Management of Technology: The Drivers of Technological Changes in the Twenty First Century

A Report of the Workshop on Management of Technology

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MANAGEMENT OF TECHNOLOGY: THE DRIVERS OF TECHNOLOGICAL CHANGES IN THE TWENTY FIRST CENTURY

A Report of the Workshop on Management of Technology

Sponsored by The National Science Foundation

Held in Conjunction with the
International Association for Management of Technology's
9th International Conference: the Key to Prosperity
in the Third Millennium

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Management of Technology Workshop

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EXECUTIVE SUMMARY

The University of Miami (UM), with support from the NSF, conducted a workshop to examine drivers of technological changes in the 21st Century. The workshop was held in conjunction with the 9th International Conference on Management of Technology, "The Key to Prosperity in the Third Millennium." The main objectives were to present, review and solicit comments from a large group of Management of Technology (MOT) experts on the findings of the 1998 University of Miami/NSF report "Management of Technology: Future Directions and Needs for the New Century" (Khalil 1998). Researchers, educators and practitioners provided input about drivers of MOT and indicated their views on what the topics are in which interest is rising. They also picked the topics that show declining interest. This knowledge can help develop a research and education agenda to answer MOT needs in the new century. Participants felt that significant progress in MOT has occurred in the last decade. However, previous issues discussed in the literature are still pertinent and the following set of emerging issues must be addressed.

- The MOT community must clarify the goal of their effort. The goal is using and improving technology for the purpose of creating wealth. Wealth is usually defined in terms of monetary value but in MOT it is expanded to include the well-being of government and non-profit organizations, sustainable development and better quality of life.
- It is necessary to define the target audience for MOT education and knowledge dissemination. The stakeholders include managers, engineers, public policy planners, finance, marketing, information and communication people, as well as the public at large.
- Emphasis should be put on the context in which business is operating in the new century.
- The relentless pace of technological change makes management tasks overwhelming.
- Organizations must embrace innovation as a mean to create wealth and maintain competitiveness. This is no longer a matter of choice but a matter of survival in the global marketplace.
- Managers need to be equipped with the knowledge, tools and methods that can

help them manage in a dynamic and turbulent environment of changing technology and global competition. Management of Technology is itself a technology—a set of tools to get results for the organization.

• Many traditional notions, tools and existing management practices should be challenged and new ones added. These include:

  ◆ Strategic planning: How can we strategize when technology and product life cycles are measured in months as opposed to years?

  ◆ Competitive intelligence: This practice may be providing a look backward instead of forward.

  ◆ Intellectual property: Can it practically be protected?

  ◆ Knowledge management: How can we capture and effectively apply knowledge in our organizations?

  ◆ Organizational complexity: Are we successful in integrating complex sciences and complex organizations' structures to exploit technology?

  ◆ Organizations' culture: How can we prepare and motivate our workers to work in a diverse, multi-cultural, dynamic and competitive environment.

  ◆ Intellectual capital: Can we account for it? Maybe we need to put more concentration on guarding against intellectual liability that thwarts the progress of MOT.

  ◆ New methods and tools of financing innovation are needed.

  ◆ The impact of globalization, e-business, consolidations and alliances on technology management deserve special attention.

• The MOT community, in addition to its effort to create generic approaches, should move to address the special needs of segments of the economy or industry. Issues of developing countries also deserve special attention.

• A code of ethics and conduct in MOT should be developed. The conflict and litigation regarding Microsoft is one example where such a code would have been helpful.

• Education, training and the dissemination of information through involvement of pollinator "consultants" can bridge the gap between theoretical research and the practice of MOT.

This report suggests a number of research topics and recommends expansion of MOT education. An agenda for action and assignment of roles to various organizations promoting MOT is needed.

I. BACKGROUND

The NRC report on Management of Technology (1987) provided an agreement on a definition for the MOT as a field of study, research and application. It detailed several industry needs that should be addressed and incorporated within research and development of new teaching and management practices. These are:

- How to integrate technology into the overall strategic objectives of the firm
- How to get into and out of technologies faster and more efficiently
- How to assess/evaluate technology more effectively
- How best to accomplish technology transfer
- How to reduce new product development time
- How to manage large, complex and interdisciplinary or interorganizational projects/systems
- How to manage the organization's internal use of technology
- How to leverage the effectiveness of technical professionals

Research and education diverted towards satisfying these needs were deemed essential for US industry to regain its leadership position.

Working towards the same end goal, a NSF sponsored workshop was held at the University of Miami in 1988. It followed the 1st International Conference on Management of Technology held in Miami, Florida in February 1988. A report on the workshop, published by UM/NSF entitled "Challenges and Opportunities for Research in the Management of Technology" was released in 1988 as a result of this two-day workshop. The International Conference on MOT and the ensuing workshop devoted a significant effort in clarifying the emerging MOT field. The released workshop report defined five major issues as the key priorities for research opportunities within the MOT. These issues are:

1) Methods and tools for managing technical resources

2) Managing the interface between the organization and the external environment

3) Management of technological organizations and technological change in times of high competitive pressure

4) Management of R & D and engineering projects

5) Management of human resources under conditions of rapid technological and social change.

In 1998, a decade later, issues were revisited in another NSF/UM sponsored workshop. Participants at the 1998 NSF/UM workshop discussed MOT future directions and needs. They identified many issues as the new primary drivers of change that are expected to impact the Management of Technology in the 21st century (Khalil, 1998). These drivers were classified under seven main topics:

1. Technology
2. Changes in Business Environment
3. Communication, Integration and Collaboration
4. Strategic Directions of Industry
5. Changes in Organizational Structure
6. Financial Sector Structure
7. Education and Training

II. CHANGES IN DRIVERS

In conjunction with the 9th International Conference on Management of Technology, a special workshop was held to present and solicit comments on the findings of the 1998 UM/NSF report from a large group of experts in the field. It was also aimed to take into consideration all the discussions of the conference. Special consideration was taken to determine (1) what are the MOT driver topics where interest is rising and (2) what topics are of declining interest and therefore may be phased out of the list of priorities.

The primary reason of revisiting the MOT issues and drivers of the past was to ascertain if any revisions were to be made based on progress and new developments within the field of Management of Technology in the last decade. In order to create these revisions much development of background work was discussed.

Some participants felt that we should reduce emphasis on drivers where good progress seems to have been made. Another point of view expressed only saw the need for expansion on the issues previously established by the 1987, 1988 and 1998 reports. The first 100-200 years of anything are typically progress, that is the nature of development. As we develop logic, we develop nature—the logic that went into creating technological developments has always added to civilization. Issues in MOT discussed in the previous reports are still pertinent today. Expansion in the field due to the new knowledge and multimedia advances is a proper next step. The emerged consensus is that although great progress has been made within the field, many of the drivers are still applicable in today's environment.

An important issue to highlight is how to develop a broader functional management perspective to accompany drivers of change. The ongoing debate over which comes first, the market or the innovation, yields to the conclusion that fusion allows the organization to work together.

Another important caveat is that the need for technology is based upon the market, region and the realities within each business and industry.

In an open discussion forum, many issues came up. The following are the main points of discussion and observations related to the current issues of the day in Management of Technology and the changes that need to occur within the context of the changing environment at the beginning of the millennium.

1) Clarifying the Purpose of MOT

The workshop panelists felt that discussions about the Management of Technology is meaningless until we clearly define the purpose of MOT and explain the role of innovation in creating wealth and improving the quality of life. We should define the target audience for MOT, focus on the gaps that exist in research, practice and education, and recommend the steps we need to follow in order to allow technology to attain the great growth in wealth. It is agreed that the purpose of MOT is the creation of wealth. In this context the definition of wealth creation must be expanded to include the well being of government and non-profit organizations, the quality of life and environmental concerns.

What is missing in the practice of MOT is the understanding of the context and the environment in which we operate. We are now operating in an environment of innovation and great wealth. Additionally today's industries operate in a combination of established and emerging environments for technology and for business. Technological change opens up a chance for new innovation. If we don't take up that opportunity to merge the two environments then we may miss out on some new technologies or new business opportunities. Innovation and the accommodation of new markets should be used to create wealth.

Traditional functional practices and traditional marketing alone will not get an organization where it wants to go in an innovative technology environment. It must figure out how to market in this type of environment and put into practice the management of technology principles. However, the dearth of knowledge and lack of use of new and innovative functional practices seem to be missing.

In order to advance the field of Management of Technology we must first develop a goal and begin working through a strategic plan. By clarifying the goal, context and directions for the MOT movement, we should be able to develop education, training and skills development programs necessary to achieve the goals.

Since a goal of MOT is to make innovations happen, we must do a better job of defining innovation and stressing its value to organizations and to society's advantage. The purpose for innovation is indeed the creation of better wealth and better quality of life across the board. The whole change in nature of the lives we live that are now based upon technological innovations also seems to fall under wealth creation. Wealth is typically defined in terms of dollars but it is also well being in government and non-profit technologically driven organizations. It is only in recent times that concentration on sustainable development and the quality of life issues have begun to be discussed as related to desirable results of technology management (Lefebvre et.al., 1998, Khalil, 2000). The end goal for most parties is the wealth creation process; therefore by expanding the definition we are creating better lives for all.

Another important issue to consider is that of social justice among all people of the world. This issue can trigger problems that could occur, while the wealthiest are becoming wealthier. This financial divide deserves a special forum for discussion in the future - to research into the best manner to bridge the digital and financial divides.

2) Defining the Target Audience

Panelists emphasized that the MOT audience has not been clearly defined. The audience includes the following stakeholders:

- General managers
- Engineers
- Public policy planners
- Finance people
- Marketing people
- Information and communications people
- The public at-large

Traditionally the audience for MOT has been technology based, but if the client and audience base is restricted, then we are limiting opportunities. Increased visibility and insight into MOT through greater inclusion of the broadened stakeholder base holds the promise of expanding its application and maximizing benefits to society at large.

As a follow up to this rationale, the following question emerges: "Does a person have to have a technical undergraduate degree in order to pursue educational opportunities in management of technology?" The consensus is that this has been the tradition, but it is changing now because of the invasion of technology into all aspects of business including upstream and downstream activities. Expansion of MOT fundamentals and their applications is indicated.

As a result, education in the management of technology has two main audiences today:

a. Engineers, scientists and people with technological careers, who are involved in or looking to learn how to manage research and development and the process of technological innovation

b. Business, communications and other workers who want to learn about opportunities to leverage technology in order to better direct today's corporation.

Attention to the difference in global cultures, the changes in business practice and what this means for the management of technology, creates the need for expanded cross-disciplinary education, training and much more.

3) The Relentless Pace of Technological Change

The state of the business today is that technology, and the responding management of technology field, is moving rapidly. Information technology is encouraging, stimulating and diversionary. It is leading the way in improving productivity in all sectors of the economy. But the challenge remains to not slow down development in all sectors of technology.

The rate at which technological change is occurring makes management in this field overwhelming. Education and training are required to be continuously and rapidly changing as well.

As a result, there is a need to re-examine our assumptions as they relate to MOT education. The development of a focused and long-range strategic plan for the Management of Technology education must be formally developed. Goals for the development of skills related to MOT, capabilities to deal with the changing environment, marketing goals, systems of management and more, are needed.

4) In View of Fast Pace of Change

Following are other needs that must be incorporated in the goals and strategic plan for the Management of Technology:

a) Changes in culture and terminology: The changes that have occurred over the past few years have changed cultural terminology dramatically. As noted by Mariann Jelinek of NSF, it was not long ago that a virus meant the flu, a mouse was chased by the cats, a program was something we heard on the radio or television, a keyboard was for making music and we used to believe that memory degrades by age but computers keep adding information to memory without degradation.

Changes are constant; they have crept into our every day general uses. Many of today's changes in terminology are directly related to our work in the Management of Technology. Even the changes within technologies themselves require a reconfiguration of our thought processes. We must capture the changes in terminology and culture. We may have to challenge several notions and re-examine how to operationalize others that were advocated earlier by MOT scholars.

b) Strategic planning: The notion of strategic planning needs to be re-examined. The market, business and environment are no longer the same as they were ten years ago. How long a strategic plan is viable in view of the fast changing pace? How long will a technical plan remain valid from a strategic point of view? In consideration of this concern, does a corporation still need to strategize? Does the Management of Technology movement need to define goals and a plan of action? The answer is yes, but the focus is still to be determined. Old assumptions must be re-examined.

It may be that the focus will be on and around alliance, competency, skills and a reconfiguration of skills to meet changing market opportunities. Additionally, attention should be given to systems that are also re-configurable to help support the enterprise.

c) How to get in and out of technology: The issue of "how to get into and out of technologies faster and more efficiently" is a complex one. How will that particular statement become operational? There is definitely a need to define how to enter and exit from technologies, but timing is not something that can be formalized outside of specific corporations. Many corporations and practitioners have recently been successful in integrating technology and business strategies. Can their knowledge be reduced to a set of tools useful to practitioners? What is needed is a book of knowledge for MOT.

d) Competitive intelligence: The notion of competitive intelligence (benchmarking) may be a backward look – we should be projecting forward. In this age, by the time you get the information, you are probably already two or three steps behind the competition. A focus on the market opportunity is probably more effective.

e) Intellectual Property (IP): What is the meaning of property in an environment where the cost of knowledge is going to be available to everybody immediately? What is the meaning of owning? In this environment it is not what you know, but what you do with this knowledge and how fast you can do it. The time to capitalize on Intellectual Property is very short, and therefore competitiveness will depend upon who moves faster to capture knowledge. Stock market discounts patents immediately as the technology becomes known, IP values what your possible next patent may be - we should focus on how fast we can exploit technology and innovative ways to protect it.

f) The knowledge age: There is a trend to move from tangible, physical product into "solution services". Emphasis is on intellectual property or a thinking sort of product that might involve more tacit knowledge. For example, John Deere moved from the development of solely farming equipment to include the development of farming solutions.

Some corporations, such as Xerox, are now marketing document management tools and management solutions. These new formats are designed to deal with the digital revolution. They are adapting to meet the needs of today's business with new strategies based on new technology. Currently 50% of all e-mail is printed. Xerox expects that by the year 2005 twenty trillion documents from the Internet will be committed to paper and Xerox is now working to find solutions that bridge the divide between paper and electronic documents rather than just being an equipment company. IBM has also moved from being a computer manufacturing company to being a solution provider company.

g) The notion of value: How can company valuation be developed objectively and accurately? For example, many of the software companies and the new ".com" companies have more market capitalization value than General Motors, which is the highest revenue producing company in the world. Now there are many companies that have not produced a thing and are capitalized many times more than the value of companies that existed for many years and produce many billions of dollars worth in merchandise. How can the value of technology and innovation be captured a priori before a company achieves any profit? New methodologies are needed to resolve this issue.

5) About Managing Knowledge

The edge will be for organizations that value knowledge, capture knowledge, understand the application of knowledge and manage its implication. The question is to find the technique and develop the organization that can best leverage knowledge for the creation of wealth.

Education and training should be geared towards equipping today's managers with knowledge and tools to meet the business of providing solutions, problem solving, critical thinking and problem identifying processes. The speed at which technology moves today is beyond the speed that our engineers and the entire workforce are traditionally trained to fix problems. Today the

engineer must become involved in creating new ideas before the problems arrive and managers must develop an understanding of the technology and be equipped with the tools to manage it.

In addition, today's manager and all corporate employee, must be able to work in teams, and at times "collaborate" with the "competitors" in order to create solutions to technological rifts.

6) Organizations' Complexity

Business must be dynamic, flexible and understanding of differences and diversity of cultures. An organizational structure must be developed that permits:

a. Knowledge generation and application

b. Integration of organization

c. Intra- and inter-organizational communication and collaboration. This implies collaboration and alliances within organizational boundaries and with rivals across boundaries.

Science and technology are becoming much more complex. This is not only in R&D but also in products and industrial processes. What is needed to deal with scientific complexities? This may require approaching problems differently, going beyond existing practice and exploring new possibilities of applying the complex science. Interdisciplinary education as opposed to compartmentalized education of the past is needed. Also multidisciplinary involvement in research and partnering between academia, industry and government organizations is the wave of the future.

7) Organizations' Culture

Probably half of all corporate knowledge resides in the heads of employees. How to capture the tacit knowledge and permit the transfer of knowledge to others within the organization? A starting point to accomplish this is through education, training and closer interaction to permit faster knowledge sharing. Knowledge sharing has to be imbedded in the culture of organizations.

There are many human issues and cultural factors in today's workplace, and those will only expand and become broader in the future. Conflicts among people and cultural clashes have been a traditional barrier to completing a product or developing a technological advancement. Education, training and skill building are still the key to enabling knowledge sharing amongst corporate employees. The next generation of workers has been demonstrating a greater ability to deal effectively with the diverse workforce, embracing cultural and non-cultural differences that past generations could not. What is complex to our own frame of reference is different from how managers and workers of the future are going to see it. Think of the new generation of children as they approach a new problem, a new group of people, or a new culture. Children seem to have no problem, provided they attain their own personal objectives. The products of the baby boomer generation will see and do things differently than their predecessors.

The human element is very important in considering the building of the framework for MOT. The cultural element is currently being addressed haphazardly. There is a need to do research and develop a strategy to exploit the cultural values of the next generation. The results of the research will assist in the establishment and nurturing of a learning culture.

Reward systems may need to be re-examined. Rewards motivate individuals within the organization, unleash their creativity and stem the brain drain.

More than money rewards people. There should be a system of rewards consisting of a portfolio of monetary and non- monetary incentives for employees.

8) Intellectual Capital and Intellectual Liabilities

Intellectual capital (IC) is increasingly being discussed in the literature without adequate methodologies of how to account for it or harness it. We need to have accounting rules before we figure out how the intellectual capital would fit into MOT. However, intellectual capital should not be left to accountants to figure out. Accounting is not only dealing with dollars. The consensus is to stay away from the accountants' financial bottom line. Technology people should talk seriously about what the accounting for intellectual products should be in the future. The issues of how IC can be nurtured, compensated and protected are important.

An opinion was expressed that the MOT community should not rush to embrace IC until scientists, philosophers and technologists develop the framework for accounting of intellectual capital. Rather than embracing the intellectual capital, we should embrace intellectual liabilities and how and where intellectual liabilities stand in the way of effectively doing what we should be doing. For example:

- Legacy systems and how they prevent the effective development and implementation of new software
- Cultural norms and the resistance that induce people how not to look at new ways to do things
- History of past products and processes that induce organizations to stick to the last. In a rapidly changing technological era that sort of theory may be the recipe for failure.

If we take seriously what liabilities traditionally thwart the progress of the MOT, then we will move ahead.

9) Financing Innovations

The challenge in financing innovation is one that every CEO, leader and manager face. Graham Mitchell suggested the use of a 2 x 2 business/ technology matrix to classify the state of business as established or emerging, and the state of technology as emerging or established as shown in figure 1 (Khalil 1998).

The issues facing managers in each cell of the matrix are very different. In the current age of the technology revolution, the issues confronting the CEO have become how to harness the changes in technology, how much more is being done outside the company and what to do to bring it inside the business. Most revenues are drawn from companies occupying the top right corner cell. The challenge is to finance R&D, which may be considered as a cost over the short-run. The traditional corporate methods of justifying R&D are: 1) treating it as an overhead, which may be suitable in the case of high level of uncertainty; or 2) justify it on the basis of return on investment (ROI), which may be suitable in projects that have low levels of uncertainty. The ROI treats innovation as a cost, focusing more on the cost-side rather that the potential revenue side (figure 2). Both methods have strong limitations in financing innovation. New methods and approaches to financing technology need to be formulated.

CEO's should be investing in emerging technology. This can be done inside the company, or better yet, outside the company through investments in start-ups or joint ventures. In the mean time, high-tech start-ups need to become part of established business. What models of financing, marketing and growth-strategies should be advocated under these conditions? Company management may have to adopt practices followed by venture capitalists (VC). VC's tend to invest in start-ups, according to an internalized justification philosophy. One strategy used is to invest money in companies essentially to "see the next card." If things go well, they can increase their stakes (see figure 2).

BUSINESS \ TECHNOLOGY	EMERGING	ESTABLISHED
ESTABLISHED	Threats: Market position, competitive position, (attackers advantage.) Opportunities: New markets, new industries, for the prepared and positioned firm, through MOT Innovation.	Challenges: Traditional management challenges intensified by shorter product/market cycles. Incremental and continuous improvement, re-engineering, quality. Opportunities: New and improved products, services and systems, through innovative application of new tools, models, systems, i.e. the new Technology of Management.
EMERGING	HI tech start up. Entrepreneur financing, marketing, management. Management of technological innovation. Venture capital and valuation. Source of industries. New industries and national advantage.	Entrepreneurship in low-tech business and tradition-al business.

Figure 1: Framework for Key Issues in MOT

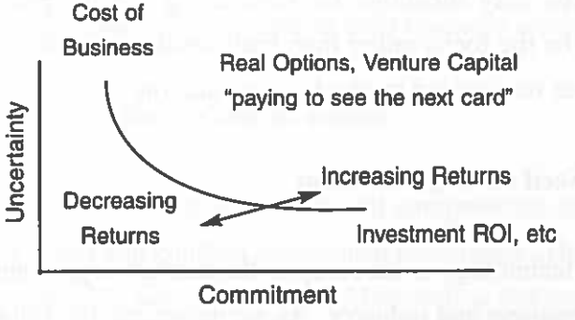

Figure 2: Management Under the Uncertainty Curve

Mitchell and Hamilton (1988) suggested that companies should treat R&D as an option, similar to the stock market option call, in order to reduce risk of investment in R&D. Venture capitalists tend to do that. The challenge for the MOT community is to capture the successful models internalized by venture capitalists and to project them for use by established businesses. We all can benefit by learning and sharing in this endeavor.

What is happening in the growth economy/new economy is much different than what used to happen in the old economy. One clear conclusion is that we need to develop new ways to embrace innovation and the new technology. In many situations, it is better to do that by working within start-ups and small business. Another situation may require using different rules for financing R&D. A third way is to link R&D innovations to commercial development, acting like small companies, making faster decisions and putting a lot more incentives into future development.

The main challenge for MOT as we go forward is how to develop the management tools and approaches that tomorrow's leaders need to know. We also must explore how to effectively deal with fast changing, unpredictable environment as opposed to dealing with slow changing predictable environment. Our traditional approaches may have to yield to newer ones. For example, learning by doing may substitute modeling, efficient experimentation may substitute for forecasting and the process of wealth creation may be the focus rather than traditional emphasis on ROI, present value and other recognized methods of evaluation.

10) The Need for Segmentation

The need for technology is based upon the market, region and the realities within each business and industry. As we move into the future, things will be specialized. We need to segment industries to address each one's specific

issues rather than rely only on generic concepts. We may also segment countries and regions by the level of technology. This will permit us to address special needs and to develop customized solutions.

11) Addressing Issues of Developing Countries

There are places in the world that will maintain the use of traditional approaches to technology justification and development. The needs of developing countries as they relate to the management of technology will be far different from those of highly developed countries. Given that the management of technology movement should not drop any segment of the world's society, we should incorporate the development of a traditional management of technology methods into curriculum, adding topics as appropriate. But we need to do research on the nature of work in different areas of the world and how this is impacted by the information explosion and new technology.

In the development of the MOT framework for curriculum, it should also be considered that the educational needs of the students are correlated to the needs of the market which they are in. Therefore, in some markets or countries, the business field may not be ready for some of the changes that occur in different locations. Programs should be developed to suit the place where they are offered. Countries should not feel obligated to take on new educational contents that will not relate to their business world.

12) The Need to Define a Code of Ethics

When considering those components that will comprise the framework for MOT, a code of ethics and conduct should also be defined. The recent legal conflict between the US Government and Microsoft is but one example of many issues that must be studied by scholars in the MOT field.

13) Globalization

The trend towards globalization is undeniable and will intensify. Technological progress has permitted improvement in communication, transportation and technology transfer across borders. The Internet has created a revolution in the flow of information and knowledge. Diffusion of information permits new models for technology acquisition, development, implementation, marketing and technology management. New marketing strategies emerge, including e-commerce and a focus on opportunities in emerging markets and economies of scale. In this regard, another issue worth exploring, is the impact of migration to e-business on Management of Technology and technology providers.

14) Collaboration, Consolidation and Alliances

This is another very important trend that is mainly focused on competitiveness on established markets and capitalizing on globalization opportunities on emerging markets. According to Dr. Hazem Ezzat of General Motors' R&D Center, a key to successful management under these conditions will be identifying synergies not only having to do with technical and organizational capabilities but also intellectual property and human resources. One should be reminded that the complexity on managing such alliance is non-trivial. It may require partnering in certain markets or product niches, while ferociously competing in others. Sharing the risk of R&D is also another driver in an environment where technology options are many and the cost to bring it to market fast is significant. So, while this used to be the case in cosmetics and pharmaceutical industries, it is now spreading rapidly to electronics, information technology, biotechnology and even some of the "old economy" industries, like the automotive industry.

15) Increasing the Power to Manage Technology

There is a need to develop better and faster tools for practitioners of MOT to use. It is highly desirable to develop a book of knowledge about MOT that includes evaluations, discussions and a code of ethics. It should include best practices and strive to go beyond what has already been accomplished. There has to be better communication between practitioners and scholars. Practitioners need to identify problems and define them conceptually. Problems should be translated into the language of scholars in their own disciplines for research and investigations. Practitioners should write the template and scholars should rewrite these templates for use. The results should then be effectively communicated back to practitioners. A stronger collaboration between industry, universities and research funding agencies is needed to facilitate this process in new forums.

To increase the power to manage technology, a new set of people—the "Pollinators" are needed. These idea carriers are predominantly consultants. Idea carriers bring the ideas into practitioners and take the ideas from practitioners to spread throughout the community.

14) The Educational Needs In Management of Technology

If the target is innovation, then we have to address the question of what does tomorrow's manager need to know about technology? A need to create "just in time" education; create a moving and changing curriculum based on the ever changing business and technology fields. In order to do this, the teachers of this curriculum must be committed to continually learning new processes as they are developed and react accordingly in the classroom, creating a dynamic and diverse curriculum, heavily dependent upon the cooperation of industry and business in order to have partners reacting to the changes.

The need for the changing curriculum does not mean that there are not frameworks to be made. It is apparent in today's field that the traditional students of both business and technological fields must be immersed into bits of the other. This will enhance future work experiences and improve the abilities of all members of the technology workforce - from the developers of the science, to those that market the sciences and technological advances. Therefore, a framework and a book of knowledge of the Management of Technology will teach all students the Management of Technology from a level playing field. Establishing minimum standards for curriculum and possible accreditation should be investigated.

Some important issues still need to be considered. For example, whether or not it should be a requirement for those seeking a Management of Technology degree to have a technical undergraduate degree to pursue MOT. The tradition has been that way, however there are trends amongst some schools to the contrary. Should graduates of other fields be limited in their pursuit of a MOT degree?

Panelists believe that there are two potential audiences for a Management of Technology degree. The technical graduates who are looking to learn how to manage an industry or business, and those business/communications graduates wishing to learn more about technology, in order to assist them in managing a technological area. Simply because an undergraduate degree is not obtained in hard science does not mean that these managers cannot think logically or not understand technical processes.

It may be a mistake to think that there are no analytical minds outside of the technological field or degrees; perhaps we should steer away from this stereotype. Perhaps the new clientele of the non-technically trained managers interested in technology may be the first to break down the barrier between the technical people and the management. If they are halfway between the

two extremes, they may be extraordinarily useful in translating between the two. However, we do not need a large group of people who are no good at anything except soft science. There must be a balance between the two. The important aspect to this is that we do not want to sacrifice solid expertise and functional skills in the mix.

When we consider the engineering population, the area we hear about as the area of greatest need, is the ability to participate well within the multicultural community. Many scientists are not comfortable in that sort of environment. The majority will be managed as part of a project team or similar experience. Those skills of being able to operate and manage in a diverse environment are the skills becoming increasingly necessary in all of today's business environments. There is a great need to create a value amongst the scientists and engineers to develop a softer side and interpersonal skills.

There may also be a need for another tier of general education for people at different educational levels to increase their sense of technology and its value in creating wealth. Great attention must be taken into the creation of requirements for these groups.

III. RESEARCH NEEDS

Several research issues emerge as needing attention. In the knowledge age of the new century, how do we think about intellectual capital? The real issue is how those minds work on the technical problems. In regard to intelligence outcomes and the corporation we ask ourselves:

- Do we manage the same way?
- How do we organize today's business to take advantage of full intellectual capabilities to leverage development?
- How are these technological innovations assessed in review, compensated for and evaluated with proper incentives for performance?

It would be economic imperialism to say that people only want money; in fact, today's data indicates people want more. As a result, if we reconfigure our traditional organization/industry to produce a product, we must incorporate the following:

- Challenge our traditional approaches and figure out how to access different problems with new solutions
- Recognize new stakes in outcomes/success
- Reconfigure assembly line model corporations to work on technical problems.

All of these questions and observations give the Management of Technology field an important growth in research possibilities, fueled by the industry's desire to have these questions answered. Private industry has billions of dollars available for research, and industry must continue to drive the way research is conducted into the Management of Technology.

We should focus on the management of knowledge in the future. Suggestions are made for research into new manners of organization, new incentives as

drivers for employees, new ways of management and how to break down barriers between practitioners and scholars. This was a common thought heard throughout the 9th International Conference on MOT. The underlying problem, or issue, is the communication wall between users and scholars. This wall and the manner in which to open it is a subject that merits research and observations.

An opportunity for real time research on managers and on real time teaching (which may be the potential solution to the communication wall), as well as research into areas previously dismissed as soluble only by economic methods, will provide innovative new solutions.

Research can also help in the definition of the need for the Management of Technology based upon the type of market you are applying it to. Sector specific issues need to be addressed. In mature technology industries it may not be necessary to drop traditional business models, but rather augment them with methods to stimulate innovation. Research on problems faced by developing countries and focused on promoting their growth is also indicated.

The following list contains summary of research topics identified during the workshop:

1) Research in cultural values of the next generation – how will they deal with complexity of science, technology and diversity
2) How do we think about intellectual capital and intellectual liabilities in today's environment?
3) How to organize to take full advantage of opportunities (innovation, intellectual capital)?
4) How to compensate in order to motivate and prevent brain drain (from one industry to another, from on region or country to another, from all types of technology to information technology)?

5) What do R&D and Marketing, of the future look like? Will we look at the technological outputs or the marketing of technology as the success?
6) The issues of segmented industries
7) The issues of developing countries
8) Codes of ethics in MOT
9) MOT tools for practitioners.
10) How to improve the function of inter- and intra-organization communication and alliance?
11) How to improve the human bandwidth for receiving and processing of information in order to get more information to end-users?
12) How to capture the tacit knowledge and improve its transfer?
13) How to manage knowledge generation, application and implication?
14) How to secure technology?
15) New approaches to strategic technology planning competency
16) Guidance for the best strategies to create alliances amongst technology organizations
17) Current skills base and the reconfiguration of the skill base in order to meet the needs of the Management of Technology
18) How to finance innovation and how to capture the knowledge of successful venture capitalists in models useful in financing new ventures?
19) The impact of globalization and e-business on technology providers, consumers and on technology management.

IV. CONCLUDING REMARKS

The first step in the endeavors we have undertaken in 1998 (Khalil, 1998) and in this report is to identify drivers of change in MOT. We pose many questions that need to be answered by researchers, practitioners and educators. The next step is to set an agenda for action and assign roles to various organizations that are involved in promoting the Management of Technology as the means for creating wealth and prosperity.

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