation and crisis (H. Maier, 1979; H.-D. Haustein, H. Maier, 1979). We are especially interested in investigating how in the different phases, the risk situation, the relatoinship between dynamic and average efficiency (H. Maier, H.-D. Haustein, 1980), the interaction between different kinds of innovation and the organizational patterns are changing. Daniel Roman contributed to this work by writing this paper "Environment, Organization and Innovation". We hope that this paper will stimulate the research on the relationship between "Innovation and Organization" which is possibly one of the most important problems which faces the management of innovation.

Harry Maier
Leader of Innovation Task
Management and Technology
September, 1980

Environment, Organization and Innovation

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INTRODUCTION

The Innovation Process

The innovation process culminates with the introduction of new products, processes, or services with the market. According to Heinz-Dieter Haustein:

> Innovation potential is the ability of effectively introducting new technical devices and organizational solutions into the production process and, subsequently, the market.[1]

Much of the impetus for technological innovation results from research and development. But, as Twiss observes, technological innovation transcends the activities of a single department responsible for R&D. Technological innovation is a total organizational involvement leading to the profitable application of the technology.[2]

Technological innovation involves highly complex decisions, including what technology to develop, evaluation of the state-of-the-art, evolutionary or revolutionary changes, market appraisal, potential risk, product control, the national and international political and economic environment, competition, and the immediate operational environment, specifically organizational processes which might abet, or retard, the innovation process.

With so many interacting considerations, there is a need to understand what advantages exist in technological innovation, how it takes place, and what external and internal environmental and operational factors serve as stimulants, or barriers, to technological innovation.

The Cycle

The innovation process is only one phase of a cycle. The complete cycle is invention, innovation, and diffusion. Invention is distinct from innovation and is the first stage in the cycle. Invention involves the demonstration of a new technical idea by designing, developing, and testing a working example of either a process, a product, or a device. Invention is a separate and distinct area from innovation, but it must be remembered that invention is frequently the prelude to innovation, which is primarily a conversion process leading to application. A much simpler distinction between invention and innovation revolves around the verbs "to conceive" and "to use". Invention entails a conception of an idea, whereas innovation is use, wherein the idea or invention is translated into the economy.[3]

The diffusion of technology is a technology transfer process. Diffusion can occur in any of several ways: directly by people, by the literature, by attending conferences and exchanging information, by the outright purchase of goods or services, through licensing, franchising, co-production, technological consortiums, or direct investment.

THE IMPORTANCE OF INNOVATION AND SCOPE OF THE PROBLEM

The Importance of Technological Innovation

There appears to be almost universal acceptance of the premise that technological innovation is critical for economic well-being. Technological innovation leads to new products, industries, improved productivity, and better living standards. Since research and development are closely allied to technological innovation, there have been pressures for greater commitment of funds for R&D programs.[4] Unfortunately, it has been difficult, if not impossible, to establish positive correlation between funding inputs and R&D and subsequent technological innovation outputs. There have been many instances where heavily funded R&D programs have ultimately been technological or marketing failures, just as there are instances, where some spectacular successes have resulted from technological innovation.

The United States in the Twentieth Century has been closely associated with technological innovation. The recent experience of the United States might serve to illustrate some of the problems related to innovation. In the 1970's, despite the acceleration of invention, there were alarming indications that the technological innovation process slowed down in the United States. The dollar expenditures for research and development have increased, but in absolute terms of real dollars adjusted for inflation, there has not been much exciting growth.[5] Industry has been cautious and generally appears to have drifted to an evolutionary, as distinct from a revolutionary, technological innovation strategy. Management has often become cautious and risk-resistent.[6] A trend of short incremental, but safe, steps seems to have developed and, as a consequence, technological leadership has been dissipated in some fields, in which the United States has traditionally had technological domination.

Of course, not all managements and not all industries have technologically hibernated. Some industries with a tradition of innovation, as in instruments, computers, and electronics, are still innovating. Other industries, such as steel, chemicals, paper, packaged goods, and automobiles, seem, at least temporarily, to have technologically retrenched as far as significant innovations are concerned.[7] Many of these technologically more conservative industries may be deterred by cautious managements which do not comprehend the various impacts of innovation, but are actively aware of the very considerable and very real developmental costs and the high failure rate of new products.

Scope of the Problem

During the 1970's, considerable research with attendant literature has been directed to various facets of innovation. To give accursory but some general indication of the range of research, studies have been directed to the economic impact of technology, innovation and productivity, social aspects of innovation, innovation and organizational size, political factors relating to innovation,ie., government involvement, investment and risk barriers, marketing of innovation, users as innovators, industries or firms threatened by innovation, operational strategies for innovation, competitive forces providing innovational incentives, and organization for innovation. This paper will concentrate on organizational factors affecting innovation.

Objectives of the Paper

Studies on organization and innovation have been conducted to look at the innovation process within organizations, including where ideas or innovations start, how innovations are processed through the organizational hierarchies, and character profiles of individuals who have been identified as organizational innovators.[8] The purpose of this paper is:

1. To identify factors beyond the immediate and obvious process of organization which could affect operational strategies and subsequent organizational forms. What external and what internal forces serve as directional pressures and how might these forces be recognized and compensated for in organization which could facilitate innovation;
2. To briefly explore the various organizational methods and operational environments and evaluate them relative to applicability for innovation;
3. To examine organizational processes in order to better understand which processes or organizational methods can encourage or discourage innovation;
4. To develop a reasonably composite model to provide overview or perspective for innovation and, more directly, organization as it relates to innovation (see Figure 1); and
5. In accomplishing the objective cited in #4, it is hoped that reasonable and understandable structure will evolve which will adapt to segmentation for future in-depth research.

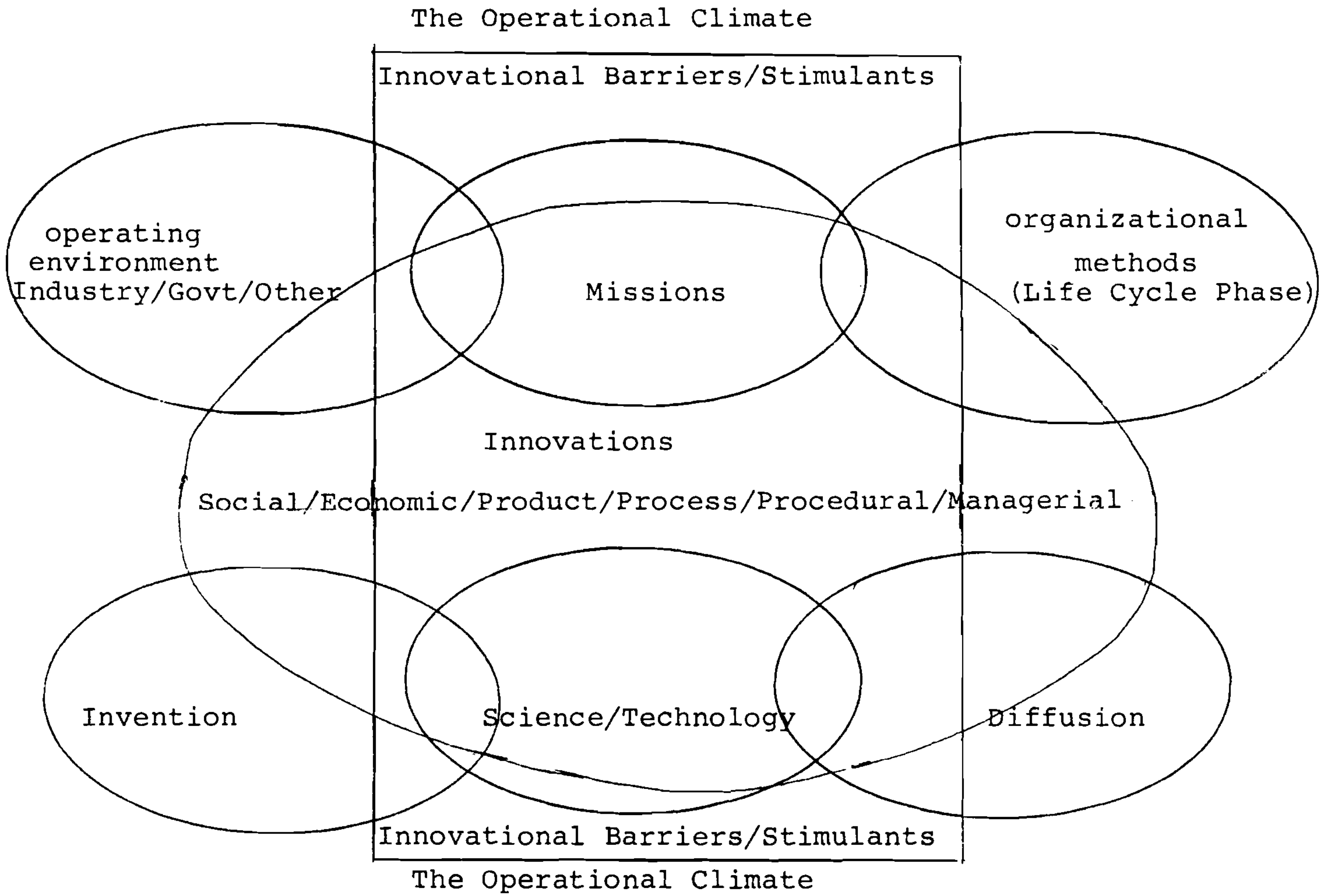


Figure 1. The Innovation/Organizational Model

Organization of the Paper

To accomplish the objectives indicated in the previous section, it is considered advisable to look at several elements which relate to innovation and how these elements might be compensated for in organizing innovation. Sections in this paper will be addressed to:

-- the Science/Technology/Innovation spectrum;
-- the various types of innovation;
-- reasons why research and development takes place;
-- the different operational environments;
-- organizational life cycles;
-- organizational methods;
-- the operational climate, including barriers and stimulants to innovation;
-- the development of an innovation/organization model; and, finally,
-- a summary, suggestive questions for future research and conclusions relating to the aforementioned factors.

THE SCIENCE, TECHNOLOGY, INNOVATION SPECTRUM

Better perspective of science and technology can be provided by Figure 2.

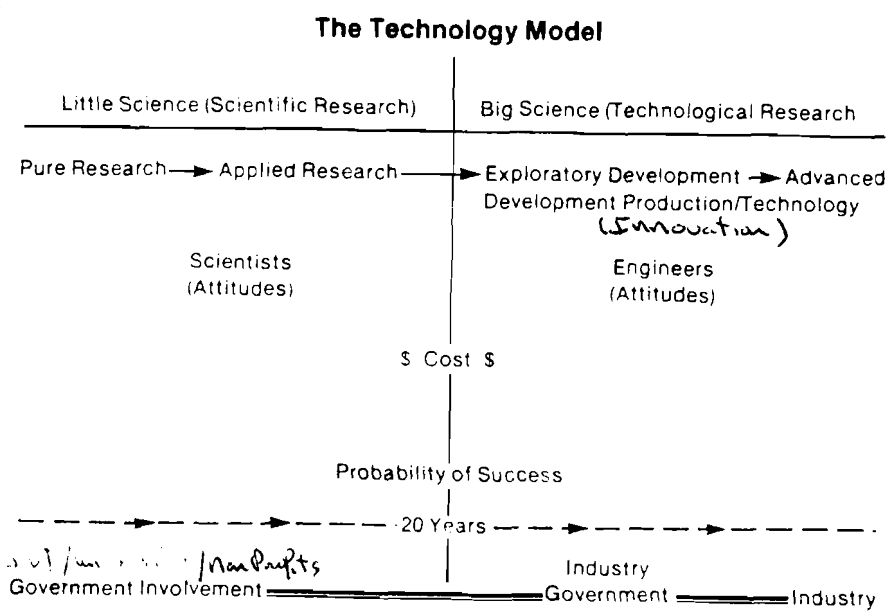


Figure 2. The Technology Model.

The effort spectrum ranges from pure research to technology. The model is one dimensional for simplicity and does not attempt to accommodate technology transfer, nor does it provide for all intermediate phases which are possible, from pure research to technology. In a complicated technology, it has been estimated that the lead time between a scientific discovery and its technological application is about twenty years.[9]

Little Science (Scientific Research)

In the pure and applied research phases, scientific effort is conducted, for the most part, by small teams of scientists. These early phases are generally characterized by a high failure rate, long research times, relatively low costs; work often is performed in universities, or non-profit organizations, and, predominately, by scientists. There are, of course, exceptions, such as some research on solid state physics, high energy particles, molecular biology, or nuclear fusion. These early phases are primarily knowledge-generating or invention-oriented. Since the probability of immediate success, in terms of commercial innovation, is comparatively small and the lead time to marketing is long, industrial firms are usually reluctant to invest heavily in this phase of knowledge creation. However, this is a vital phase in developing scientific capability and priming the pump for future discovery. This area is primarily the province of university, government, and non-profit operations, and government support in these phases is critical if a viable national scientific base is to be established.

Some additional thoughts: the initial phases in the creation of knowledge are usually the domain of scientists; managing scientific research is far more difficult than managing technological research inasmuch as these are much more intangible; innovation invariably involves something of a tangible or use nature; also, scientists' organizational attitudes differ, on the average, from engineers' organizational attitudes; the scientist in these phases is interested in discovery, professional growth, and peer acclaim, he, or she, tends to mainly associate with their profession and organizational affiliation is only a secondary factor--a vehicle which affords them the opportunity to pursue their professional objectives--which frequently are not immediately compatible with innovation.

Big Science (Technological Research)

The second part of Figure 2 depicts Big Science. The closer R&D moves toward technological fruition, the greater the cost. Technological research, generally, is expensive. Depending on the anticipated end-product of the research, it can be performed by the government, by industry, or by government and industry in some concert. Also, relating to the type of developmental work with expectant innovation, as an end-product, performance may be by small or large organizations. In short, the industry/government marriage and the organizational size of the partners would depend on the nature of the technology.

In the advanced phases of technology, engineers rather than scientists are more often involved or responsible for accomplishing technological objectives. The engineers generally see a more tangible product which has organizational association. As a consequence, engineers tend to be organizationally, as well as professionally, directed. Their operational environment definitely reflects innovation possibilities.

Engineers see their career, professional growth, and material benefits being derived from the organization. The organization invariably has product or service identification and organizational affiliation is commitment to professional scope and direction. In essence, the engineer tends to be more organization-oriented, whereas the tendency of the scientist is to be more function, or activity, directed.

TYPES OF INNOVATION

In order to develop direction for meaningful research, and a practical approach to viewing innovation and organization as related processes, two extremely important points are central to the thesis of this paper: first, innovation is an inclusive term covering a wide range of operational and environmental possibilities; second, as a consequence of the different operational environmentals, individual skills, motivations, and characteristics, are subject to variation reflecting the environments wherein they operate.

Coming back to a point discussed earlier in this paper, organization to encourage innovation must reflect the operational environments and the type of people who gravitate to these environments. Innovation is possible in the context of social, economic, product, process, procedural, and managerial situations. In some instances, there is a very fine line of demarkation in the above, especially in making a distinction between managerial and economic innovations. There is also a marked tendency to think of innovation primarily as product-directed innovation.

Social Innovation

Social innovation and government involvement are practically inexorable. Solutions to many public sector problems require innovation. Someof the more obvious public problems in need of innovative solutions are: urban renewal, environmental pollution, crime prevention, water purity and shortage, public transportation, disease prevention and health maintenance, poverty eradication, highway safety, and public education.

The solving of social problems usually entails interaction and cooperation between public and private sectors. At times, private innovations in the industrial sector have created conditions which necessitate social innovation in the public domain. There are instances, when the advancement of private innovations are dependent upon the environment of social innovations. Examples to illustrate the aforementioned are the pollution problems created by the automotive and chemical industries. Industrial innovations may be contingent on the availability of natural and human resources; to provide these resources social innovations are required.

Government should provide encouragement for the employment of private resources in social innovation. The government incentives for innovative solutions can be stimulated by: defining social problems, and establishing social priorities; opportunity and incentive for profit in the development of solutions;

intensified planning for innovative solutions; regulatory measures and other controls to compel or encourage industry action consonant with public welfare; government initiative in social innovation when inadequate incentives do not exist for such effort for the use of private resources.[10]

Economic Innovation

There is a growing body of literature on innovation. Various aspects of innovation have been investigated by Solow, Roberts, Griliches, Shapiro, Twiss, Kendrick, Utterback, Terleckyj, Mansfield, Arrow and von Hipple, to name just a few. At times, the literature is contradictory or confusing. It appears, though, that there is a strong concensus that technological innovation is important, but the social and economic effects of R&D specifically, and innovation generally, are not known well enough to confidently present quantitative indicators of these effects. Many of the studies which have been conducted differ as to method, range, and conceptualization; this adds to the difficulty of formulating a composite picture. Some of the conclusions which might be inferred from these studies are:

1. There is a positive, high, and significant contribution of R&D to economic growth and productivity.
2. The investment in R&D and innovation yields a return as high or often greater than the return from other investments.
3. There are benefits to the industries which purchase new and/or improved products from innovating companies. Often, the benefits to the recipients of innovative technology equal, or exceed, the direct benefits to the innovating companies.
4. There may be underinvestment in R&D and innovation relative to the future potential benefits to the firm and to society.
5. Existing measures of economic performance such as Gross National Product or productivity indices, are only partially reflective of the contribution that R&D and innovation make to the economy and society.[11]

In summation, Twiss states that technological innovation is vital for survival. In an analysis of business failures there were significant instances where innovators failed to translate technological creativity into profitable operations. The real challenge is not only to innovate, but to innovate for profitability. Twiss says technological innovation is critical in the survival and growth of most industrial operations and should not be left to chance. Is there any way to plan and control the process?[12]

Product Innovation

Most managers operate in a short-term environment. The pressures are for quick results and risk avoidance. Innovation is fraught with risk. Failing to innovate can also represent a high risk situation. It is not difficult to enumerate situations where competitive forces have led to the spawning of new products and entirely new industries which have neutralized or eliminated existing products and industries. The U.S. economy has thrived and grown on innovation and departure from this operational philosophy can lead to technological vulnerability.

As technology has accelerated, there have become stronger competitive pressures to innovate. Competition born from innovation has led to products which perform old functions better and products which make new functions possible. Three examples which can be cited are xerography, synthetic wash and wear fabrics, and instant photography.[13] Innovations which drastically affect existing industries and which frequently lead to new industries very often do not emanate from established companies in established industries. Synthetic fibers were developed by the chemical industry rather than the textile industry. High speed ground transportation development has extended from the automobile and railroad industries to the aerospace and electrical manufacturing industries. Instant photography was developed outside the conventional photographic industry. Xeroxing was not a product innovated by the office equipment industry.[14] The aforementioned illustrations can be supplemented with numerous other examples, The message should be obvious that competitive pressures lead to innovation and a no-risk reluctance to innovate operational policy can sooner or later prove disastrous.

Process Innovation

Process improvement affords considerable latitude for innovation. Products may be needed, technology demand pull, and subsequently designed and developed. The successful introduction of these new products may be directly related to product producibility; producibility,especially with new products, may be contingent on process innovations. Also, in a period of cost escalation, the threat exists that price increases could take the product outside its normal consumption range. Process innovations can reduce production costs to increase profits or to improve the organization's competitive position and also enable the firm to penetrate markets which were previously not economically feasible. Process innovation may be in large or small organizations, but normally one would tend to think of process innovation as a large enterprise activity where economies of scale would provide innovational incentives.

Procedural Innovations

There is a tendency for individuals and organizations to become bogged down in routine procedures. Operations change and operational climates may also change, albeit at times unperceptably. Often, routines or procedures are not reviewed or recast innovatively to reflect shifts in operations. Procedural innovation, in mechanical processes or thinking processes, can be instrumental in more effectively utilizing the organization's resources. This, unfortunately is often a neglected area, but it offers fertile innovational possibilities.

Managerial Innovation

Management is the one big variable in the innovation process. Management would be the instigating, or moving, force in the innovational possibilities suggested in this section. Organizations usually reflect management's strategy and operational policies.

Firms can be technologically aggressive, defensive, or passive. Operational philosophy can mirror the general environment; the nature of the industry, theparticular company, the degree of competition, and most certainly, management attitudes. Operational strategy reflects policy and affects planning. Ansoff establishes three classifications to describe how firms approach strategy:[15]

1. Reactors--a passive approach because firms in this classification do nothing to anticipate problems. Problems are solved as they occur.
2. Planners--companies in this category anticipate and plan for problems.
3. Entrepreneurs--companies which fall into this classification are technologically aggressive. They anticipate not only problems but also opportunities.

Market-oriented strategy is very important in planning for innovation. Market planning strategies must be developed systematically to anticipate and maximize opportunity for long-range growth and profit targets. Corbin identifies four main forces which create pressures for marketing strategies: greater size and complexity of business operations, increased competition, rapid change factors which affect the technological and marketing environments, and intensified pressures for new products and markets.[16]

Strategy, as suggested by Twiss, can involve consideration of several factors. What possible growth is possible from current products? Is it possible to expand the market by extending the product line? What prospects exist for penetration of new markets? What can be done to improve the competitive position by reducing production costs? Can profits be increased and operational control enhanced by vertical integration, even though there is no volume increase in the end-product sold? To what extent is growth feasible by acquisition or merger?[17]

Developing and implementing an innovation strategy is not a simple process. In the process, operational strategies can be dominant. Operational strategies can be motivated by a strong technological orientation, where decisions can tend to be one-dimensional technical decisions. Technical people can become obsessed with technical novelty and forget that, to be an economic success, customers must be able to respond to and use the product. Or, operational considerations involving produceability and cost may become so overriding as to discourage potential innovation with its implied deviation from the safe incremental approach.

There are times when market innovation strategy cannot be divorced from operational innovation strategy. J. Fred Bucy, president of Texas Instruments, presents a telling argument for the marriage of both innovation and operational strategies Exclusive of some critical defense technology, most U.S. technology is generally freely available. The availability of American technology comes about through foreign purchases and subsequent imitation of US products. It also transpires through information exchanges at technical meetings and dissemination of research data published in technical journals. The free and easy access to American technology throughout the world is unusual, especially in view of the costs required to generate such technology. What is not freely available is the operational know-how to produce better products at competitive prices. According to Bucy, the U.S. still maintains a competitive edge in some fields, due to innovation in operations which reflect design and manufacturing technological advantages.[18]

POSSIBLE R&D MISSIONS

Objectives

There are many purposes of science and technology, among them:

1. Discovering and furthering knowledge.
2. Developing new products.
3. Improving existing products.
4. Finding new uses for existing products.
5. Improving production processes.
6. Finding potential uses for by-products, or waste products generated by present production.
7. Analyzing and studying competitors' products.
8. Providing technical service to functional departments in the organization.

The research and development operation can perform one, several, or all these services. It can operate as a subsidiary and support group in a product-centered enterprise. Or it can fulfill a fundamental function as it does in the defense industry, where R&D may, or may not, be directed toward the production of hardware in volume. It can be organized primarily for technical service either as part of an organization, or as a separate organization. Also, it can pursue a purely exploratory purpose, with the objectives of discovering and expanding knowledge, rather than applying it. In the United States, government and military R&D organizations can also be distinguished, although comparatively little R&D is actually conducted in these. They are mainly responsible for contracting government and military work to industry, determining requirements and specifications, and managing the work through control, coordination, and evaluaton.

Considering the objectives and organization of science and technological research, is research a separate industry? Part of an industry? An adjunct operation? A means of transition?

One very important additional idea is suggested. It is highly probable that large and complex organizations doing R&D will have performance requireemnts in more than one of the service areas indicated. Such organizations may actually, to varying degrees, be involved in all eight of the service sectors indicated. Identifying and accomplishing the fundamental mission of the R&D organization is paramount. Resources can easily be dissipated in supplying nonrelated or casually related, mission services. There is also a wide spectrum of professional services which can be performed. The different service areas usually require different skills and professional interests. Failure by management to comprehend mission and service requirements will lead to poor organization, ineffective use of human resources, and disgruntled professional employees.

What is strongly suggested by the above discussion is that R&D can be instrumental in accomplishing a variety of missions consistent with the types of innovation discussed in the preceeding section. Failure to comprehend the several possibilities indicated can result in ineffectual organization as a consequence of ineffectually utilizing personnel. Management must recognize the range of activities that are possible, delineate operational goals, and allocate resources, especially human resources, that are compatible with the operational objectives.

THE OPERATIONAL ENVIRONMENT

One recurrent theme of this paper is that differences in operational environments must be recognized as a prelude to organization. Understanding the operational environment can facilitate organizational processes which would provide a receptive arena for innovation. Some of the environmental areas that could be explored as to organizational methods and intensity of innovation are different political entities, industry, and other organizations, such as non-profit research institutes, etc.

Political Operational Divisions

The benchmark frequently used for measuring an organization's performance is profit. However, many organizations, especially governmental organizations, do not function under a profit-directed motivation. What criteria can be applied to determine the effectiveness and efficiency of an organization? Chester I. Barnard has said that for an organization to continue to exist, either effectiveness, or efficiency, is necessary; and the longer the life, the more necessary are both.[19] Effectiveness in an organization is essentially its ability to achieve its objectives; its efficiency is the degree to which it actually achieves them. An action is effective if it accomplishes its specific aim. It is efficient, according to Barnard, if it satisfies the motives of that aim, whether it is effective or not, and if the process does not create offsetting dissatisfactions.[20] The effectiveness of a cooperative effort concerns the accomplishment of an objective within the system, and is determined by the system's requirements.

Efficiency is related to the satisfaction of individual motives. The efficiency of a cooperative system is the result of the efficiencies of individuals who furnish constituent efforts, and thus can be considered to derive from the capacity of the system to maintain itself by the satisfaction if affords the individuals involved. Efficiency can be promoted by motivating individuals, or by changing the individuals within an organization so that the productive results obtained can be distributed to them. Productive results, Barnard says, may be material, social, or both. An individual may obtain satisfaction from material benefits in some cases and from social benefits in others. Most people require both, though in varying levels and proportions.[21]

In government operations, material incentive would appear to be secondary to social incentives. The assumption is that material returns provide an acceptable standard of living. A more intense material environment would be the industrial setting where some correlation might be shown between material rewards and incentive to innovate.

Even though material incentives would not appear to be a paramount motivational factor in government, there obviously are motivational factors which do exist and which should be investigated relative to innovation within government organizations. Government organizations and innovational accomplishments might be looked at under a variety of political circumstances, such as a market-dominated political economy and a sociolistic planned economy. Further breakdown in examining government organizational structures might be to look at operational experiences relative to innovation in developed and developing countries.

Other Operational Divisions

In thinking of "other operational divisions," industrial organizational processes come immediately to mind. The possible industrial operational environments are infinite. Organizational patterns can be studied in a variety of ways, such as by industry, by regulated types of industries, by nonregulated types of industries, technologically-innovative industries, technologically static industries, old industries, new industries, innovative firms within an industry and non-innovative firms within the same industry and organizational size as an innovatively influential factor. Also, industry organizational variences, based on national or cultural characteristics, should be looked at as impacting on innovation. "Other operational divisions" can take in non-profit research organizations, international non-profit organizations, universities, etc.

Roberts, Shapiro, and Bragow, among others, have studied innovation in organizations on a regional basis. This is only one slice of the cake. Many more organizational schematics should be studied, in situations suggested in the previous paragraph, before any valid conclusions can be made pertaining to organizations and innovation.

ORGANIZATION

A Frame of Reference

Organization is the grouping of people and functions to accomplish specified objectives. It is based on a division of labor and a delineation of activities for administrative purposes. Human resources are organized to show functional interrelationships, indicating responsibility and authority, and to establish communication. An organization may be a company, a division of government, or a military unit. It may also be a subgroup within a larger unit. Organizations, people, and functions are not constant; they must be continuously regrouped and redefined to cope with dynamic operational conditions.

Organizational Structures

Organization is an integral part of management. Just as there is no one approach to management, there is no one approach to organization. Different structures can, and do, exist in a company, an industry, industry in general, the government, and the military. Objectives may or may not change; in any event, the means of achieving them will reflect mainly the philosophy of the leadership.

In a large organizational unit, top management has generalized responsibility. Responsibility becomes more specific in the lower echelons. The organizational structure in industry frequently reflects the functional orientation of the president. Similar patterns of leadership exist in government an in military operations. As a result, functions may be maneuvered organizationally to place emphasis on the leader's past functional affiliation. Different leaders, given the same objectives, but possessing different operational backgrounds, will, in all probability, adjust the organization's structure to coincide with their views on how to attain goals. Since various means can produce comparable results, it is very difficult to erect a general theory of organization.

ORGANIZATION GROWTH AND DEVELOPMENT

Organizations grow and develop personalities. Speaking anthropomophically, it can be said that organizations, science and technology groups included, evolve through infancy, adolescence, maturity, and, possibly, senility.

Infancy

Infancy, the initial phase in the organization's development, usually extends from its inception through the first three to five years of its life. In R&D organizations, the period of infancy can run beyond five years.

Organizational infancy is a time when a new objective is being undertaken, or existing objectives are being modified, with a corresponding augmentation, reduction, or redirection of available resources. In this phase, the group gains and loses personnel frequently, formal organization is sketchy, and functional responsibilities are highly flexible. This is a shakedown process, and strong proprietary interests have not had time to develop. Organizational lines are short and informal, communications are normally good, employees are sensitive to operational objectives, and reactions to problems are fast.

In infancy, functions are not well defined, and formal authority and responsibility, except for the leader's are hazy. The organization is objective-directed, and survival is the paramount consideration. Informal cliques appear, perhaps bearing little relation to the formal hierarchy, to span organizational deficiencies. Alignments are predicated on the need to get the job done. Common law types of agreements are made between individuals or interacting groups. Often, the informal organization spills over into social alliances. Social gatherings of the in-group become shop-talk sessions. Free from on-the-job distractions, these casual gatherings become powerful influences molding and directing organizational objectives.

Ultimately, the informal organization may become almost fraternal in operation. It can be a strong factor in promoting careers; ostracism or exclusion from it can spell future career restrictions. It invariably exists within every organization, operates at all levels, and is an evolutionary force which must always be reckoned with organizationally, but is most effective in the infancy stage.

Few research and development units progress beyond the infancy phase. The nature of R&D projects and programs generally precludes a long organization life. R&D may be organized along three general lines: (1) as an adjunct function to support or contribute to a product-centered operation, (2) as a fundamental function, but directed to hardware development, (Where commercial hardware is developed, a separate engineering organization is often formed.) or (3) as part of an organizational complex where research, and not product development, is the basic objective. (Where R&D is an adjunct function supporting a large-product-centered operation, as in DuPont, General Electric, or the Bell System, the evolutionary process is somewhat different because R&D is tied into a mature organization with product continuity. R&D objectives in such situations support the product organization, and the R&D operation will have more stability than in cases (2) and (3), although many of the characteristics of organizational infancy are also applicable.)

In each of these situations, the composite organization can experience an evolutionary growth cycle. However, the total organization exists in an operational framework made up of short-lived internal suborganizations. In this important respect, there is a sharp difference between R&D and traditional organization structure.

Most concerns have a continuity based on a product, a product line, or an established service. Even though the product or service undergoes constant modification, it acts as an organizational anchor. An R&D unit normally has very limited continuity. Usually a service (rather than a product) is sold which varies with, and reflects, rapidly evolving technology. Consequently, R&D projects are constantly phasing in and out, and orderly internal organizational transition is very difficult.

R&D subgroups have relatively short life spans; the average project lasts from a few months to a few years. A large organization composed of many short-lived subunits has severe managerial problems. Overall structural maturity is difficult when the components are chronic organizational infants. Several factors inherent in R&D contribute to this situation:

1. Combining many objective-directed groups into an organization creates coordination difficulties, frictions, and problems over priorities and resource allocations.
2. R&D project units are new. People have to be welded into cohesive teams. Change is continuous, and the organization is always in ferment. Though change is looked upon as a desirable stimulus, it adds to management's difficulties in balancing human resources.
3. Communication lines within a project group are generally short and effective, but they are frequently restricted outside it.
4. Organizational functions may not be well defined, except for the R&D program manager's, so that there is confusion in authority and responsibility.
5. Project-centered groups develop which foster intra-organizational rivalry and conflict. There is competition between projects for common organizational resources.
6. Since each suborganization is objective-directed, it is often reluctant to release resources into the general organizational stream where they might be utilized more effectively.

Adolescence

The second growth phase is adolescence, a transitional stage between infancy and maturity, which can last ten to twenty years.

Organizational objectives, products, personality, and management come into focus with adolescence. The emphasis shifts from short-run survival, intense in infancy, to long-run perpetuation. Management's increased confidence and developing maturity result in clearer definitions of objectives. Organizational structure becomes firmer, but is kept flexible by general, rather than definitive, functional assign ments. Exit from, and entry into, the organization are still subject to fluctuation, but the turnover rate is considerably lower than in infancy. Leaders begin to emerge, and organization strata develops as skill and performance levels become more obvious. Personnel procurement is directed to filling in organizational gaps, bringing managerial strength into areas where internal leadership has not been forthcoming, and introducing specialized people to initiate needed functions.

The adolescent organization is searching for internal equilibrium. The physical growth rate usually is fairly rapid. Overextension of resources, common in this phase, leads to new organizational idiosyncrasies which replace many of those experienced in infancy. Strong proprietary interests begin to develop, creating pressure to shift the focus from objectives to functions. Strong, ambitious people move to claim strategic positions in the growing organization, and their maneuvers to enlarge, combine, neutralize, or eliminate some positions create a traumatic but challenging environment. In the function-directed organization, communication is confused or poor; sensitivity to organizational objectives is diminished and reactions to operational problems are slower. The importance of informal cliques in adolescence rises in proportion to the intensification of internal "functional warfare." The formal organization is in a process of constant revision; the informal organization often provides the only organizational continuity.

Management frequently uses the "confusion technique" during the adolescent phase. It may even subtly encourage internal agitation, short of impairing or compromising overall objectives. If functions are defined in restrictive terms and responsibility and authority unequivocally delienated, organization structure can become formalized too soon. Performance should be used as the basis for evaluating and promoting personnel; good people often become frustrated and bored with narrow job interpretations. Mediocre people may be assigned to positions beyond the scope of their ability, and committing supervisory positions too early may entrench average or weak people in important roles before an internal competitive process has time to function. Any of these situations can discourage capable persons to the point when they leave the organization, and can lead to an inflexibility which might place an insurmountable barrier in the way of the organization's perpetuation.

Performance evaluated without prejudice is the most valid criterion for recognizing and promoting the best personnel within the organization. Selection and development of personnel are a significant feature of the organization in adolescence.

Many infant firms have not been able to surmount the managerial and technical difficulties of coping with multiple subgroups formed to carry out relatively short-lived projects and have been either terminated or absorbed by larger R&D organizations.

A major problem of the adolescent R&D unit is perpetuation. Flexibility has always been a prerequisite for survival in R&D, but organizations in the field are also looking for additional growth, stability, continuity, and established products. Hence, many pursue a policy of active diversification to develop continuity through product lines.

Maturity

The third growth stage is maturity. When the organization enters this phase, it is usually well entrenched in the market. It has a seasoned management which projects the organization's personality, character, and reputation. Objectives are fairly well established, though often not well communicated to the internal organization, which may be aware only of the more generalized goals.

In maturity, employee turnover, especially at the upper echelons, is slight compared with the fluctuations in infancy and adolescence. Proprietary interests have had time to develop and are usually firmly set. Interfunctional movement is restricted and promotion to higher management generally follows established functional channels. The well managed, mature organization seldom recruits outsiders for executive openings, but generally promotes from within, which inspires loyalty and stimulates morale.

A policy of internal executive development distinguishes mature organizations. It counteracts the universal human inclination toward complacency, which breeds reliance on seniority and stagnation. Inbreeding, especially in R&D organizations, can be an erosive force, unless performance and personal development rather than tenure, become controlling criteria for promotion.

Other characteristics are evident at maturity. The organization becomes formalized, although the informal groupings are still potent forces. Responsibility and authority are well delineated, and definitive operational procedures are established.

Internal competition still exists, but is less obvious than in adolescence and infancy.

Large organizations have extended lines of communication, and these commonly lead to information gaps. Poor communication militates against organizational cohesiveness. Often, the individual feels a sense of dissociation from the larger group and tends to ally himself, or herself, with a constituent function, rather than with broad organizational objectives. The mature organization usually exhibits a pronounced evolutionary shift toward a function-directed philosophy; if the bias is extreme, organizational objectives become obscure, and personal sensitivity to problems is lost or blunted. The focus on function can compound communication problems in the same way the concentration on objectives does among R&D project groups in the infant organization. In such situations, strong vested interests come to the fore, and, often, red tape is so stifling that assistance can be obtained and accomplishment made possible only through informal alliances.

R&D is relatively a new industry. Only a few pioneering organizations are approaching maturity, and only those in which the R&D effort supports a product line have achieved maturity. Research and development is fraught with uncertainty, and most people are reluctant to inhabit an environment of perpetual change. The professional in the field is conditioned to, and attracted by, changing work assignments. His, or her, major concern is not the uncyclical nature of the work, but whether the organization will continue to undertake challenging assignments which will utilize his, or her, professional skills.

Senility

Organizational senility can be the final phase in the life cycle. Of course, organizational senility should be avoided. In the senility phase, many of the less desirable characteristics of maturity are compounded. Communication becomes more difficult. Part of the communication problem can be attributed to entrenched vested interests and extreme functional orientation. When there are zealously guarded vested interests and functional emphasis, information is often considered a proprietary and a critical competitive asset.

Another characteristic of senility is the growth pattern--or perhaps the lack of a vigorous growth pattern would be a more accurate description. Stagnation can be relative or absolute. The organization can grow, but the growth can be trivial, compared to other organizations in comparable technology. Or, there can be retrogression to absolute stagnation, where the level of activity actually recedes. Where erosion of activity reflects a deteriorating market position, senility is very obvious and the organizational life expectancy is tenuous. Lack of innovation and growth are symptoms of not keeping up with market demands. Stagnation is further reflected by the failure to keep technology current, to introduce new products or services, to be a high cost producer affecting the competitive position, and to produce products where the quality is questionable and consumer acceptance is less than enthusiastic.

Senility can frequently be traced to poor leadership. Management can get old physiologically or mentally. Ideas can be stiffled in a negative environment. Bright, energetic people can be discouraged from entering such an organization, or, if they do manage to surface, they can be frustrated and, subsequently, leave the organization. In a senile environment, there is little personnel turnover in critical areas, where new blood can provide the influsion of operational momentum.

IDEAL ORGANIZATIONAL CHARACTERISTICS

Each of the first three phases of the organizational life cycle have desirable characteristics. Management should assess the organizational operational phase and make the necessary transitional adjustments. Ideally, the organization should have the enthusiasm, the free information flow, and the extreme flexibility of infancy. The organization should have the focus of objectives, the goal of long-run perpetuation, and the confidence of accomplishment associated with adolescence. And, finally, the desirable characteristics of maturity of experience, reputation, growth reasonable stability, and market position should be sought. (See Figure 3)

CHARACTERISTICS	INFANCY	ADOLESCENCE	MATURITY	SENILITY	UTOPIA
Objective	Survival	Perpetuation	Growth	Survival	Growth
Personal mobility	very rapid--all levels	rapid-shake out process, fill in organizational gaps	frequent at lower levels, slow turnover at middle & top levels-promotion from within	individual stagnation, age disequilibrium static structure entrenched hierarchy	upward mobility avoidance of individual obsolescence-promotion by merit-infiltration of new ideas
Formal organization	Sketchy (objective directed)	evolving (objective directed)	established formal structure-job descriptions (functional directed	rigid (extreme functional direction)	evolving and flexible to accommodate change-objective directed
Functional responsibilities	vague	evolving	specific-some interpretive latitude	rigid-little interpretive latitude	evolving and flexible to accommodate change
Proprietary Interests (Sacred Cows)	non-existent	emerging	some definite proprietary operational areas	strong territorial claims	none-organizational welfare and attendant human concern paramont
Communications	excellent short lines	very good	good to fair definite structure based on protocal	red tape--communication often treated as proprietary	excellent-interface encouraged
Reaction to problems	very fast	fast	responsiveness varies from slow to fast	slow	fast
Informal Organization	strong-objective directed	strong-groups begin to form	existent but not as pronounced as in previous phases	strong--"old boy" system	geared to accomplishment
Internal competition	slight	moderate	high	extreme	slight
Growth	extremely rapid	rapid	predictable	static	predictable, manageable, competitive
Innovation	high	high	moderate	static	high
Market position	tenuous	being established	entrenched	deteriorating	influential

Figure 3. Life cycle organizational characteristics

FORMS OF ORGANIZATION

There is often confusion between organizational forms and the mechanics of implementation. There are several organizational forms: often different variations of these organizational forms are possible and exist, simultaneously, within the same organization. Organization can be directed and motivated by such operational considerations as function, product, process, geographic, (decentralization), project, hybrid or matrix, or free form. The mechanics of implementation include accommodation for line-staff relationships and committee formations and assignments.

A single product or purpose, operation could be organized along functional lines. If the organization evolves there may be a combination of objectives and/or products and services; different organizational forms, or combinations of organizational forms, may be developed in response to operational objectives. Not all possible organizational forms will be discussed in the following sections; only those organizational forms generally considered applicable to high technology environments, such as function, project, hybrid or matrix, and free form are reviewed.

Organization by Function

Organization by function is based on specialization and division of labor. It is the most common organization form.

A function is an action, or activity, which supports, or is part of, a larger organization or activity. An organization is a composite of functions which are established to accomplish one or several goals.

The function form has important advantages, but some actual implementations become limiting. Too narrow a functional outlook tends to create little empires within the organization. Overall objectives become obscured, and defense mechanisms develop to promote a particular function into an independent entity instead of part of the entire process.

In most organizations, there is a lack of understanding of the contributions made by different functions and their interrelationships. Function-directed activity can become an end in itself, instead of the means to an end. Too often, specialized groups consider themselves competitors with other groups, instead of collaborators with them for organization-wide goals.

The function-directed organization is comparable to the human body, in which many organs contribute to physical survival, well-being, and accomplishment. Some organs perform functions basic to life itself; others provide services that are desirable, but not essential. To develop the analogy, functions in an organization may not be critical, but they should help it operate more effectively. Either inadequate, or excessive, activity may impair operations. Oversized, or undersized, functions may perform too aggressively or too sluggishly for actual requirements. Such functional maladjustment can throw the organization out of balance, and functional breakdown can ultimately cause the disintegration and collapse of the entire organization. When people view total operations from the narrow perspective of their immediate functional role, they tend to treat the welfare of the overall enterprise as incidental to the local activity they are associated with. On the other hand, of course, unless the parent body is healthy and productive, it is impossible for any of the functional appendages to grow or to operate at maximum efficiency for any extended period of time.

Research and development work is characterized by great refinement of specializations and functions, and this hampers intra-organizational mobility. Functional isolation creates communication barriers; compartmentalization impeded coordination, cooperation, and a proper recognition of the value of other activities. It is not uncommon to find many functions in R&D organizations relegated to second-class citizenship. In such an environment innovation is discouraged.

In professional organizations, the emphasis on function can become exceptionally intense, and personnel are particularly prone to forget that the whole of the organization is the sum of its functional components. Finishing a work phase does not mean that the entire operation is successfully completed. The failure of any functional part can cause the termination of a program, and, indeed, jeopardize the entire operation. If a program is canceled, functions which have isolated their contribution will be affected just as detrimentally as those which have not performed properly. Going back to the analogy of the human anatomy, we can compare such a situation with a case in which the kidneys, liver and lungs are in excellent working condition, but the patient dies of heart failure.

There is no easy solution to this problem because, excluding some higher-echelon managers, people are hired, reputations made, and careers developed on the basis of functional contribution.

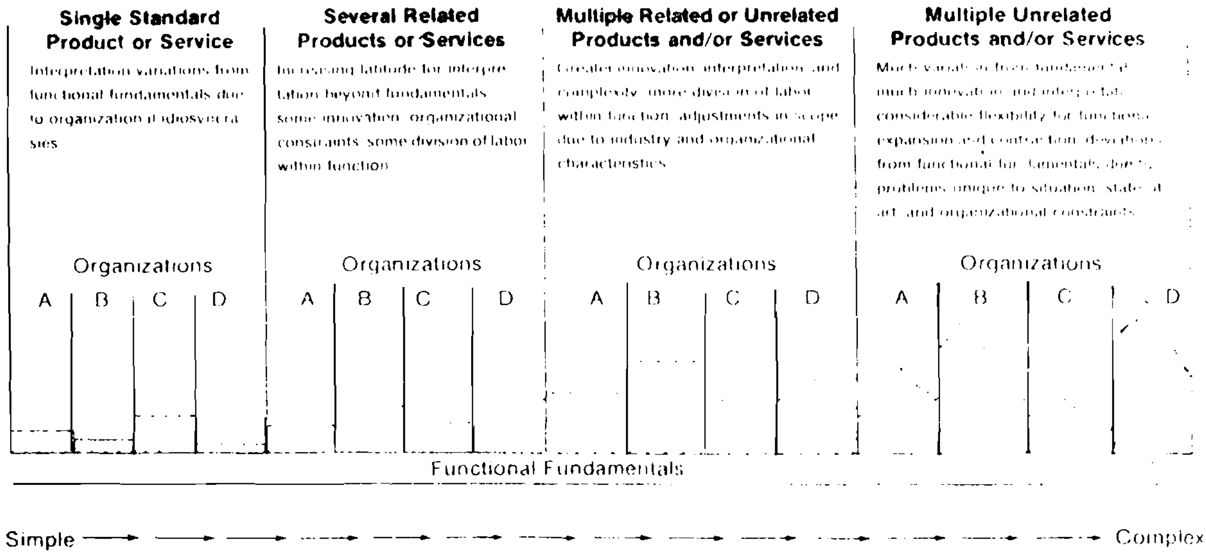
In an emerging technology, functions in different organizations may vary substantially in scope, skill requirements, and definition. Depending on objectives, organizations will differ in the way they locate, interrelate, and evaluate functional activities.

There has been a general failure to recognize the degree of functional latitude and variation in skills needed to respond to different operational environments. Often, the definition of a function reflects the definer's immediate experience, rather than the operational environment of the activity. Figure 4 shows variations in a given function owing to the degree of complexity of an organization's operations. The more complex the environment, the greater the latitude for innovation.

There are functional fundamentals common to most organizations. The essential characteristics may constitute almost the total functional requirements in some operations, but only a very small part in others. There is some latitude in each organization in interpreting how best to perform the functional mission to meet the operational requirements. There are also variations in performance, of course, due to the differing ability and skill of the staff members.

The first group of organizations depicted in Figure 4 provides a single standard product or service. This is perhaps the simplest operational situation. Here, functional activity is likely to be restricted to fundamentals, and the minor variations among the four firms are the result of each organization's character and differences in the performers' capabilities.

The second segment of the chart shows homogeneous operations dealing in several standard products or services. The addition of products, or services, increases the complexity of the functions. There is greater latitude in defining the activity and



→ increasing innovation latitude →

Figure 4. Increasing functional variation corresponding with increasing complexity in an organization's products and operations.

some room for innovation, but there are also inherent organizational restraints. At this point, an organization offers possibilities for division of labor within a function.

The third situation is that of a multiproduct, or service, organization. The products and services may, or may not, be related. There are considerably more possibilities for innovation, the function is subject to wider definition and greater complexity, and there is, usually, a more extensive division of labor within the function. There are also adjustments in scope of functional performance, due to industry or organizational characteristics. The growth of a function beyond its fundamentals is much greater than in the first two groups in the figure.

The fourth illustration depicts the R&D type of organization. in this situation, there are many projects and a heterogeneous operation. Much innovation and flexibility are necessary in a function to meet the organizational requirements. Functional activity must far exceed the mere fundamentals. The performer follows only a general pattern, for the changing operational structure makes it impossible to establish a reliable cycle of activity; operations may expand, contract, and drastically change direction. There is need in such a dynamic environment to constantly review, evaluate, shift resources, and modify functions.

Organization by Project

Project organization is common in R&D or other knowledge development enterprises. The project framework combines features of the product and function approaches and has been improvised to meet organizational objectives.

In this form of organization, a project engineer, or manager, controls one or more technically-related projects. Project work is intense, specialized and costly, and continuity and control are important. The project, as a suborganization, is structured to permit as much control as possible, consistent with its needs and the available resources.

Theoretically, the project manager is responsible for the successful culmination of all the operations under his or her guidance. In practice, however, control is only partial since the project manager does not have jurisdiction over all required resources. Management must decide which people, materials, equipment, and facilities to place at the exclusive disposal of a project, and which to retain for the common use of all subunits. As an example, scientific equipment, much of it very expensive, can often serve many projects; in such instances, priorities must be established. Test and production facilities also, generally, involve costs that prevent the organization from duplicating them for individual projects. Actually, if every function and physical resource required at some phase of a project's life were allocated to its task force, the parent concern would have a function, or product, rather than a project form of organization.

The human resource is the most critical and the most duplicated resource in R&D; some functions are frequently duplicated under each project manager or engineer. In the production facility, each function is normally provided for once. After accomplishment within a project has reached the point when common services or resources are required, the problem inherent in R&D work comes to the fore--how much and which of the general resources are to be allocated to the project, and when?

The Matrix or Hybrid Organization

The matrix or hybrid organization has often evolved from project organization. In the project form of organization, the project manager usually has a high level of technical competence. In project organization, the manager has direct technical responsibility and general managerial obligations. The technical resources under project organization are usually within the immediate jurisdiction of the project manager. In the project form of organization, as mentioned in the preceding section, there is considerable duplication of human resources. The organization is likely to suffer from operational inflexibilities in project organization because people tend to become very project centered, highly specialized, and relatively organizationally immobile. These problems intensify when there is a multi-project operational base and the attendant constant organizational flux precipitated by the steady phasing in and phasing out of projects.

The matrix or hybrid organizational form was a response to eliminate, or minimize, some of the difficulties inherent in project organization. The project organizational form does provide a degree of technical control, but it is operationally costly. The matrix form represents a shift in operational philosophy. In matrix organization, the project manager does not directly control all the necessary technical resources. Technical resources are organized functionally and administratively report to a functionally-directed manager. The project manager in such an organization buys the technical services needed for the project from the different functional managers who assign functional people to support the project manager.

In most cases in matrix organization, the project manager has related technical qualifications. However, there are times in matrix organization when the project manager does not have the qualifications to technically direct the project. In such instances, the project manager has to rely on the technical staff, or other technically qualified sources, for guidance and evaluation. In one large, very technical, company using matrix organization, in which the author had a consulting assignment, the most successful project manager, according to top management, was a former high school music teacher. In matrix or hybrid organization, where work is segregated into projects, there is a shift in emphasis to managerial skills. The project manager does not have direct control of resources. The functional resources "purchased" from functional managers report technically to the project manager, but administratively to the functional manager.

The matrix or hybrid organization represents operational compromises and trade-offs. Functional people have dual reporting obligations. This arrangement violates the classical management principles of unity of command or organizational hierarchy. They report administratively to a functional manager and technically to a project manager. This situation can lead to divided loyalties. Frictions can occur since the project manager has limited personal control and frequently no direct control in selecting people for their project. Differences of opinion can develop between functional managers and project managers as to who should be assigned to a job. Performance evaluation and differences are also possible which might, subsequently, affect individual salary and promotional considerations. Another serious friction point can be the determination of project priorities. The project manager is responsible for the project, but can be frustrated because the skill requirements are not available, or, if so, the calibre of people assigned to the project by the functional manager may not meet standards desired by the project manager. Persuasive project managers on good terms with functional managers can succeed in getting the timely assignment of capable people to their projects. Other project managers with less persuasive talents may come up short, even though their projects can be significantly more important.

All functional specialties may not be required by the project manager. Depending on the nature of project requirements it is possible that two or more functional specialists within a particular area of specialization may be assigned to a project manager. It is also possible that one functional specialist may divide work time between two or more project managers.

Despite inherent limitations, there are distinct advantages in the matrix or hybrid organizational form. Duplication of human resources is minimized. People with similar functional specializations are grouped. This encourages professional exchange and provides more latitude in the utilization and assignment of human resources; this is an additional important advantage of operational flexibility. The matrix or hybrid organization is less susceptible to operational disruptions due to the loss of personnel, than is the project organization. People hav broader operational interests and hopefully, greater functional skill and awareness. There is less individual and operational vulnerability due to the phasing in and out of projects. Human resources in this operational form are more intraorganizationally mobile, since there is usually avoidance of vesting people to specific projects. Finally, under such an organizational arrangement, there should be focus on total operational objectives, rather than individual project concentration and identification.

The Free Form

The free form operational mode is another possible consideration for organizations where there are professionally diverse activities. In this method, there is no formal organizational structure. Groups form, expand, contract, and disband in response to operational needs. There are two basic assumptions underlying this approach as a method for achieving operational objectives; first, a volatile environment of change, and second, a work force dominated by professionals with diverse specializations--something of this environment exists at IIASA.

Organizations, regardless of operational objectives, invariably make some accommodation for rank, or some recognition for service and accomplishment. In some operational settings, status provides a strong framework for superior and subordinate relationships. In a professional organization in which career entry is generally contingent on very special educational attainment, and subsequent career progression on accomplishment, the superior subordinate relationships are likely to be less distinct. In such operational environments colleague authority may be more pervasive.

In the free form approach, there is much operational flexibility. A person can be a member of one group, or a member of several groups, simultaneously. A person can have a supportative role in one group and be the leader or dominant figure in another group. One advantage of this approach, which immediately comes to mind, is intraorganizational mobility. In project management, or matrix and hybrid organization, there is a placement problem for the project manager once the project is completed. A formal project manager title is a connotation of professional attainment, and once this status has been reached, there is a very understandable reluctance to accept other assignments of lesser organizational status. The free form approach excludes permanent titles and lastingorganizational commitment. Professionals have much more mobility to move to areas where they can be used and where there are opportunities to employ their professional skills and interests. The operational norm is such that there is no established hierarchy, and assignments reflect potential contribution, rather than being largely motivated by organizational position.

Free form operations usually result in team formations. For a team to operate effectively, there still must be some directional force to identify objectives and instigate the formation of teams. Much of the ultimate accomplishment in such an environment depends on human factors. People must work together. Individualism must be subordinated to group effort. Good communication is important. Personal dedication, control, discipline, and participation are essential.

Free form operations are relatively new. Like any other method employed in the use of human resources, there are advantages and disadvantages. Some of the advantages have been discussed in the preceeding paragraphs; these advantages, in certain situations, can be compelling enough to force consideration of this operational philosophy. There are also some very real problems which can result from this type of policy. The operational environment must be right. This concept won't and can't work where there are entrenched interests and strong functional affiliations. There is the human variable and this is a considerable problem; to be successful, there must be the immediate subordination of individual goals for group objectives. There is the assumption that people will be dedicated, selfless, and perceptive in working to general objectives. There is the further assumption that people will derive enough personal satisfaction from professional contribution to offset the normal strong human desire for individual status and recognition. There are also, and perhaps most important, management philosophies and attitudes; the receptivity to innovative operational methods; the degree and direction of managerial guidance; the selection, training, and motivation of people to perform in such an operational environment; and management's confidence in people and its dedication to making such an approach operationally feasible.

THE ORGANIZATIONAL CLIMATE

Some Factors Which Affect Innovation Strategy

The nature of the industry can be a compelling factor as to the nature and degree of incentive for innovation. Consumer product industries are likely to be technologically conservative. Innovations in this type of environment are not normally geared to truly new products and new marekts. Innovation in such an operational milieu tend toward an evolutionary approach--the modified variation of the old theme. The more significant innovations in such a setting would probably be in production, processes, and marketing.

When the industry is technologically dynamic, an offensive innovation strategy is a must for growth and survival. If competitive pressures are intense, a strategy of heavy commitment to research, development, and innovation may be dictated. In this operational setting, the innovations would tend to be more revolutionary than evolutionary and, immediately, more product-centered than product-directed.

Innovation strategy can be influenced by the desire for fast pay-off. In a volatile market, the risks are too great for long-lead times for development. Also, in many markets, the product life cycle has become alarmingly compacted. As an example, it has been estimated that in the frozen food and dry-grocery business that the introduction of new products have increased at a tremendous rate and, concurrently, the average product "life expectancies" have declined from thirty-six months to twelve-months.[22] If new products are constantly being introduced, if there is a high product mortality rate, strategy might be directed to keeping the pipeline full of new products. Total commitment to one or a few products is not strategically feasible. Other considerations for a strategy of steady product innovations are the unpredictability of product successes or product life expectancies. A broader-based product line, buttressed by managed introduction of new products, could provide an operational hedge. Fast pay-off strategies mean less expenditures for basic research projects which are generally long-term and are uncertain as to accomplishment and application.

Innovation strategies should be sensitive to organizational resources. Resource allocation depends on company goals and the amount and kind of resources available. The resource mix could be distributed in several ways, but should be coordinated with, and consistent with, company strategy.

Most of the aforementioned situations were primarily addressed to aggressive or offensive innovation strategy. Defensive innovation strategies do exist and should not be ignored.

Some companies enjoy greater returns from investment in research and development than other companies. This may happen because the product of the R&D may be better, or it is possible that those more successful companies are more adept at innovating from the knowledge gleaned from R&D? There are situations leading to reluctance to invest in R&D because it is easy for competitors to build on the effort. The strategy may be imitation rather than innovation. There can be significant advantages in imitation. Only successful products are copied. Major developmental costs are not incurred. Risk is minimized. If such a strategy is adapted, arrangements can be made with innovating companies to license the technology.

A compromise position is another possibility. The company may be unwilling to depend on other companies for licenses, may want to keep at the forefront of technology, and yet may also be reluctant to incur the developmental costs in the light of risk and product life uncertainties. A middle position can be affected by being the licensor, instead of the licensee. The innovation can be licensed to other companies, subject to stipulated controls. In this type of situation, part of the developmental costs can be recouped from licensing fees and there still can be some control of the innovation. It is also possible to make legal arrangements to share in incremental innovations introduced by licensees. Another possible strategy which would be offensive, rather than defensive, would be for the innovating firm to take the initiative in pushing incremental innovation.

Licensing under the proper circumstances, can be very effective defensive innovation strategy. The Japanese, in particular, have enjoyed great success using this approach.

Some other defensive innovation strategies can also be considered. Legal harassment can be taken. Such obstruction can be formidable, even if it is eventually doomed. Legally retarding an innovation may give the defensive firm the time and opportunity to take countervailing measures.

Another defensive tactic could be to shift product lines so the innovation does not have full impact. The product line can be broadened, or compacted, to avoid direct confrontation. With a competitive innovation, the defensive firm can also attempt to develop a market position, or market segmentation, which cannot easily be reached by the innovation.

As the Cooper and Schendel study indicated, it is possible to substantially improve existing products, even though the innovation introduced does offer an option which is directly competitive.[23] A good example to illustrate the aforementioned is the improvement of razors, and razor blades, long after the introduction of the electric shaver.

One other defensive strategy merits strong consideration. If you can't beat them, join them. It could conceivably be much the simplest strategy to acquire an innovating company, which competitively is a threat, rather than engage in other defensive strategies, or attempt to fight them head-on in the market place.

STIMULANTS TO TECHNOLOGICAL INNOVATION

The major stimulation for technological innovation is the probability of success. Successful innovation requires both technical accomplishment and market acceptance. Mansfield and Wagner identify three probabilities which are critical for successful innovation; the probability of technical accomplishment, the probability of commercialization based on technical completion, and the probability of economic success on the assumption of commercialization.[24]

The total environment must also be condusive to technological innovation.[25] Many environmental factors are involved. Venture capital must be available. Capital sources should understand, and be comfortable with, technologically-oriented innovators. Most capital sources do not understand science, technology, and innovation and, consequently, are unable to translate a technical idea into a potentially profitable undertaking.

Universities are also important in the technological environment. Areas where there are concentrations of technological activities and technologically-oriented universities encourage interface between the academic and business community. There should be information exchange and job opportunities for business faculty, and students and stimulation to formulate technological enterprises.

Close and frequent association between entrepreneurs, technical people, the academicians, venture sources of capital, and other community elements touched by the innovation process provide an encouraging environment. When there is an intellectually and economically receptive environment, there is a tendency for environmental perpetration. An entrepreneurial environment is conducive to entrepreneurship.

The convergence of several other elements are also critical to technological innovation: need, personal commitment, management support, organizational objectives, available resources, receptivity of the organization to innovation, effective project selection, management and control, human resources, a favorable environment for risk-taking, timing, and a proven record of accomplishment.

Most successful technological innovation is need or market-stimulated. Innovation can evolve through "demand-pull" or "technology-push" projects. More often, innovation failures can be attributed to marketing failures than technical failures. Technicians often become enamoured with the technical aspects of a project and ignore, or pay insufficient attention to, the commercialization prospects. The result, in such instances, is technical achievement, but a product which cannot economically justify the technical expenditures. In studies by Mansfield and Wagner,[27] Utterback[27] and Bragaw[28], need, dictated by market potential, predominantly provided the incentive for companies to embark on innovative projects.

New products, processes, and services are frequently critical to the survival and growth of companies. This is apparent in technologically dynamic industries, but it can also be true in what might be considered more prosaic industries. For instance, the introduction rate in 1977 of new products in the grocery and drug lines averaged 3.3 per day. It was estimated that 1,218 new products were introduced in the aforementioned fields in 1977 and, in a fourteen year period studied, 21,969 new grocery and drug products made their market debut.[29]

Innovation is not a natural process; it is forced. To bring invention to successful innovation, dedication and effort are required. Commitment is essential. First, organizational commitment is required. Without organizational interest, resources, and sponsorship, innovation is highly improbable. Top management must also be dedicated. In smaller companies, top management probably will be intimately involved with the project. Commitment requires not only organizational sponsorship, but also an innovation champion who has organizational clout and sufficient support of other people to bring the idea to fruition.

As indicated, organizational sponsorship is vital for innovation. Top management's attitudes will be reflected in the organization's willingness, or unwillingness, to push innovative projects. In small companies with a narrow operational base, top management will, in all probability, be involved. Most small companies came into being on the basis of an idea generated by the top people. With rapid acceleration of technology, ideas which provided initial impetus for formation may, or may not, continue to be feasible. Management must be responsive and flexible and shift resources to meet opportunities. In small firms, management may become wedded to the initial idea, or ideas, and not respond to new opportunities for innovation. The author was part of such an organization where the company was formed to produce ram-jets. The development of ram-jet technology was significant. Unfortunately, management was so involved with this technology that they failed to grasp the impact of competing technologies, or other technological opportunities which offered better prospects for the organization's resources and survival.

Large firms tend to lose flexibility and responsiveness. Top management desires safe and controlled growth. If the firm is already a significant factor in the market, there may not be too much incentive to innovate.

Organizational objectives are another consideration in the innovation process. Is the company in a technologically dynamic or static industry? What is the company's position in the industry? Is it a leader or a follower? Is it technologically aggressive or technologically defensive? Does it innovate or imitate? Are innovative prospects relevant to the organizational objectives and compatible with marketing, production, and managerial capabilities? If the objectives reflect an aggressive organization, innovation will be encouraged and be an operational norm. In short, there will be an organizational climate which is receptive to innovation.

The availability, or nonavailability, of resources can be determinate factors in stimulating, or retarding, innovation. Resources can be available, but interpretation of environment factors can be pessimistic. In such instances, the prospects for innovation may not appear good, even if resources are available.

A situation may exist where resources are scarce, or practically nonexistent, but environmental factors appear very favorable. In such an optimistic setting, the firm may decide to innovate and put itself into a leverage position.

Another possibility may exist in which there are surplus resources which can be diverted to innovative projects which might not normally be attempted. The incentive to use such resources could relate to updating human skills by pursuing new technologies, modernizing facilities, anticipating the phasing-out of current income generating activities, or to entering new fields.

In each of the possible situations discussed, risk analysis has to be a compelling factor in the decision to initiate or refrain from innovation.

Effective project management and control would also involve project selection. Projects should be evaluated for economic and technical potential and how they relate to organizational objectives. Resource availability and potential risk must also be factored into a selection process. Other important factors involved in project management and control are the innovative aspects which could provide the organization with technical leadership, and a strong competitive position. In a technologically-conservative environment, projects are likely to be selected when the technology is evolutionary. In such situations the management process is simplified because of the restricted scope of the project; control is relatively easy, reflecting the monitoring and evaluation of state-of-the-art work.

Managing innovative projects is far more complex, due to the increased technical and economic variables; the risk element is greater, but the potential for rewards may be a compelling incentive to innovate.

In creative environments, people represent the basic productive force. A receptive environment will stimulate and encourage innovation. Such an environment will foster communication and the exchange of ideas leading to innovation. Collaboration will be prevalent and problem identification and solving expedited. Creative people in an environment where there is relatively free movement will benefit from exposure to new concepts. If an environment of mutual reenforcement can prevail, innovation should follow. Success seems to breed success. Where a record of accomplishment exists, enthusiasm, dedication, and ability thrive, all of which improve the probability for successful innovation.

Barriers to Technological Innovation

Innovation involves change. The repercussions of change stemming from innovation are extensive. There are internal disruptions which could impact on part or the total organization and affect some, most, or all of the functional areas. Invariably when change takes place in an organization, vested interests are affected. The gain or loss, real or perceived, as a consequence of change, is bound to vary in degree of organizational acceptance from all-out support to passiveness to outright resistance. The change can affect production processes, pursuing a new technology, the introduction of new products, or product variations, or different operational methods.

External factors affecting innovation involve risk predicated on market environmental forces, most of which are uncontrollable. The affect of innovation, and subsequent change, are largely unknowns. The unknowns, internal or external, create psychological barriers which must be circumvented. The farther into the future, the greater the uncertainty. When the environment is technologically evolutionary, innovation is likely to be incremental and change is transitional. Where the environmental pressures are for dynamic technological change, innovation can be radical and the change is revolutionary.

Innovation processes have not proceeded evenly. In some industries or nations, there has been relatively little innovation--virtual technological stagnation. In other instances, there has been steady, but less than revolutionary, innovation. In some other industries and nations, innovation has been constant and dynamic. A categorical commitment to stagnant, evolutionary or revolutionary innovation is unrealistic. However, in view of the barriers to innovation, it would appear that unless cataclymic environmental conditions dictate drastic innovations the trend is toward evolutionary innovation.

There are many risk considerations related to the unknowns associated with innovation. Some of the more obvious are the ability to achieve technical objectives, high developmental costs competitive forces, the political environment, and the high failure rate of new products.

Engineers and scientists tend toward optimism. They are usually optimistic as to the extent of technical accomplishment, the developmental time, and the costs involved. The degree of optimism varies by the magnitude of the technical problem and the individual making theprognostications. Management must factor each situation, since there is no general rule of thumb, Perhaps it is because of the extent of technical uncertainties, where major innovations are involved, and the difficulties in coming to a realistic appraisal of the full scope of the technical problems, that has acted as a conditioner for management to sponsor short, incremental but manageable steps.

With a tendency to understate, or underestimate, technical difficulties, there is also a tendency to miscalculate developmental costs. Developmental costs escalate because the magnitude of the technical problems was not understood and more work is required. Developmental costs can also extend beyond original estimates, because the product which was originally envisioned is substantially changed. The product ultimately built is much different than the product originally planned. This is very common in the development of military weapons systems. Another factor causing cost escalation is inflation. Professional estimators take inflation into consideration when projecting developmental costs. What is difficult to anticipate is the broadening of the scope of the original program and the attendant time extensions, with more and higher costs than originally estimated.

Competition, real and potential, is another risk that serves as an innovative barrier. There may be inducement to take a risk position, if the invention can be protected and becomes proprietary to the innovating company. On the other hand, if there are large developmental costs and uncertainties, and if competition can readily imitate the end product, the incentive to innovate is sharply reduced. This has happened with many American products when foreign companies have built upon the existing product technology and have added marketable innovations.

The political environment can also serve as an innovation barrier. Legal restrictions can dampen innovation enthusiasm. A politically-unstable government can discourage venture capital, especially in high risk areas. Also, government fiscal policy can be instrumental in encouraging or discouraging innovation. A good example is the extremely high tax rate in England which, in concert with high developmental costs and the high risks of innovation, acts as a negative incentive. The evolving tax structure in the United States can be taking the U.S. down the same risk avoidance path which exists in England.

The uncertain technical environment is another barrier to technological innovation. A parallel or radical technical development, which is unknown, can obsolete a product or entire industry. The diesel engine materially affected the railroad industry. The telephone was the ultimate death knell for the telegram. Streetcars were affected by automobiles. Passenger trains felt the impact of airplanes and buses. And, perhaps, the transistor has affected more industries and products than any other innovation.[30]

There have been many testimonials to the contribution of new products to organizational growth and prosperity. Successful new products do not occur as a natural phenomena. There are more failures than successes. The estimates of product failures vary. A Wall Street Journal article estimates a forty percent to fifty percent failure rate of new products.[31] A Business Week article reported that A.T. Kearney, Incorporated, management consultants, estimated the chances for success of a new product in a new market to be only one in twenty.[32] And, still another Business Week article estimated new product failure rates as high as eighty percent. it was also estimated that the waste in R&D effort can run to seventy percent or higher.[33] The extreme incidence of failure in innovation certainly has to be a consideration and a barrier in undertaking innovative activities.

With market uncertainties and the level of risk, there is increasing pressure to shorten the cycle time from product inception to market introduction. Everybody wants to be first in the market. Most so-called new products are really variations of existing products. Definitionally, a truely new product represents a significant innovation and opens up an entirely new market. A major new product would be a Xerox, a Polaroid, or television. Being first in the market with a drastic innovation does give considerable competitive advantage, even though there are subsequent imitations. The disadvantage of introducing an innovation is advertising and consumer education costs and risks.

Shortening developmental time has other very important considerations. When the go-ahead is given for product initiation, the decision is likely predicated on the marketing and technical feasibility analyses. The shorter the time from the decision base to market introduction, the smaller the probability that consumer tastes will drastically change, or that there will be some technological intervention which will obsolete the product.

The advantages cited in the preceeding paragraph for compacting developmental time are compelling, but not always possible. There may be technical problems which were unforeseen and which take longer to solve than originally anticipated. There may be health or safety issues, as in the development of drugs which require extensive testing before they can be introduced on the market. New technological developments may also force modification to existing, or planned, processes to meet competition. This can extend developmental time. When there are many developmental uncertainties and prospects for long developmental time, there will normally be barriers to innovation, especially where consumer products are involved in a competitive market.

Market share, as indicated by Rosenberg, may be a barrier to innovation. If the firm is already in a dominant market position chances are that innovation will not further enhance that position.[34] Having little to gain from innovation, the firm will be reluctant to take a risk position. The aforementioned might be definitionally qualified. There is strong evidence that firms in a dominant market position do innovate, but the innovation is incremental--the new wrinkle affect, rather than a really new product in a totally new market.

Since the 1960's, consumerism has certainly had an impact on innovation. The consumer impact has been very real, if not immediately obvious. The courts have handed down some stunning judgments against companies due to product liability. Product liability insurance has become an imposing cost in doing business. Product liability insurance rates have escalated tremendously and, in many instances, threaten the financial structure of smaller enterprises. There has been an interesting parallel on the costs, or product liability insurance, and doctor's malpractice insurance costs.

With product liability and the attendant unfavorable publicity, companies are becoming increasingly reluctant to introduce major innovations which might give rise to legal actions. In the event significant product change is indicated, there is a tendency for extensive product and market testing before formal product introduction. This is an innovation barrier because developmental times are extended and added risk is incurred.

Pricing policies can also be affected by product liability considerations and developmental time. A product may have a potential market, but higher or unforeseen contributing developmental costs can price the product out of the market. Consumers have much competition for expendable dollars; and even though a product may be technologically advanced, consumers will generally go to another product, if there is a reasonable substitute of performance and the price differential is attractive.

Another problem with innovative products is market maintenance once the products are introduced. Getting through the maze of barriers confronting the innovative process is formidable. Keeping the product in the market and getting a payback, as inducement for innovation, are other problems. A product may be well received when it is first introduced. It may capture a reasonable market share. However, the reasonable market share, rather than grow, may disintegrate. Market positioning or segmenting are important considerations in the innovation decision process. There is market positioning--appealing to selected market clientele in deodorants, hair sprays, cigarettes, shaving products, aspirins, and automobiles, to cite just a few products. If there is no market segment, or potential market protection for the innovation, there could be an unfavorable market feasibility analysis. In a swirling market environment, product life cycles are tenuous. If the product life expectancy is suspect, a formidable barrier against innovation will probably be erected.

DISCUSSION, RECOMMENDATIONS FOR ADDITIONAL RESEARCH, CONCLUSIONS

Discussion

This is a very complex subject. When the study was initiated, the magnitude of the problem was not apparent. Part of the tendency to oversimplify is attributable to research, which has already been conducted on organizational processes and innovation. There is no attempt to discredit research which has been performed, but past research has only looked at a very small part of the total picture. Often, organizational patterns affecting innovation have concentrated on one or a select few industries, and have looked at organizational innovation directed to product innovation within tight regional constraints. The major criticisms stem from the failure to indicate the range of possibilities in looking at innovation, the fact that studies have concentrated on product innovation, and the inference that the research results have implications beyond the immediate area sampled.[35]

The main thrust of this paper has been identification, rather than solution. Many facets have been touched upon; some of these facets appear to be very germaine to organization and innovation, and other facets may offer relatively little encouragement for productive research, or, at best, may only be incidental considerations. In examining some of these facets, questions come to mind which are considered relevant for structuring the subject and developing processes for directed research.

For instance, there are several types of innovations which are possible. The nature of these innovations suggests that some organizations might be more inclined than others to innovate in these areas. Also, since the types of innovations are numerous, and the types of operational environments are diverse, it is highly probable that the human factors--types of people to gravitate to these environments--are extremely critical. There are also many external, as well as internal, environmental stimulants and barriers to innovation; these must also be factored into any equation on innovation.

Recommendations for Additional Research

If nothing else, a conclusion from this paper is that the subject is extensive and the research possibilities tremendous. The type of investigations suggested are so broad that in the near future a total approach does not seem to be feasible. Based on some structure, a segment, or some segments, might be investigated. Following are some questions, the answers to which might serve as potential research projects. No attempt has been made to prioritize, or structure, the following questions:

1. It would appear that innovations processes are low in developing countries. What factors can stimulate innovation in such environments? Where has there been successful innovations? Are there any organizational patterns in such instances which can provide guidance for intensifying innovations in developing nations?
2. What types of innovations have taken place in developing countries? It is theorized that a small innovation (small by industrial country standards) in such a society will have a proportionally larger impact than a more technologically advanced innovation in a high technology society.
3. Can innovation be stimulated? How? Is the phase in the organizational life cycle relevant to innovation?
4. Do certain organizational environments tend to spawn innovations in specific areas? For instance:

Innovation	Environment
social	government
process	large organizations
productivity & procedural	large organizations
product	small organizations

5. Do organizations reach saturation points or diminishing innovational returns? What factors contribute to such situations?
6. Why does innovation happen or not happen? What external, or internal, forces seem crucial to encouraging or discouraging innovation?
7. Are some organizational forms more conducive to stimulating innovation than other organizational forms? What

advantages and disadvantages are there in traditional organizational forms relative to stimulating innovation?

8. Can innovatively productive organizational forms be identified and classified by type of operational setting and type of innovation?
9. At what phase of the pure-research-through-production-cycle is innovation most likely to occur? Is innovation desirable in all phases of the cycle and, if so, to what extent are organizational processes a factor to be considered?
10. To what extent do political or cultural factors affect innovation? A study might be conducted of similar industries in different social/political environments.
11. How does management affect the innovation process? A study of high innovation environments to determine motivational role of management.
12. Are there any discernable characteristics of innovators, such as age, education, experience levels, organizational position, functional orientation, etc.? Are people with some functional backgrounds more apt to innovate than people with other functional backgrounds? In what types of innovations? Is the innovation a product of the individual's functional orientation?
13. Would it be feasible to establish an "innovation" function and assign people to that function? Their sole mission will be to innovate-within their functional area of expertize--or using their functional know-how to work in concert with other functional experts. Functional tenure in the "Innovation Department" would be subject to periodic review.
14. What are the sources of innovations within organizations? Can these be understood within the context of type of innovation, the operational environment, or functional affiliation?
15. How does technology transfer and the diffusion process, within the organization, affect innovation?
16. To what extent do reward or recognition systems within organization serve as innovational stimulants. Is there

any correlation between reward systems and intensity of innovation? If so, which reward systems appear to be most successful?

17. Are interdisciplinary interactions within organizations effective in encouraging innovation? How? What methods can be employed to encourage intraorganizational communication?
18. How can interorganizational processes be used to stimulate innovation?
19. What type of outside exposures are most fruitful in instigating thought processes leading to internal innovations?
20. Are there any discernable patterns of organization in government where there has been a high incidence of innovation? Are there variable patterns based on political ideology?
21. In looking at industrial organizational patterns and innovation, it is suggested that such studies should be structured to consider: types of industry, regulated and non-regulated industries, competitive and monopolistic industries, technologically aggressive industries and technologically static industries, old industries and new industries, large industries and small industries, and industrial variations, based on geographic location and/or cultural difference.
22. Are certain types of organizations more adept at original innovations? Are there distinct organizational characteristics where innovations emanate from initiation vis-a-vis the Japanese system of sharp improvement over established processes?
23. What affect does the constant phasing in and phasing out of projects, a common practice in R&D organizations, have on innovation? Is there any correlation between project life expectancy, i.e. long or short duration projects and innovation?
24. Is it possible to study project or work units and organizational factors assocated with work where there has been innovations? If so, this might give some clues

as to what types of activities encourage innovation solutions and how organizational factors act as reinforcement for innovation.

25. How does internal functional competition affect innovation?
26. Is there any correlation between organizational stability turnover or attrition rates, and intensity of innovation? Is innovation more apt to take place in organizations where there is constant people movement in and out of the organization, or where there is stability? Can attrition norms be developed to provide a climate where innovation might be stimulated?
27. How does the formal and informal organizations affect innovation?
28. From research, would it be possible to evolve a new organizational form, which would be conducive to innovation?
29. How effective would it be to develop a matrix, showing advantages and disadvantages of each organizational method, as each method relates to innovation?
30. How do organizational decision processes affect innovation--degree of decisional latitude as encouraging or discouraging innovation? Hierarchical or colleague authority?
31. What is the effect of physical proximity-functions or disciplines on innovation?
32. Does organizational position, or rank, have any bearing as to individual's proclivity to innovate? If so how?
33. Is intraorganizational mobility a factor in innovation?
34. How does seniority, or organizational tenure, affect individuals who might or might not innovate?
35. Does the nature of the industry--ease of exit or entry--have any bearing or tendency to innovate? Also, what types of innovations take place.

Conclusion

Innovation is a very complex process. No one organizational form, or method, has universal applicability. Different types of innovations in different types of political, social and economic environments take place. Considering the extensiveness of the range of innovational possibilities accommodation must be made for human variances as to skills and temperment. These human variances must be carefully considered and factored into organizational design. Organizational design must be innovated to facilitate innovation.

In approaching the problem of organization, as it affects innovation, I would recommend that some structure be developed to identify the possible universe applicable to the subject. Next I would evaluate the possibilities suggested by the universe. What segments are feasible to study, and what segments of the universe may be of fleeting importance, or of no discernable relevant significance? Finally, selecting, expanding, and modifying the questions raised in the preceeding section, I would develop a methodology directed to providing information of a substantive nature and a useful value.

FOOTNOTES

[1] H. D. Haustein, "Human Resources, Certainty and Innovation: The Conflict Between Homo Faber and Homo Ludius," invited paper for the Sixth World Congress of the International Economic Association (IEA), Mexico City, 4-9 August, 1980, prepared under auspices of International Institute for Applied Systems Analysis, Laxenburg, Austria. November 1979, WP-79-112, p.20.

[2] Brian Twiss, "Managing Technological Innovation, Longman Group Limited, London, 1974, p. 2.

[3] Technological Innovation: Its Environment and Management, U.S. Department of Commerce, Washington, D.C., 1967, p. 2.

[4] Bela Gold, "Alternate strategies for Advancing a Company's Technology", Research Management, July 1975, p. 24.

[5] "The Silent Crisis in R & D," Business Week, March 8, 1976, pp. 90-92.

[6] See "The Breakdown of US Innovation," Business Week, February 16, 1976, pp.56-68.

[7] Ibid, p.57.

[8] To cite a few representative studies: Louis K. Bragaw, Jr., "Some Characteristics of Successful Technological Innovations and their Patterns", doctoral dissertation, The School of Government and Business Administration, The George Washington University, September 1970; J.M. Utterback, "The Process of Technical Innovation in Instrument Forms", doctoral dissertation, Massachusetts Institute of Technology, January 1969; A few others who have contributed in this area are A. Shapiro, E. Roberts, and J. Goldhar.

[9] John Verhoogen, "Federal Support of Basic Research," in Basic Research and National Goals, Report to the Committee on Science and Astronautics, US House of Representatives by the National Academy of Sciences, 89th Congress, 1st Session, March 1965, p. 270.

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[13]Technological Innovation: Its Environment and Management, op. cit, p.7.

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[15]H. Igor Ansolf, "Corporate Strategy", (New York: McGraw-Hill, 1965) p.104.

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[17]Twiss, op. cit, p.28.

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[19]Chester I. Barnard, "The Functions of the Executive", Cambridge, Mass., Harvard University Press, 1938, p. 82.

[20]Ibid. p.20.

[21]Ibid. pp. 56-57.

[22]"New Products: The Push is on Marketing", Business Week, March 4, 1972, p. 72.

[23]Arnold C. Cooper and Dan Schendel, "Strategic Responses to Technological Threats," Business Horizons, February 1976.

[24]E. Mansfield and S. Wagner, "Organizational and Strategic Factors Associated with Probabilities of Success in Industrial R & D," Journal of Business, Vol. 48, No. 2, April 1975, p. 175.

[25]Technological Innovation: Its Environment and Management, Op cit, p.14.

[26]E. Mansfield and S. Wagner, op.cit.

[27]S.M. Utterback, "The Process of Technical Innovation in Instrument Forms, (Doctoral Dissertation, Massachusetts Institute of Technology, January, 1969).

[28] L. Bragnaw, op. cit.

[29]"The Breakdown of U.S. Innovation", op. cit. p.60.

[30]"Marketing Observer, "Business Week, March 6, 1978, p.92.

[31]"Disastrous Debuts", Wall Street Journal, Tuesday, March 23, 1976, p. 1.

[32]"The Breakdown of US Innovation", op. cit., p. 58.

[33]"New Products: The Push is on Marketing", Business Week, March 4, 1972, p. 72.

[34]Joel B. Rosenberg, "Research and Market Share: A Reappraisal of the Schumketer Hypothesis", Journal of Industrial Economics, Vol. XXV, No.2, December 1976, p. 104.

[35]In discussing this aspect of the research with one person who has worked extensively in this area he was prone to criticize the generalized assumptions made by another highly respected researcher who using inductive reasoning tended to generalize from a very limited sample. On examining other prospects of this nature it became apparent that this is not an uncommon practice.

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