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CHALLENGES OF MANAGING IN HIGH TECHNOLOGY

HUGHES AND THE DIRECT BROADCASTING BUSINESS

Today, Hughes Electronics, a unit of General Motors, is a successful part of the communications revolution. The company designs, manufactures, and markets advanced electronic systems, including telecommunications equipment, offering digital television entertainment and information programming via satellite. Hughes operates a network of satellites, including DIRECTV, the largest US direct broadcast satellite (DBS) system, marketed via PanAmSat Corporation, offering 150 channels of movies, cable TV programs, and sporting events directly to anyone in the United States, Canada, and part of South America. Hughes had secured part of this market niche already in 1997 by forming an alliance between its PanAmSat subsidiary and SatMex (Satellites Mexicanos) to bid for an additional strategic satellite position. Other bidders included Primestar and EchoStar. At 77 degrees west longitude the Mexican slot was the last to allow a satellite to beam full conus coverage of the United States and Mexico.

The direct broadcast satellite (DBS) ventures are part of the world's most complex, but also fastest growing businesses. Today, DIRECTV/Hughes markets its services through PanAmSat to more than 10 million subscribers with annual revenues of nearly $7 billion. For Hughes Electronics, a subsidiary of General Motors, this new business started 15 years ago, when the Federal Communications Commission (FCC) set aside part of the radio spectrum for

TV programs. But digital compression had not been invented then, and satellites were more primitive. Yet, competitors such as Rupert Murdoch's Sky Broadcasting in Europe and Hutchison Whampoa of Hong Kong broadcasting into Asia started their ventures as early as 1990. DIRECTV/Hughes' satellite factory, "High Bay" in El Segundo near Los Angeles International Airport, appears unusual by traditional norms of manufacturing. There are no assembly lines, no conveyor belts, and no grinding machine tools. Workers gather around a half-dozen shiny objects, which create a *Star Wars* ambiance. High Bay is the plant where Hughes finishes satellites before launching them into space. Many of the satellites are more conventional telecommunications relays that will handle international calls. But the stars of High Bay are the body-stabilized DBS models, which are crammed with stuff: power amplifiers, radio-wave propagators, titanium fuel tanks, navigational gear, explosive charges for deploying solar panels, azure-blue glass solar cells, thruster jets, antennas, solar panels. Hughes hopes that this product will transform the television industry, and the anticipation in this plant is palpable. The combination of great stakes, exotic technology, and painstaking team efforts by many people, culminating in a single event that may bring instantaneous success or the total disaster of launch failure, makes satellite building the most tension-laden business in the world.

At the beginning of 2004, Hughes Electronics planned to sell its DIRECTV business for $6.6 billion to News Corporation, while GM intended to sell the remaining Hughes Electronics businesses, including satellite network operator PanAmSat and satellite equipment maker Hughes Network Systems, to EchoStar (DIRECTV's main rival) for $18 billion. However, the GM-EchoStar deal was rejected by the FCC.

Source: Hughes Electronics Corporation at *www.hughes.com.*

1.1 MANAGING IN TODAY'S HIGH-TECH BUSINESS ENVIRONMENT

The complexities and challenges faced by Hughes Electronics and its DIRECTV business are quite common in today's technology-based business environment.[1] Activities often cluster around projects with team efforts that span organizational lines involving a broad spectrum of personnel, support groups, subcontractors, vendors, partners, government agencies, and customer organizations. Effective linkages, cooperation, and alliances among various organizational functions are critical for proper communication, decision making, and control. This requires sophisticated

[1] For additional discussion on these challenges and issues of high-tech management see Armstrong (2000), Barkema (2002), Barner (1997), Dillon (2001), Gray and Larson (2000), and Thamhain (2002).

teamwork and, as is typical for many high-tech organizations, the ability to manage across functional lines with little or no formal authority, dealing effectively with resource sharing and multiple reporting relationships and accountabilities.

Yet, to be sure, technology and its management are not new phenomena. It has been around for a long time. From Noah's Ark and the Egyptian pyramids to railroads and steel mills, people have used and managed technology, and developed special skills to deal with the challenges, risks, and uncertainties. However, today's technologies have created a new business environment that has pushed conventional boundaries ever farther, with high risks and great opportunities for big gains. New technologies, especially those related to computers and communication, as shown in the Hughes DBS situation, have radically changed the workplace and transformed our global economy, with a focus on effectiveness, value, and speed. Every organization is under pressure to do more things faster, better, and with fewer resources. Speed especially has become one of the great equalizers of competitive performance. As for the Hughes broadcasting satellite, a system that requires five years of development time, it may be obsolete in a couple of years, unless provisions for continuous upgrading and enhancement have been built into the system and are implemented according to evolving market needs. The impact of accelerating technology is even more visible in consumer markets. A new computer product introduced today will be obsolete in four months, while the firm's concept-to-market development cycle may take a year or more! Hence, the new breed of business leaders must deal effectively with a broad spectrum of contemporary challenges that focus on time-to-market pressures, accelerating technologies, innovation, resource limitations, technical complexities, social and ethical issues, operational dynamics, cost, risks, and technology itself, as summarized in Table 1.1. Traditional linear work processes and top-down controls are no longer sufficient, but are gradually being replaced with alternate organizational designs and new management techniques and business processes, such as concurrent engineering, design-build, and Stage-Gate protocols (Thamhain 2003). These techniques offer more sophisticated capabilities for cross-functional integration, resources mobility, effectiveness, and marker responsiveness, but they also require more sophisticated management skills and leadership.

Taken together, the business environment is quite different from what it used to be. New technologies and changing global markets have transformed our business communities. Companies that survive and prosper in this environment have the ability to deal with a broad spectrum of contemporary challenges that focus on speed, cost, and quality. They have also shifted their focus from managing specific functions efficiently to an integrated approach of business management with particular attention being paid to organizational interfaces, human factors, and the business process.

1.2 MOT SCOPE AND FOCUS

Both the scope and the definition of *management of technology (MoT)* have been the subject of intense debate, controversy, and confusion. The words "management" and

Table 1.1 Characteristics and Challenges of Today's Technology-Based Businesses

Characteristics and challenges:
• High task complexities, risks, and uncertainties
• Fast-changing markets, technology, regulations
• Intense competition, open global markets
• Resource constraint, tough performance requirements
• Tight, end-date-driven schedules
• Total project life-cycle considerations
• Complex organizations and cross-functional linkages
• Joint ventures, alliances and partnerships; need for dealing with different organizational cultures and values
• Complex business processes and stakeholder communities
• Need for continuous improvements, upgrades, and enhancements
• Need for sophisticated people skills, ability to deal with organizational conflict, power, and politics
• Virtual organizations, markets, and support systems
• Increasing impact of IT and e-business
Resulting in demand for:
➢ High market responsiveness
➢ Fast developments
➢ Low cost
➢ High levels of creativity, innovation, and efficiency

"technology" each carry different meanings and boundaries, and in combination, they stand for a wide array of actions, methods, tools, and techniques. For some people, MoT relates to scientific research and the development of new concepts. To others, MoT means engineering design and development, manufacturing, or operations management, while yet others relate MoT to managing hospitals, financial businesses, the Olympic Games, or eBay. Indeed the scope of MoT is very broad and diverse. Its boundaries also overlap considerably with those of the major disciplines of science, engineering, and management. Furthermore, with the increasing complexity of our business environment, MoT focuses more strongly on "managing" the organizational processes and the people affiliated with them.

Over the last 20 to 30 years, management literature has shifted its technology focus from R&D to new product development and then to product enhancement. In more current times, its emphasis has been gravitating toward market development and e-commerce. However, the scope of technology management has not changed. *In its fundamental form, the scope of technology management* runs parallel to the general field of management. It includes the planning, organizing coordinating, and

integrating of all the resources needed to achieve the enterprise-specific goals and objectives. However, what makes MoT unique and differentiates it from other established fields of organization and management are the special knowledge and skill requirements for applying the technology, including organizing and coordinating technology resources, and directing the people involved with it. In this context, *management of technology* can be broadly defined as the art and science of *creating value* by using technology together with the other resources of an organization. This definition points toward the well-supported position that management of technology is not be confined to R&D, engineering, or scientific work, but includes many other facets of the enterprise and its environment. This is the context in which the definition of MoT will be further developed and discussed in the next section.

1.3 DEVELOPING A FORMAL DEFINITION

By its very nature, *management of technology* is multidisciplinary. It involves at least two established areas of knowledge: (1) organization and management and (2) natural sciences and engineering, plus a broad spectrum of disciplines from other fields, in support of either management or technology, such as social sciences, information technology, and industrial engineering.

In 1987, the National Research Council released the following definition of management of technology:

> *Management of Technology links engineering, science and management disciplines to plan, develop and implement technological capabilities to shape and accomplish the strategic and operational goals of an organization.*

The specific dimensions of this definition are worth emphasizing. They are also graphically summarized in Figure 1.1.

1. MoT involves the *management of engineering, natural science, and social science.*
2. MoT involves *administrative science* in the planning, decision making, development, and implementation of technology.
3. MoT focuses on the *development of operational capabilities* such as manufacturing, distribution, and field services.
4. MoT involves *operational processes, tools and techniques, and people* who make it all happen.
5. MoT involves *guidance and leadership* aimed toward the development of products and services.
6. MoT is influenced by business strategy, organizational culture, and the business environment, and vice versa.
7. MoT involves managing many *interdisciplinary* components and managing their *integration* into a whole system. It also involves managing the system.

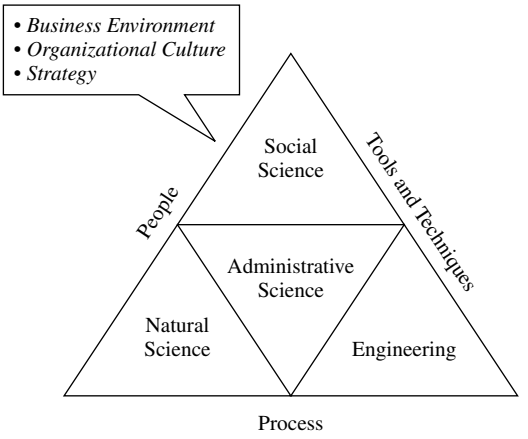

Figure 1.1 Dimensions of MoT.

Beginning with the 1990s a body of specialized knowledge emerged linking MoT with the broader enterprise operation and its strategy. Technology became broadly recognized as a resource for conducting business more effectively throughout all functions of the enterprise, from concept development to distribution, and for sustaining economic growth.[2] Moreover, technology became a strategic weapon for positioning products and services uniquely in the marketplace, and the *management of technology* emerged as a managerial specialty and professional field.

Today, businesses must function in an environment of increasing global competition, rapid technological changes, time compression, and ultra-efficiency. Virtually every organization aims to make things better, faster, and cheaper. Success is driven to a significant degree by an organization's ability to integrate and utilize technology effectively. *Management of technology* is recognized as a core competency, critical to the survival and growth of virtually every enterprise. It includes to some extent the creation of new technology, but in most situations it focuses on the *application* of technology toward the creation and improvement of products and services, and the enhancement of business processes toward more effective, faster, more agile, and more socially acceptable operations. In this context, management of technology can be broadly defined as follows:

> *Management of technology (MoT)* is the art and science of *creating value* by using technology together with other resources of an organization.

[2] The National Science and Technology Council (NSTC) concluded in 1996 (Report: *Technology in the National Interest*) that technological progress is the single most important determining factor in a nation's sustained economic growth, crediting one half of the U.S. economic growth during the past 50 years to advances in technology.

From my vantage point, this is a good working definition which focuses on the managerial processes, skills, tools, and techniques needed to achieve business results. It also establishes the platform for the discussions in this book. However, the term *technology management* can be defined in many ways depending on the emphasis and context in which technology and its management are seen as part of the enterprise.[3] Within today's enterprise, technology management crosses all disciplines, functions, and levels of the organization. It seems less important to arrive at a perfect definition than it is to understand the role of technology for the enterprise and the way it can be leveraged toward business performance. A more advanced discussion on the unique characteristics of technology management is provided in Chapter 2.

1.4 THE SPECIAL ROLE OF ENGINEERING MANAGEMENT

Engineering management (EM) focuses more specifically on managing in an *engineering* environment. It deals with the application of engineering principles and organizational and people skills to the delivery of engineering-based results. Engineering management is often conducted within a project context. There is a *great deal of overlap* between *engineering management (EM)* and *technology management (TM).* Yet, a persuasive argument can be made that EM, with its somewhat better established theoretical framework,[4] is a subset of TM, regarding its body of knowledge and managerial practice. Engineering a special area of the broader field of technology, but the management of engineering focuses more exclusively on the operational aspects of the firm, while technology management covers virtually all facets of the enterprise.

When analyzing the two areas of management from a *career path perspective*, technology management often becomes the umbrella for engineering management. Engineers, scientists, and other technical personnel with managerial aspirations

[3] There are a large number of definitions for MoT. Often each subject expert creates his or her own definition with focus on a specific area of managerial focus. Here is a sample of MoT definitions from well-known scholars of management: Michael Badawy of Virginia Polytechnic Institute states "technology management . . . is the architecture or configuration of management systems, policies and procedures, governing the strategic and operational functioning of the enterprise in order to achieve its goals and objectives." According to Steven Wheelwright of Harvard University, MoT is based on "the theoretical and practical knowledge, skills and artifacts, useful to the development of products and services as well as their delivery systems." Peter Drucker focuses more on the human side, referring to technology management as an "interrelated system of intercommunicating units and activities." Ray Gehani of the University of Akron, in his book *Management of Technology and Operations* (1998), describes technology management as "the transformation of proprietary know-how to commercialization."

[4] The beginnings of engineering management as a formal discipline can be traced back to the 1940s. One of the early recognitions of EM as a profession was the formation of the Engineering Management Society, as part the newly organized IEEE, in 1963. The body of knowledge of engineering management has been developed for a long time with the support of many government institutions, universities, and professional organizations. Many publications helped in documenting the building blocks of EM. One of the oldest and highly respected journals reporting EM research today is the *IEEE Transactions on Engineering Management,* now in its fiftieth year of publication.

might grow into engineering management positions, often via project team leadership assignments. Depending on the company's size, these engineering management positions can be connected to long career ladders, leading to senior management positions such as director of engineering, director of manufacturing, or VP of marketing. However, with increasing responsibilities, the engineering manager becomes involved with the broader issues of the enterprise, requiring more interdisciplinary, integrative, and strategic business skills, which span the wide spectrum of technology areas within the company and across its boundaries. At this point the engineering manager's responsibilities strongly overlap with the responsibilities for managing the technology of the business; essentially the *engineering manager* becomes a *manager of technology*.

1.4.1 Educational Impact

This observation also has educational implications for both students and educators. Choosing an EM versus MoT curriculum is a difficult decision, especially for engineering professionals in their early career stages. William Lannes (2001), director of engineering management at the University of New Orleans, provides a very good perspective with the following advice:

> *We differentiate between the two options of EM and TM by telling students that if they want to remain in their technical area of expertise, but see a need for improving their managerial skills and understanding of business, then the* Engineering Management Program *is right for them. On the other side, if they want to use their engineering knowledge and expertise as a stepping stone to grow into a stage in their careers in which they have to make executive decisions on the use of technology in their corporations, then the* Master's Program in Management of Technology *should be considered.*

As a final note to the EM versus MoT discussion, it should be emphasized that neither field should be seen as "superior" to the other. I am saying this as an engineer who has worked in and studied both the EM and TM areas. Clearly, both fields overlap a great deal, in concept and in practice. While one could argue that *engineering management* has a more established body of knowledge with better-defined boundaries and career paths, it is the area of *technology management* that crosses virtually all organizational areas and levels of the enterprise, regardless of its industry, markets, or business specialization. Many of the managerial issues, tools, and processes apply to both concepts and are discussed in this book under the label of *management of technology.* Hence the focus of the following chapters is on *managing* effectively in technology-based organizations.

1.5 GLOBAL DIMENSIONS

Globalization and technology are perhaps the two most significant drivers of business performance. They are interrelated. Companies benefit from economies of scale and scope by exploiting technology globally, but they also need technology to operate

globally. Therefore, technology is both an enabler of globalization and vice versa. Yet, multinational commerce flourished long before the computer age. Motivated by opportunities for economic gain, companies have ventured into international operations since the dawn of civilization. However, in the past, the ability to gain access to supporting resources, such as labor, raw material, energy, and knowledge, was limited. In addition, coordination and integration of activities across international borders was difficult and costly. While these are still major challenges, new multinational trade agreements and new technologies, especially computers and information technology, have radically changed the way an enterprise can operate and have transformed the business environment into a global economy that is reoriented toward service and knowledge work, with a greater mobility of resources, skills, processes, and technology itself. Driven by the promise of new markets and cheaper resources, and in many cases access to new knowledge and talent, today's companies are trying to take advantage of the new global marketplace. As demonstrated by Nokia, Harley Davidson, Volvo, Wendy's, and Briggs & Stratton, just to mention a few well-recognized names, not only the giants in their industry but any company in any market can operate multinationally with potential benefits in the following areas:

- New market penetration
- Accessing new and complementary knowledge and talents
- Accessing resources more economically
- Economies of scale and scope
- Technology and resource sharing
- Capacity enhancement
- Joint ventures and partnering

Taken together, these benefits translate into "faster-cheaper-better" business results, specifically (1) faster market response, (2) lower costs, and (3) more innovative, higher-quality products and services, all aimed at a favorable impact on overall business performance. Thanks to standardization, digitization, favorable weight-size-value ratios, and the Internet, high-technology firms are especially well positioned to take advantage of these opportunities and have to reevaluate their own business models to take advantage of the new e-commerce environment.

Yet, despite the many benefits, there are great challenges in dealing with the enormous dynamics, complexities, and risks of global enterprising. As a result, many companies have opted for alliances, partnerships, joint ventures, or acquisitions, rather than in-house expansion, for reaping the benefits of global business. This introduces important strategic business dimensions. Companies that fund and manage multinational activities internally (from R&D to manufacturing and marketing) instead of outsourcing them do so under the assumption that long-term economies of scale or scope or a monopolistic advantage can be gained. Actual success will often depend on how well these assumptions hold in our ever-changing world of business. In addition to the sourcing decision, companies must choose the proper organizational design for optimizing managerial control. As researched by West (2004), firms that carry out only a small part of their activities abroad try to exercise relatively tight

cross-border control from their home base. However, as the importance and scope of these activities grow, the organizations abroad need more autonomy. The greater the cultural and geographic distances, the more likely that they are going to get the additional power. This will increase the quality and effectiveness of local decision making, resulting in greater organizational flexibility, speed, and adaptability. The potential *downside* is the deterioration of the parent company's network structure, linkages, interoperability, and integration processes, precisely the mechanisms that drive the economics of scope and scale within the enterprise. This dilemma and managerial complexity grow with the scope of multinational operations. That is, the more subsidiaries, R&D laboratories, or field operations a company runs, the more complex becomes integration with its total enterprise, a condition necessary for wringing out operational synergism. Especially from the technology side, the creation, transfer, and coordination of knowledge, key to successful R&D, is one of the most difficult areas in multinational management. Flexible and innovative organizational designs and policies have been advocated by business leaders and researchers to cope with this challenge. Concepts such as the *transnational management model* have been proposed for some time (Bartlett and Ghoshal 1989) to deal with the polarized issues of local authority, integrated decision making, and central control. Management in our global environment requires more than a simple theory or a set of business policies—it requires a well-defined, yet flexible business process that has been worked out and agreed to by all key stakeholders, an approach that is being advocated for managing technology throughout this book.

1.6 IMPACT OF INTERNET AND E-COMMERCE

Modern computers and information technology have created vast opportunities for managers and their organizations for leveraging their resources. With over 500 million end users worldwide and increasing exponentially, the Internet and all its global subnetworks has become one of the most dominant enablers toward better-faster-cheaper business operations. From in-house R&D to joint developments, shareholder services, medical surgery, and technical field support, the Internet opens up new and more effective ways of operating the enterprise and conducting its business with customers, suppliers, regulators, and other partners, and has become the operational backbone for many companies. Distance and time no longer matter. The cost, speed, and capacity of data handling, together with its 24/7 access, define the advantages of the Internet and its value for e-commerce. Business activities from design to manufacture, and from accounting to human resources, consist to a large degree of information processing, transferring, storing, and retrieving. Hence, Internet technology enables the enterprise to conduct more business over geographically dispersed areas with great speed, flexibility, and economics. In addition, sophisticated systems interoperability and data processing allow the enterprise to conduct vastly more complex ventures than was ever possible in the past, such as the recent Mars explorations and the development of nanosecond-speed microprocessors. While these technologies have created great opportunities for running

the enterprise more efficiently and pursuing new business ventures, they have also created enormous pressures for delivering cutting-edge products of superior quality and service, and produced a business environment with fast changes, high risk, uncertainty, and virtually no barriers to competitive entry. This has profound *implications especially on the practice of technology management*. The value of technology-based companies lies increasingly in the creation and transfer of *knowledge*, rather than in the brick-and-mortar assets that appear on the balance sheet. In fact, it is estimated that intellectual property, including R&D, franchises, patents, brands, ideas, and experience, accounts for 85 percent of the market value of technology companies (Cairncross 2002). To run these businesses calls for different leadership and managerial skill sets that focus especially on knowledge generators: the human side of the enterprise. This includes virtually all the people of a technology-based organization, plus many people at the supplier and customer interface. In addition, managers must pay attention to the decision-making processes and build collaborative communities and learning organizations. Knowledge creation relies on information access. Managers must provide the people in the organization with systems for sharing intellectual capital and new ideas that emerge. They must continuously develop the infrastructure needed for effectively handling the increasingly vast amount of information that flows across the enterprise and all of its partner communities. Using Internet technology, *intranets* and *extranets* have become important electronic data interchange (EDI) systems of choice for moving large sets of data, centrally managed and controlled, among validated user communities, anywhere, anytime.

1.7 TECHNOLOGY AND SOCIETY

Technological progress is the single most important factor driving a nation's sustained economic growth.[5] In the United States, as much as half of the economic growth gained over the past 50 years is being credited to technological advances (Khalil 2000). Yet, the issues underlying economic growth are highly complex and interrelated with a vast array of ethical values and social responsibilities. For a long time scholars have argued over which processes drive technological advancement. Are these drivers derived largely from scientific or social sources? Two primary theories evolved.

Rational-Objective View. According to the oldest and still prevailing theory, technological advances result from purposeful, empirical/scientific discovery. That is, new technology is, by and large, the result of rational thought, independent of social influences (Volti 1995). In its purest interpretation, this theory argues that *science leads and society follows*, a view that is labeled by Pacey (1983) as *"technological determinism."*

Social Constructivism. This theory makes the compelling argument that technological advances are, by and large, the result of social influences. Thomas

[5]Cf. *Technology in the National Interest,* Special Report by the U.S. National Science and Technology Council, Office of Technology Policy, U.S. Department of Commerce, Washington, DC, 1996.

Kuhn presents one of the classic discussions of this concept in his widely quoted book *The Structure of Scientific Revolutions* (1962), which provides the basis for much of today's theory on social constructivism (sometimes also referred to as *social constructionism)*. In its extreme form, social constructivism argues that there is *no basis* for the belief that technological advances result strictly from logical thought processes, because all scientific processes are influenced by social value systems (Pool 1997). This is the *cultural dimention* of technology development and its penetration into our society (Pacey 1983).

So much for the two poles of the theoretical spectrum. The applied literature and practice of MoT take more of a "middle-of-the-road" approach, recognizing both the power of focused scientific discovery *and* the social/cultural influences (Haddad 2002). In addition technological advances are potentially influenced by other factors, such as the organizational culture of the enterprise, personal objectives of powerful leaders, and special events, such as September 11, that create a sudden paradigm shift of culture and values within the society.

Social Responsibility. Social responsibilities and business ethics add yet another dimension to the management of technology. Many of our social problems, from health to environmental pollution and unethical business practices, are caused or promoted by technology. Yet, it requires more technology to solve these problems. This puts pressure on the leadership of technology-based companies to run the enterprise in a socially responsible way. From maintaining environmental quality to performing community service, companies are expected to contribute their share to society as a whole. The more technology-oriented an enterprise is seen as being, the more technological solutions are expected from it by society. Business performance is no longer a simple financial measure, but has been redefined by consumers, competitors, and regulators into a complex set of parameters that translate into market capitalization. Government and public pressures have pushed companies toward treating social issues more realistically, focusing on longer-range cost-benefit analyses and integrating environmental challenges in particular into the total business process (Singh 2000). The challenges are obvious for companies that sell cigarettes, breast implants, or telephone services; although they are more subtle, they are equally serious for technology businesses in automotives, food, pharmaceuticals, or computers, requiring sophisticated business strategies and management skills and great leadership.

1.8 FUTURE TRENDS

The magnitude and speed at which technological advances and changes in management practices have occurred over the past 50 years are stunning. "Technology is reshaping our world and has influenced our life at a speed unimaginable just a few

years ago." This conclusion, reached by the U.S. National Science and Technology Council in its 2000 annual report, is typical for the changing environment we are experiencing. There is no reason to believe that the current rate of change will slow down anytime soon. The great challenge is to harness this newly emerging technology for the benefit of society. This is where *management of technology* can make a difference. Great potential exists for further advances in the area of technology integration toward larger multidisciplinary applications, such as those needed for electric cars and seamless product development from R&D to manufacturing and distribution. To benefit from these broadband technology applications, our business processes, management techniques, educational methods, and lifestyles have to change further. The current trend toward flatter, leaner organizations, collaboratively networked, with higher levels of shared authority, operating-level autonomy, and automated work processes, is expected to continue. Economically, these trends will lead to a steady increase of gross domestic product (GDP) for those who can participate in the exploitation of technology. More difficult to determine is the true benefit of these technological advances to society. While the quality of life is indeed difficult to quantify or to assess uniformly across all people, scholars agree that technology advances, by and large, have had a positive effect on our quality of life, and this trend is expected to continue.

1.9 SUMMARY OF KEY POINTS AND CONCLUSIONS

The key points that have been made in this chapter include:

- *Management of technology* is the art and science of *creating value* by using technology together with other resources of an organization.
- Technology is reshaping our world and influencing our lives at a speed unimaginable just a few years ago. In particular, computers and communications have created a new business environment focused on effectiveness, value, and speed.
- Companies that survive and prosper in today's environment have the ability to deal with a broad spectrum of contemporary challenges that focus on speed, cost, and quality.

  Traditional linear work processes and top-down controls are no longer sufficient, but are gradually being replaced with alternate organizational designs and new management techniques and business processes.
- Engineering and technology managers are involved with the broad issues of the enterprise, requiring more interdisciplinary and strategic business skills that span a wide spectrum of technology areas within the company and across its boundaries.
- Engineering managers are to a large extent responsible for managing technology; essentially, the *engineering manager* has become a *manager of technology*.
- As a result of the complex dynamics and enormous risks of global enterprising, many companies have opted for alliances, partnerships, joint ventures, or acquisitions rather than in-house expansion.

- Modern computers and information technology have created vast opportunities for leveraging their resources. Distance and time no longer matter. The cost, speed, and capacity of data handling, together with 24/7 access, define the advantages of the Internet and its value for e-commerce.
- The value of technology-based companies lies increasingly in the creation and transfer of knowledge.
- The current trend toward flatter, leaner organizations, collaboratively networked, with higher levels of shared authority, operating-level autonomy, and automated work processes, is expected to continue.
- To run technology-based businesses requires new leadership and managerial skills that focus on knowledge generators, the human side of the enterprise.
- Social responsibility and business ethics are important dimensions of technology management. Many of our social problems, from health to the environment, are caused by technology. Yet, it requires more technology to solve these problems.

1.10 CRITICAL THINKING: QUESTIONS FOR DISCUSSION

1. What is the role of technology in today's enterprises?
2. What characteristics differentiate high- and low-technology companies?
3. What are the benefits of establishing a chief technology officer (CTO) position?
4. How does technology affect the "globalization of business"?
5. Should the U.S. government develop a strong national technology policy and influence "desirable" technology developments?
6. Why are traditional management styles with emphasis on central control apparently ineffective in high-technology organizations?
7. Analyze your company in terms of its technology-supporting infrastructure and resource functions. What changes would you recommend?
8. Analyze your company in terms of organizational structure and the effectiveness of its management style. What changes would you recommend?
9. What kind of changes in organizational structure and leadership style do you see for companies 10 years (or 20 years) from now?

1.11 REFERENCES AND ADDITIONAL READINGS

Armstrong, D. (2000) "Building teams across borders," *Executive Excellence,* Vol. 17, No. 3 (March), p. 10.

Barkema, Harry G., Baum, Joel A., and Manix, Elizabeth A. (2002) "Managing challenges in a new time," *Academy of Management Journal*, Vol. 45, No. 5 (October), pp. 916–930.

Barner, R. (1997) "The new millennium workplace," *Engineering Management Review* (IEEE), Vol. 25, No. 3 (Fall), pp. 114–119.

Bartlett, C. and Ghoshal, S. (1989) *Managing Across Borders: The Transnational Solution,* Boston: Harvard Business School Press.

Cairncross, F. (2002) *The Company of the Future*, Cambridge, MA: Harvard Business School Press.

Dillon, P. (2001) "A global challenge," *Forbes Magazine*, Vol. 168 (September 10), pp. 73+.

Gaynor, G. H., editor (1986) *Handbook of Technology Managing*, New York: McGraw-Hill.

Gehani, R. R. (1998) *Management of Technology and Operations*, New York: Wiley.

Gray, C. and Larson, E. (2000) *Project Management*, New York: Irwin McGraw-Hill.

Haddad, C. J. (2002) *Managing Technological Change*, Thousand Oaks, CA: Sage Publications.

Khalil, T. (2000) *Management of Technology*, New York: McGraw-Hill.

Kruglianskas, I. and Thamhain, H. J. (2000) "Managing technology-based projects in multinational environments," *IEEE Transactions on Engineering Management*, Vol. 47, No. 1 (February), pp. 55–64.

Kuhn, T. S. (1962) *The Structure of Scientific Revolutions*, Chicago, IL: University of Chicago Press.

Lannes, W. J. (2001) "What is engineering management?" *IEEE Transactions on Engineering Management,* Vol. 48, No. 1 (February), pp. 107–110.

Marshall, Edward (1995) *Transforming the Way We Work*, New York: AMACOM.

National Research Council (1987) *Management of Technology: The Hidden Competitive Advantage,* Washington, DC: National Academy Press, Report No. CETS-CROSS-6.

Oakey, R. (2003) "Technical entrepreneurship in high technology small firms: some observations on the implications for management," *Technovation,* Vol. 23, No. 8. (August), p. 679.

Pacey, A. (1983) *The Culture of Technology*, Cambridge, MA: MIT Press.

Pool, R. (1997) *Beyond Engineering: How Society Shapes Technology*, Cambridge, MA: MIT Press.

Singh, J. (2000) "Making business sense of environmental compliance," *Sloan Management Review*, Vol. 41, No. 3 (Fall), pp. 91–99.

Thamhain, H. J. (2002) "Criteria for effective leadership in technology-oriented project teams," Chapter 16 in *The Frontiers of Project Management Research* (Slevin, Cleland, and Pinto, eds.), Newton Square, PA: Project Management Institute, pp. 259–270.

Thamhain, H. J. (2003) "Managing innovative R&D teams," *R&D Management*, Vol. 33, No. 3 (June), pp. 297–312.

Thamhain, H. J. and Wilemon, D. L. (1999) "Building effective teams in complex project environments," *Technology Management*, Vol. 5, No. 2 (May), 203–212.

U.S. National Science and Technology Council, Office of Technology Policy (1996) *Technology in the National Interest,* Special Report, Washington, DC: U.S. Department of Commerce.

U.S. National Science and Technology Council, (2002), Annual Report, Washington, DC.

Volti, R. (1995) *Society and Technological Change*, New York: St. Martin's Press.

West, D. C. (2004) "Global marketing," Chapter 22.1 in *Technology Management Handbook* (R. Dorf, ed.), Boca Raton, FL: CRC Press.