



Challenges and Opportunities for Research in the Management of Technology



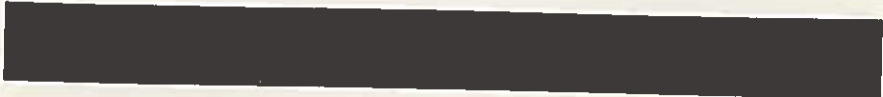
Workshop Report

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**The University of Miami
College of Engineering**



Challenges and Opportunities for Research in the Management of Technology

Report of the Workshop on the Management of Technology

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**University of Miami/National Science Foundation
Workshop on the Management of Technology**

**Miami, Florida, U.S.A.
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Table of Contents

Acknowledgement	vi
Preface	vii
Summary	1
Introduction	5
Research Opportunities in the Management of Technology	
1. Methods and Tools for Managing Technical Resources	11
2. Managing the Interface between the Organization and the External Environment	14
3. Management of Technical Organizations and Technological Change in Times of High Competitive Pressure	17
4. Management of Research & Development (R&D) and Engineering Projects	20
5. Management of Human Resources under Conditions of Rapid Technological and Social Change	24
Conclusions	29
References	30

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Preface

The decline of U.S. industrial competitiveness has been a subject of increasing concern in recent years. Several efforts have been mounted to determine the sources of this decline and to formulate a successful response to the challenge it presents.

The Management of Technology has been viewed as a critical component of the effort to address questions of American competitiveness in the marketplace. A 1986 National Research Council workshop first focused attention on this approach, and the report which resulted was instrumental in defining the scope of Management of Technology (MOT) as a field. The report [1] recommended that significant measures be taken to build national awareness of the strategic importance of Management of Technology and to support research in this area. A 1987 workshop, organized by the Public Affairs Council of the American Association of Engineering Societies, sought to build greater understanding and awareness of MOT issues [2]. The report of this workshop contrasted the widespread belief in the importance of technology management to U.S. industrial competitiveness with a corresponding absence of concrete steps to pursue relevant avenues of research.

Paralleling these efforts, the University of Miami Department of Industrial Engineering organized two meetings in 1988. The First International Conference on Technology Management was held in Miami on February 17-19, 1988 [3]. More than 300 scientists, engineers and managers from 30 countries attended. A workshop, jointly sponsored by the National Science Foundation Division of Cross-Disciplinary Research and the University of Miami, followed. The present report summarizes the results of this two-day meeting.

The workshop participants were carefully selected from an international group of industrial, academic and governmental representatives; most had served as rapporteurs in the paper sessions at the preceding Technology Management conference. The objective of this workshop was to recommend important topics for future research in the field of technology management. Participants were asked to identify and summarize the issues emerging from their particular paper sessions, and to offer their insights on specialized aspects of the field. A list of potential topics was assembled from these presentations and broken down for discussion by smaller working groups. The topics were then presented to the entire group for further refinement and evaluation of their importance to a national research agenda. The ideas resulting from these exchanges are summarized in the body of this report.

In the concluding session of the workshop, the participants recommended that four statements be used as a framework for evaluating this report. The first of these is that the topics identified here should be viewed as a representative sample of opportunities for research in MOT. The time limitations of the workshop and the immediacy of the challenge confronting U.S. manufacturing industries dictated a focus on manufacturing issues. However, the topics identified here are thought to have equal relevance for service industries.

The second statement is that the national research agenda must look beyond the needs of the manufacturing base. Although a sound manufacturing base represents a major wellspring of technology and innovation, the service industries now comprise the largest sector of the U.S. economy. Service industries are the locus of the greatest economic growth in the U.S., but continued growth will depend upon additional advances in productivity. The national agenda must address the needs of this expanding sector or fail to address the needs of the future. It was the consensus of the workshop participants that the National Science Foundation consider the service industries as a fruitful topic for review in future workshops in the Management of Technology.

The third statement is that the issues of managing technology must be examined increasingly in a global context. In an era marked by the rise of multinational corporations and the rapid emergence of strong international competitors, the high costs of technological innovation and the cyclical nature of businesses will demand greater dependence on global alliances as a necessary stratagem of survival.

The fourth statement concerns the current revolution in information technology, which promises only to intensify in the years to come. As the information available to decision makers increases exponentially, the critical issue will be how to absorb and manage this information and evaluate its impact on individual organizations and society at large.

On behalf of the participants at the NSF Workshop on the Management of Technology, we thank the National Science Foundation and the University of Miami for the opportunity to participate in this significant endeavor.

Tarek M. Khalil & Bulent A. Bayraktar

Summary

In recent years, international competition for domestic and overseas markets has increasingly challenged the U.S. economy, threatening the long-term job security and prosperity of American workers. The decline in U.S. industrial competitiveness has spurred efforts to find ways of restoring American leadership in world markets. A crucial component of this effort will be to improve the management of our technological base, since the decline of U.S. industry is widely perceived to have resulted not from an inability to develop new technologies, but because of the failure to manage the available technology in an effective and timely manner.

Technology plays a pivotal role in the interaction of the individual, society and nature. Technological advances have major effects on each of these entities and are in turn influenced by them. The Management of Technology involves understanding these relationships and dealing with them in a rational and effective manner.

One definition of the scope of technology management as a field of study was provided in a recent National Research Council report [1]:

“Management of Technology links engineering, science and management disciplines to plan, develop

and implement technological capabilities to shape and accomplish the strategic and operational objectives of an organization."

Management of Technology holds great promise for addressing competitiveness not only in the manufacturing sector but in the service industries as well. As a scholarly discipline, the Management of Technology [MOT] is an emerging but distinct field of education and research. The proliferation of courses and degree programs in MOT at leading educational institutions, and industry's mounting interest in seeking professional training in MOT are reflective of a widespread belief in the potential applications of technology management.

The University of Miami / National Science Foundation Workshop on the Management of Technology was held in Miami, Florida, on February 20-21, 1988. The objective of this workshop was to identify potential research topics in technology management which would have a positive impact on the competitiveness of American industries.

Current research efforts in the Management of Technology can best be characterized as fragmented. It was the consensus of the workshop participants that specialized research in this area is needed since research in traditional engineering and management disciplines does not address issues vital to the successful management of technology. The unprecedented pace of technological innovation and the new characteristics and impacts of emerging technologies demand reevaluation of current engineering practices, organizational structures and management approaches. New and revised theories, methodologies and decision criteria are in order. The participants further agreed that research in technology management requires a linking of the methodologies employed in the fields of engineering, management and the social sciences, particularly those of sociology, economics and organizational psychology. Expertise in several methodologies

is considered crucial to successful research in the Management of Technology.

The researchable issues identified by the workshop participants were classified under five broad categories:

- (1) methods and tools for managing technical resources;
- (2) managing the interface between the organization and the external environment;
- (3) management of technical organizations and technological change in times of high competitive pressure;
- (4) management of research and development (R&D) and engineering projects; and
- (5) management of human resources under conditions of rapid technological and social change.

Specific research opportunities and the corresponding rationale for each are identified in later sections of the report. While discussions at the workshop were framed in the context of manufacturing industries, it was the belief of the participants that the issues identified here are also applicable to the service sector.

No attempt was made to determine the state of the art for each research topic because of time constraints imposed by the workshop. Such evaluations should be the subject of future studies and workshops. Significant levels of funding will be required to stimulate quality research on the topics identified in this report. Stronger and more coordinated efforts among industry, academe and funding agencies are essential to meaningful research in MOT.

Improving the competitiveness of American industry could very well depend upon the success of research efforts in the areas mentioned in this report. The insights to be gained from research in technology management have implications not only for the ways businesses are managed, but for the long-term growth and stability of the economy and for society at large.

Introduction

Technology is perhaps the most important human creation. It is central to the means of production and a major determinant of a society's way of life. Technological advances are primary agents of change affecting all aspects of the human experience and environment. Technology thus plays a pivotal role in the interaction of the individual, society and nature. Technological advances have major effects on these entities and are in turn influenced by them. In a broad sense, therefore, the Management of Technology involves understanding these relationships and taking the measures necessary to deal with them in a rational and effective manner.

Continuous incremental changes and occasional breakthroughs alter the technological landscape with ever increasing speed. This dynamism is correlated with the growth and spread of scientific and technical enterprise throughout the world. Particularly since World War II, the scientific knowledge base and technological capabilities have grown at an explosive rate. Major scientific discoveries and technological breakthroughs have opened up new territories for new processes with totally new applications. Worldwide economic growth fueled the technological enterprise, requiring ever-increasing commitments of intellectual, financial and material resources.

The technological production base previously confined to the industrialized nations of the West soon spread to a large number of countries which viewed industrialization as the only means of reaching socioeconomic parity with Europe and the United States. For many Asian and Third World countries, technologies imported from industrialized countries, particularly the U.S., provided the initial base to establish industries requiring lower levels of skill. These countries gradually introduced industries requiring both greater levels of skills and technological capability. They are now equipped with an appropriate industrial and technological base which has become highly competitive in world markets. In some instances, they enjoy the support of governmental-instituted fiscal and economic measures. They may also possess other advantages, such as social characteristics or lower wage scales. As a result, exports from the Pacific Basin and some developing countries have successfully penetrated the domestic markets of industrialized nations, particularly those of the United States, on an increasing scale.

In the majority of these cases, the technology bases were transferred through either direct purchase from U.S. sources or through the establishment of overseas manufacturing facilities by multinational U.S. corporations. U.S. corporations have frequently chosen to invest in other countries to maintain competitiveness, rather than investing in new and advanced technologies at home. As a result of this evolution, the U.S. industrial base has become increasingly less competitive. The crucial element is not a lack of competitive technologies (which historically have been primarily developed in this country) from which to choose, but a managerial attitude which failed to utilize them in a timely and effective manner in the domestic workplace, particularly in the manufacturing sector.

The perception that U.S. corporations have been slow to exploit new processes and manufacturing technologies in recent decades is widespread ; it is true that in many instances, American businesses have failed to respond to market conditions and opportunities in a timely manner by reducing product development cycles. Timely exploitation of new technological opportunities is not fundamentally a problem of technological capability, but of management. A frequent explanation holds that American corporate managers have sacrificed commitment to long-term technological superiority in favor of realizing short-term profit. Managers must not only have the foresight to anticipate changes: they must also possess the courage to write-off investments on an existing manufacturing base without fully recovering initial costs, when circumstances warrant it. Hesitation may actually cost companies the time crucial to implement more efficient, superior technologies. Decisions to implement this course of action have wide-ranging implications for management practice, organizational structure, operational procedures and labor relations.

The Management of Technology is frequently mistaken to be limited to the management of the creation of technology, i.e., limited to research and development. Research and development do push technological advances, but they are not the only means of establishing a needed technology base. Economic considerations frequently dictate that more efficient and effective technologies be adopted; these may already be a part of the worldwide technological inventory, obtainable through any of several transfer mechanisms. The purchase and sale of technologies are now common events; technology has become a marketable commodity transcending national boundaries. Consideration of an array of possible technologies should thus be embedded in the strategic planning of corporations.

As technologies become more sophisticated, they require the commitment of higher levels of skill, manpower and capital. Product life cycles need to be shortened; institutional cooperation in research and development becomes an important mechanism for change. Joint governmental, industrial and university support of R&D efforts has become a major source of scientific progress and technological advance. The global spread of technological capabilities also encourages cooperative R&D ventures among corporations from different countries.

Much of the following discussion on the Management of Technology has been developed in the context of the manufacturing industries. The workshop participants were particularly sensitive to the fact that the Management of Technology is an issue critical to the survival and growth of U.S. industry, not only in the process and manufacturing industries, but also in the rapidly growing service industries. The impacts of new technology on traditional ways of running a business are as significant for the banking, telecommunications and airline industries, for instance, as they are for manufacturers. However, because of time limitations, discussions were concentrated on the manufacturing sector.

The workshop participants sought to identify researchable issues in the field of technology management that could have a positive impact on the competitive posture of a single organization or the economy at large. These topics were classified under one of five listings:

1. Methods and Tools for Managing Technological Resources
2. Managing the Interface between the Organization and the External Environment
3. Management of Technical Organizations and Technological Change in Times of High Competitive Pressure
4. Management of Research & Development (R&D) and Engineering Projects

5. Management of Human Resources under Conditions of Rapid Technological and Social Change

The topics identified within each grouping were further evaluated for the probability of success and importance to the issue of competitiveness. These topics are presented and discussed in the following sections. No attempt was made to assess the state of knowledge in each area identified, again because of time considerations. It was felt, however, that such in-depth assessments would be useful and could be accomplished in future workshops.

Although research has been conducted in each of the five areas identified above, research in the Management of Technology differs from traditional research in management and engineering. The scope of MOT research cuts across many disciplines and requires a multitude of methodologies. The interactions among engineering, management and the social sciences are seen to be critical components of the conduct of successful research in MOT. Research in this field is perceived to be critical because pressures created by the unprecedented pace of technological innovation and the radically different characteristics of new technologies demand reconsideration and possible revision of the organizational approaches and management attitudes which may well be inadequate in this new and dynamic environment. New, updated theories, methodologies and decision criteria are in order.

Research Opportunities In The Management Of Technology

1. *Methods and Tools for Managing Technical Resources*

The efficient utilization of technical resources is a critical aspect of the management of techno-economic enterprises. In a way of life based on technology, the rational and productive use of available instruments, equipment, tools, materials, methods, software, skilled manpower, information, intellectual assets, and financial resources is crucial in providing a competitive posture for corporations.

In a highly competitive environment where error tolerance is limited, managers must be equipped with predictive methodologies and decision tools that are reliable, flexible, practical and fast. There is a need for new ideas, imaginative methodologies and performance criteria that have been tested in real-life situations.

Among a large number of proposals, the following areas were identified as the most critical to the question of industrial competitiveness and deserving of a high priority. A brief rationale for each is given.

1.1 Methods of Performance Assessment

Traditional measures of performance are sterile and unimaginative. Methods of accounting and financial assessment are biased against technological innovation and underestimate the risk of maintaining the status quo. There is a need to know the extent to which the specific characteristics of a new technology influence methods of general and financial assessment of performance, i.e., the risks, the quality of the process and products, market entry, competitive positioning, and short- and long-term profitability.

1.2 The Measure of Performance of a Technology

There are no reliable methods to measure the performance and competitiveness of specific technologies in the marketplace. The problem is more acute for new technologies untested in a competitive environment. Different criteria may be needed for different circumstances.

1.3 The Measure of Benefits of R & D Activities

Benefits from R & D activities may be manifold. A rational approach to identify potential benefits and a set of measurement criteria to compare the outcomes of R & D projects should be developed.

1.4 New Tools for Optimizing Decisions

Since resources are scarce and time is limited, optimal allocation of financial, material and human resources is needed. Areas for investigation include:

- (a) Improving methodologies of technology forecasting and of integrating technology forecasting within the planning and decision-making processes. Because of technological discontinuities, adaptive models providing for the continuous evaluation of prior assumptions are required in lieu of methods based on the extrapolation of past data.

- (b) Classical optimization methods rely on performance measures such as ROI (Return on Investment), ROS (Return on Sales) and PER (Price/Earnings Ratio), etc. A new and more representative set of criteria is needed to optimize the performance of high technology firms.
- (c) What should be the optimum mix of "high technology" versus "traditional" products in a large business? At what level of decision should particular criteria and attributes of decision be taken into account?

1.5 Alliances as Alternatives to Rivalry

Fierce competition in the form of market-share shifts and takeover bids is not necessarily the most efficient way of using scarce human, financial and material resources. It causes an excessive level of insecurity and disorganizes industrial teams. It will be useful to know:

- (a) Would alliances on specific projects among national and international competitors offer successful alternatives to attain optimal R & D effectiveness? If this is so, would it be possible to standardize the format of the agreements to facilitate negotiations on new products and technologies?
- (b) How effective are government initiatives (e.g., incubators) in introducing new technologies and opening up large industrial firms to outside suggestions? Would joint ventures and the sharing of innovation between a large firm and a small firm take advantage of the strengths and supplement the weaknesses of each?
- (c) When can research results and/or generic technologies be shared through alliances? To what extent do patent laws assist or prohibit cooperation among companies?

2. Managing the Interface between the Organization and the External Environment

Organizations operate in a socio-techno-economic environment and interact with it. Within the context of technology management, interest is primarily focused on technological factors, activities and plans. How do external factors affect the creation and introduction of technological change within the organization, and how do technological changes that take place within the organization influence the environment?

The introduction of a technological innovation in the marketplace, particularly when it has been widely adopted through the processes of transfer and diffusion, impacts a society, its economy and the natural environment to varying degrees. These impacts may have varying levels of acceptance and/or desirability according to the prevailing value systems of the society.

Any technological change that affects the public at large and/or the natural environment becomes an issue for the potential exercise of public power at different institutional levels. Legislative, administrative & regulatory machinery can be set in motion to counteract perceived or potentially undesirable consequences or to facilitate the widespread adoption of those changes seen to promote the public welfare.

The involvement of public power entails careful assessment of technologies that are of societal concern, and the evaluation of risks associated with public exposure to them. Organizations themselves must be aware of potential public concerns with the product that they are about to market and the processes they plan to introduce in their production and operation systems.

The ultimate measure of success or survival of a corporation is the market performance of its products and services.

It is incumbent upon organizations to translate market indicators to strategic decisions and operational plans.

Another important environmental factor that influences business strategy is competition in the marketplace. No corporation can afford to ignore what its competitors are doing, especially with regard to technological opportunities. In order to remain competitive, a firm must anticipate and evaluate technological opportunities before other firms attain an insurmountable competitive edge. These considerations are reflected in technological plans which must be incorporated into the strategies and plans of the business firm.

The workshop participants considered several proposals as potential research topics in this area and identified the following as priority issues:

2.1 The Integration of Technological and Strategic Plans

Technological planning involves the decisions affecting the selection of R & D projects, allocation of resources and timetables for successful implementation. It also involves choosing among a number of technologies for incorporation in the production process and evaluating whether such technologies should be produced internally or purchased. Each of these options must be addressed in the strategic plan. There is a need for methodological guidance for managers and planners for rational and efficient means of discharging this responsibility.

2.2 The Impact of Third Parties on Technological Change

What are the impacts of third-party regulations (e.g., judicial decisions, legislative and regulatory action, decisions regarding insurance risks and liability) on firms' decisions to pursue and implement particular technologies? While there is general acceptance of the proposition that each of these factors affects a firm's utilization of some process technology

and its market policy toward some questionable products, there is insufficient understanding of the underlying relationships to provide management with guidance to anticipate and take timely actions.

2.3 Increasing the User's Influence in the Selection and Application of Technologies

There is a need for more understanding of the feedback mechanism between the users and the producers of a technology, and for means of strengthening user influence in the selection and application of technology. Businesses may then address the actual needs of the marketplace, so that products having little or no potential market are not produced under the push of science and technology.

2.4 Means of Decreasing Social Resistance to the Introduction & Adoption of Technology in the Workplace

Given the prevailing tendency to resist changes that influence work rules and organizational structure, plans to introduce new technological systems to the workplace cause apprehension and opposition. To overcome these difficulties, management must be provided with adequate insights as to the factors underlying such opposition and with strategies to deal with it constructively.

2.5 How Can the Benefits from New Technologies Be Distributed to Gain (Labor/Management/User) Acceptance?

For example, would a reduction in the labor share in the total manufacturing costs of a product reduce the incentive for off-shore facilities and thereby increase the availability of manufacturing jobs in the U.S.?

2.6 Other Research Topics

Other issues mentioned as worthy of being researched but were given somewhat lower ranking in priority as to their immediate impact on the U.S. industrial competitiveness are:

- Potential obstacles to and benefits of inter-firm cooperation.
- Appropriate strategies and time points for the transition from cooperation to competition in inter-firm technological alliances.
- The impact of technology on quality of life, health and safety.

3. *Management of Technical Organizations and Technological Change in Times of High Competitive Pressure*

Rapid technological change accompanied by intense global competition creates considerable organization problems for management in every sector of industry.

In industries such as manufacturing, where installations of computer-based manufacturing and information systems are widespread, the necessity of manning these systems with highly skilled personnel tends to change the need for hierarchical organizational structures in favor of shallower, or "flat" structures.

Computer-integrated information and manufacturing systems allow close and real-time coordination and cooperation among departments charged with separate functions. New opportunities for cooperation raise questions regarding

the design of organizational structures along functional lines.

The existence of in-house R & D activities and the necessity of coordinating them with the production and marketing functions at early points in the design and development stages creates problems affecting organizational structure.

In technologically dynamic companies, the installation of technological gatekeepers, the encouragement of internal entrepreneurship, and the increase of joint ventures in both R&D and production have major consequences for organizational structure, all of which need to be addressed rationally.

Re-examination of the effect of organizational change on technological creativity and the internal dynamics of organization is also needed.

In sum, organizational structures and considerations interact intimately with the technological posture of an organization and provide a wide array of topics for constructive research.

The following topics were viewed as priority issues in the area of organizational structures:

3.1 Factors Leading to Reorganization of Technological Activities in Large/Small Firms

The question of reorganization is usually considered in terms of centralization vs. decentralization. Dynamic technological imperatives necessitate the investigation of other issues and forms of reorganization. Shuffling organizational arrangements may be an inadequate way of dealing with more fundamental technical or managerial problems. Trade-offs may exist between organizational structures that are efficient in motivating and carrying out technological advances and those that favor current production modes and activities.

Research in this area must also determine whether organizational structures that are responsive to industrial and technological requirements are industry-dependent. Proposing improvements to organizational structures requires development of a better understanding of existing motives and practices in restructuring organizations.

3.2 Evaluating the Impacts of Reorganization on Technical Activities

Reorganization may directly impact the technical activities (e.g., research, development and manufacturing engineering) of a firm and also the interaction of these activities with production and marketing. The issues raised here address the set of possible trade-offs incurred when reorganization of the firm occurs. Specific topics should include evaluation of the perceptions and expectations about the benefits and costs of reorganization, and should also attempt to obtain an objective *ex post* evaluation of the results of such reorganizations.

3.3 The Advantages and Disadvantages of Different Organizational Structures on the Efficiency of the Product Development Cycle, from Concept to Volume Production

The key research issue here relates to the timing and organization of manufacturing engineering and operations involvement in the R&D process. Topics of interest include:

- (a) determining what kinds of interfaces are helpful
- (b) what kinds of interfaces impede higher levels of innovation
- (c) whether efficient arrangements differ among basic technologies or industries

3.4 Facilitators and Inhibitors of Technological Innovations and Transfers within Organizations

The objectives of research in this area are two-fold: first, to learn more about the organizational arrangements and incentives that facilitate the transfer of technology within organizations as opposed to those that seem to encourage the secrecy and insularity of teams/groups/divisions. For example, intrapreneurship is a two-edged sword: technological advances may well be achieved, but potentially the strong "ownership" of the information developed may prevent the rest of the organization from benefiting from it.

A second aim of research here is to provide more insight into the organizational factors that encourage and support effective performance of technological gatekeepers, internal entrepreneurs and others who are committed to bringing about innovations, and those which hinder them.

3.5 Other Research Topics

Documentation of the decision processes leading to organizational changes was thought to provide good material for research; however, its immediate importance to competitive positioning in U.S. industry was not ranked sufficiently high to warrant its inclusion as a topic of priority.

4. *Management of R & D and Engineering Projects*

Complex R & D projects require the mobilization of large amounts of resources and the coordination of activities situated in different laboratories (and sometimes located in different countries). The management of such projects constitutes a formidable task that demands considerable skill.

Comparable challenges exist when a new industrial product is designed, developed and marketed. The entire process involves people from several departments and disciplines in one or more laboratories, firms and/or institutions. Individual efforts must be joined in getting the product from concept to "launch," and yet organizationally, they belong to separate parts of the enterprise, or even another organization. In large projects, where several firms and institutions are involved, the project manager's difficulties are obviously compounded.

R & D and engineering projects have other characteristics: they are carried out by a highly trained, highly motivated professional staff; mostly, they are one-of-a-kind undertakings involving considerable uncertainty and risk. Project managers therefore need tools and techniques that will help them better grasp the intricacies of the relationships among various components, and also equip managers with capabilities for skillful handling of human problems.

The mechanics of project management involving the scheduling of tasks and allocation of resources are well explored; many software systems are available to help project managers. However, there is still room for improvement in providing them with rapid feedback about the process, in particular, with early warning signals about potential failures.

There is also an urgent need for improved understanding of the human components of the project management process: how to select people with different skills and training; how to make them operate in a multidisciplinary environment composed of individuals from different cultures. These are issues requiring special skills. A majority of project managers are engineers promoted to managerial positions, and they need training in people-related skills. Such managers primarily rely on their personal aptitudes and such skills as they acquire on the job, with little or no formal training. Much

needs to be done to help engineers and scientists learn and develop these "people" skills, and to incorporate them as a part of their professional training, for later use as either a team member or a team leader.

One of the important tasks of organizations is the selection of appropriate R & D projects among the many that may represent some potential for future exploitation consistent with the firm's growth strategy. There is a need for more practical and powerful new selection methods.

R & D projects that are part of the innovation process pose a challenge to management in reconciling the visions and ideas originating in the ranks of scientists and engineers throughout the organization with the views and plans of upper management, and in translating them to a workable program. There is a need to understand the internal dynamics of these relationships.

The workshop considered about half a dozen proposals and assigned a high priority for immediate attention to the following four items:

4.1 Project Portfolio Selection

Organizations frequently have several, and occasionally, a large number of ongoing projects. Not only do these projects need to be constantly monitored and evaluated for their potential usefulness to the organization evaluated, but their utility must also be compared with new opportunities. The re-examination and reevaluation of priorities are thus an important part of the management of R & D.

There is a concomitant need to develop easy-to-use decision-support systems for managers so that they can focus on the content rather than the mechanical aspects of project management.

4.2 Initiation of Innovative Ideas in Organizations: Top Down, or Is It Bottom Up?

In organizations with long-term business strategies, it is expected that strategic decisions and operational plans, when communicated from upper management, will be translated into focused programs and projects. However, these instructions may not fit well with the ideas and aspirations of scientists and engineers in the innovation chain. Studies are needed to:

- (a) define the factors that influence the balance between these divergent views;
- (b) provide an understanding of the dynamics of this balance; and
- (c) discover any patterns that may exist in their impact on organizational performance.

4.3 Human Problems in Project Management

Project management continues to grow in importance, domestically and internationally, in public and in private organizations. Although many capabilities have been developed for scheduling and monitoring, much needs to be done to help project managers in personnel selection and in coping with the problems created by the multidisciplinary and multicultural background of the professional project staff.

4.4 Postmortem Analysis of Projects

It is of considerable interest to explore mechanisms to establish and conduct postmortem analyses of projects with successful and unsuccessful outcomes. Understanding the commonalities and divergences among projects with similar outcomes can be helpful to decision makers. The effects of the interfaces between the projects and the rest of the organization, and between the projects and the external environment, on the eventual success or failure of the project also need to be investigated.

5. *Management of Human Resources Under Conditions of Rapid Technological and Social Change*

Recent advances in communications technology, transportation systems, computer-based information systems and new developments in computer-integrated manufacturing and office automation have drastically altered the character of modern manufacturing and service enterprises. The spatial, as well as temporal, characteristics of the workplace have been undergoing significant changes. Work locations, the scale of operations, the criticality of time, skill requirements and operational parameters represent a core of issues associated with the management of organizations of the future.

The incremental technical obsolescence of the professional staff, the insufficiency of past training, and the inexperience of even skilled labor in handling newly-implemented tools and equipment create continuing problems for management and workers alike.

Professional staff must keep abreast of recent developments in scientific knowledge and technological innovation through a variety of means, e.g., reading, professional meetings and continuing education programs.

Management must anticipate the skill requirements of new technologies scheduled for implementation and try to match existing skills to them or seek, through retraining and relocating measures, to minimize operational disruption and redundancy.

Cost accounting methods, productivity evaluations and operational procedures must be revised to meet the needs of new and changing situations. The reexamination of the performance characteristics of human resources is also required.

In technologically dynamic corporations, highly trained professionals will be needed to evaluate newly-implemented technological advances and those that have the potential of becoming a reality in the near future. The motivational and reward systems of corporations should be designed to encourage and support the activities of technological gatekeepers and internal entrepreneurs who will take the lead in stimulating corporate awareness of new technological opportunities and their efficient applications.

Research is needed to provide better understanding of the underlying factors and their interrelationships in the areas noted above, leading to the development of tools that are useful for management. As most of these problems have heavy behavioral and social components, attempts should be made to improve the methodological underpinning of these investigations to bring them in line with traditional scientific methodology. Possible generic characteristics should be investigated to determine if it is possible to develop context-free models or whether such models are applicable only to a particular industry.

Of the dozen or so possible research topics discussed, the following were recommended for immediate attention:

5.1 *The Effects of Technological Change on the Skill Requirements of the Workforce*

The introduction of new and advanced technologies in the workplace immediately results in different skill requirements. The magnitude and nature of these changes may be influenced by the economic sector and the type of industry involved. Scientific studies are needed to determine the variables and parameters that will lead to the development of predictive models useful to management.

5.2 Matching and Training the Skilled Workforce to Meet the Requirements of New Technologies

Once the decision to adopt a new technology has been made, management must determine before implementation the skills necessary to run new installations efficiently and effectively. Management must also develop operational plans to accomplish the transition with a minimum of disruption to operations and with minimal adverse effects on the existing workforce. There is a need for reliable, perhaps industry-dependent, data to guide management as to the extent the existing workforce can be absorbed in new situations and the amounts and kind of re-education, retraining and relocation that will be needed.

5.3 Obsolescence of Professional Staff and the Continuing Need for Professional Development Activities

The growth in scientific knowledge and rate of technological change renders obsolete the training professional staff acquired during their formal education or prior work experience. There is a growing need for continuing education for the professional staff. Reliable data must be developed to provide guidance in determining the proper mode of activity to meet this need under different sets of circumstances.

5.4 The Role of Technological Gatekeepers and Internal Entrepreneurs in Organizations

In view of the rapid nature of technological change, organizations must find ways to determine, choose, adopt and implement appropriate technologies. Studies examining the role of an organization's technological gatekeepers and internal entrepreneurs in the successful identification, implementation and utilization of new technologies are needed.

5.5 Social Consequences of Technological Change

Technology is the most important source of change in the human experience. Its impact on our daily lives, socioeconomic structure, political system and employment necessitates a thorough understanding of its implications and the development of reliable predictive models. Research is necessary to determine what social support structures within organizations, particularly high technology organizations, exist or should exist to assist the following groups in coping with the demands of new or changing technologies:

- (a) working couples, single parents or individuals with extended family obligations
- (b) workers and professionals with changing or interrupted careers
- (c) workers and professionals displaced by technology.

5.6 Other Research Topics

The following topics were selected for their value as researchable issues in technology management, but were perceived as likely to have less immediate impact on the effort to restore U.S. industrial competitiveness:

- Reward and incentive systems for engineers, scientists and internal entrepreneurs in corporations (e.g., evaluation of "dual ladders")
- Measures to facilitate the transition from technical specialist to technical manager
- Measurement methodologies related to professional, human and man/machine interactions.

Conclusions

The categories and specific topics for future research identified in this report were selected on the basis of their perceived relevance and impact on the competitiveness of U.S. industries. This report is an attempt to focus attention on important issues in the complex process of planning, developing and implementing modern technology in an industrial setting. It is the hope of the participants in this workshop that this report will stimulate further research in these areas of critical concern to the nation's economy. It is believed that significant levels of support by funding agencies and the encouragement of research along the lines of investigation identified in this report will have profound long-term effects on the prosperity of American workers and the rejuvenation of American industry.



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